Predicting extubation failure in blunt trauma patients with pulmonary contusion

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BACKGROUND: The need for reintubation after weaning from mechanical ventilation (extubation failure) is associated with increased morbidity and mortality. In blunt trauma patients with pulmonary contusion, factors predicting successful weaning have not been reliably defined. The purpose of this study was to identify criteria predicting successful extubation in these patients.

METHODS: Retrospective review during a 10-year period at a Level 1 trauma center was performed. A total of 173 extubations in 163 blunt trauma patients with pulmonary contusion requiring mechanical ventilation. Exclusion criteria include Glasgow Coma Scale (GCS) score of less than 9T before extubation, successful use of noninvasive positive-pressure ventilation after extubation, quadriplegia, and preextubation FIO_2 of greater than 0.5. Data included age, Injury Severity Score (ISS), ventilator days, as well as GCS score, FIO_2, the ratio of arterial oxygen tension to FIO_2 (P/F ratio), and alveolar-arterial oxygen (A-a) difference at the time of extubation. Failure was defined as reintubation within 72 hours (excluding stridor or acute decline in GCS score). Mann-Whitney U-test, χ^2 analysis, and logistic regression analysis determined variables associated with extubation failure. Odds ratios were used to compare P/F and A-a values associated with failed extubation.

RESULTS: A total of 147 extubations (85%) were successful; 26 required reintubation. Patients did not differ by ISS, chest Abbreviated Injury Scale (AIS) score, presence of sternal or rib fractures, and admission pneumothorax or hemothorax. Increased age, A-a difference (≥120 mm Hg), and decreased P/F (<280) were associated with reintubation ($p < 0.0001$). By logistic regression analysis, P/F and A-a were independent variables for failed extubation; both remained independent risk factors when adjusted for age, ventilator days, GCS score, and preextubation FIO_2. Using receiver operating characteristic curve inflection points for both P/F and A-a difference (area under the curve of 0.8 for both), patients with a P/F ratio less than 290 and an A-a difference of 100 mm Hg or greater were more likely to fail extubation (odds ratio, 9.2 and 8.7, respectively, $p < 0.001$).

CONCLUSION: Blunt trauma patients with pulmonary contusion who are likely to fail extubation can be reliably identified using the readily available criteria of P/F ratio less than 290 and A-a difference of 100 mm Hg or greater. (*J Trauma Acute Care Surg*. 2013;75: 229–233. Copyright © 2013 by Lippincott Williams & Wilkins)

LEVEL OF EVIDENCE: Prognostic study, level III.

KEY WORDS: Extubation; P/F ratio; A-a difference; pulmonary contusion.

Positive-pressure mechanical ventilation is a common treatment modality used in the management of critically injured trauma patients in the intensive care unit (ICU). Although mechanical ventilation has many benefits, it may also contribute to significant complications.[1] Furthermore, the need for reintubation, whether the extubation was planned or unplanned, has multiple adverse consequences, including increased morbidity and mortality.[2,3] These complications also increase with the duration of invasive mechanical ventilation, emphasizing the need to predict successful extubation or its potential failure.[3,4]

Numerous studies in both the critical care and trauma literature have analyzed criteria for extubation, examining both calculated and clinical factors that may help predict its success or failure.[1–3,5–12] Patients with blunt thoracic trauma, especially pulmonary contusion, present a significant challenge for weaning because of direct lung and thoracic injuries, associated multisystem trauma, and other associated chest injuries identified as radiographic abnormalities.[13–15]

Alveolar-arterial oxygen difference (A-a) and the ratio of arterial oxygen tension to FIO_2 (P/F ratio) are readily available and easily calculated measurements. Neither has been used as a parameter to predict success of extubation or the likelihood of reintubation in trauma patients with pulmonary contusions.

PATIENTS AND METHODS

A 10-year, retrospective review of blunt trauma patients with pulmonary contusion admitted between January 1, 2002, and December 31, 2011, requiring intubation and mechanical ventilation at an American College of Surgeons–verified, Level I trauma center was performed. Patients with specific radiographic evidence of pulmonary contusion on chest x-ray and/or computerized tomography were identified. Exclusion criteria included Glasgow Coma Scale (GCS) score of less than 9T before extubation, noninvasive positive-pressure ventilation after extubation, quadriplegia, and preextubation FIO_2 of greater than 0.5. Age, preextubation/postextubation GCS score, FIO_2, P/F ratio, and A-a difference at the time of extubation; days on ventilator; and injury type; and severity were noted. Failure was defined as

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reintubation within 72 hours (excluding those patients reintubated for stridor or acute decline in GCS score).

A-a difference, or "gradient," is the difference of average alveolar oxygen tension (mm Hg) and measured arterial oxygen tension (mm Hg) or

$$A - a = P_{alveolar}\ O_2 - P_{arterial}\ O_2.^{16}$$

Alveolar oxygen tension is calculated using the alveolar gas equation:[16]

$$P_{alveolar}\ O_2 = P_{inspired}\ O_2 - 1.2(PaCO_2)$$

where $P_{inspired}O_2 = F_{inspired}O_2$ (P_B − 47 mm Hg) where $F_{inspired}O_2$ is the fraction of inspired oxygen as decimal, P_B is the barometric pressure at sea level, or 760 mm Hg, 47 mm Hg is the water vapor pressure at normal body temperature, 1.2 is the inverse of the respiratory quotient, 1 / RQ.

Mann-Whitney U-test, χ^2 analysis, and logistic regression analysis determined variables associated with extubation failure. Odds ratios (ORs) were used to determine and compare P/F and A-a values associated with failed extubation. Predictive value was also calculated for using A-a difference and P/F ratio for predicting reintubation. This study was approved by the institutional review board of Community Medical Centers of Central California and the University of California, San Francisco.

RESULTS

During the study period, there were 20,659 trauma admissions, 17,244 from blunt trauma mechanisms (83%). Of these, 3,659 patients required endotracheal intubation and admission to the ICU for mechanical ventilation for 1 day or more (Fig. 1). Of these, 163 blunt trauma patients had pulmonary contusion and met study criteria. There were a total of 173 extubations. A total of 147 (85%) were successful, and 26 (15%) required reintubation within 72 hours. The variables related to failed and successful extubation are listed in Table 1. Patients did not differ by Injury Severity Score (ISS), chest Abbreviated Injury Scale (AIS) score, presence of sternal or rib fractures, or pneumothorax or hemothorax at admission.

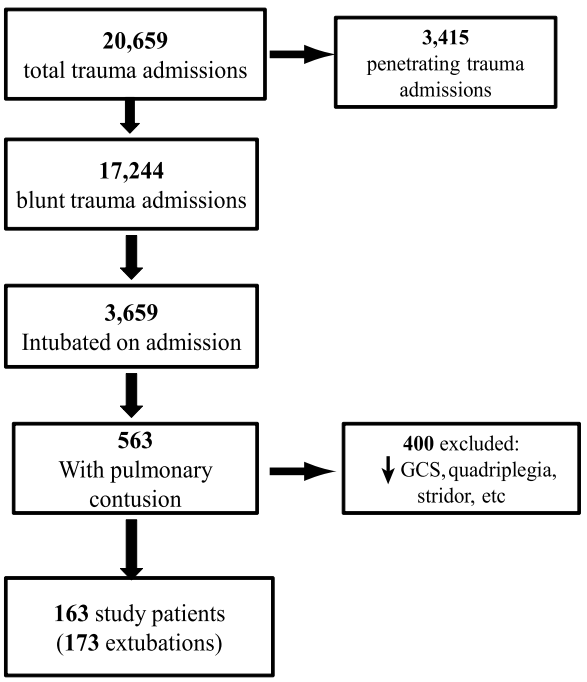

Figure 1. Flow diagram of patient selection from 10-year period.

TABLE 1. Variables Related to Failed and Successful Extubation

	Successful	Failed	*p*
n	147	26	
Age, y	36.1 (18.4)	44.5 (17.4)	0.02
ISS	29.1 (10.7)	27.8 (11.2)	NS
AIS score (chest)	3.5 (0.8)	2.5 (0.8)	NS
P/F	370 (103)	279 (82)	0.0001
A-a, mm Hg	75 (38)	120 (39)	0.0001
Ventilation days before initial extubation	7.1 (5.9)	6.9 (6.9)	NS
FIO_2 preextubation	34.4 (4.6)	37.9 (5.5)	0.002
GCS_T score preextubation	10.7 (0.6)	10.6 (0.5)	NS

NS, not significant.

Increased age (44 years vs. 36 years), increased A-a difference, and decreased P/F ratio were associated with the need for reintubation. By logistic regression analysis, P/F ratio and A-a difference were independent variables for failed extubation. Both remained independent risk factors even when adjusted for age, ventilator days, GCS_T score, and preextubation FIO_2. Receiver operating characteristic curve for both P/F ratio and A-a difference had area under the curve of 0.8 (Figs. 2 and 3).

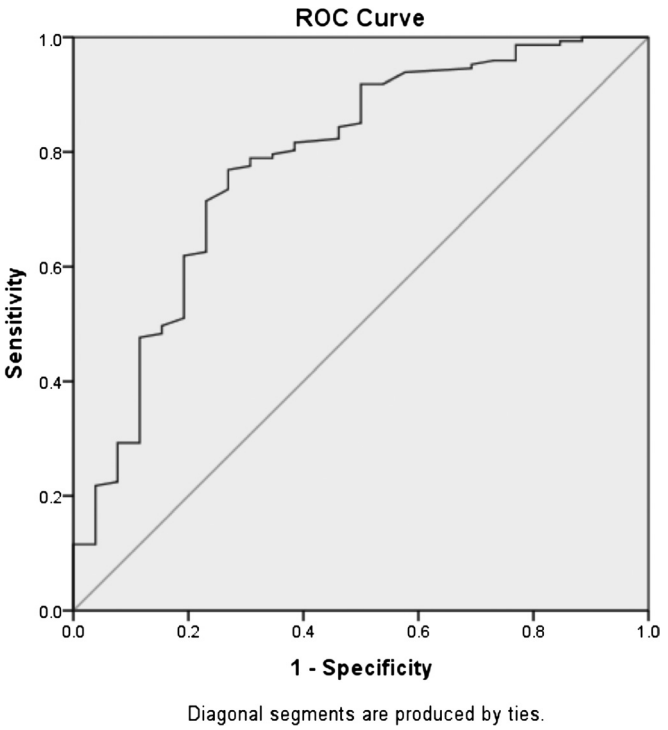

Figure 2. Increasing P/F ratio versus likelihood of successful extubation.

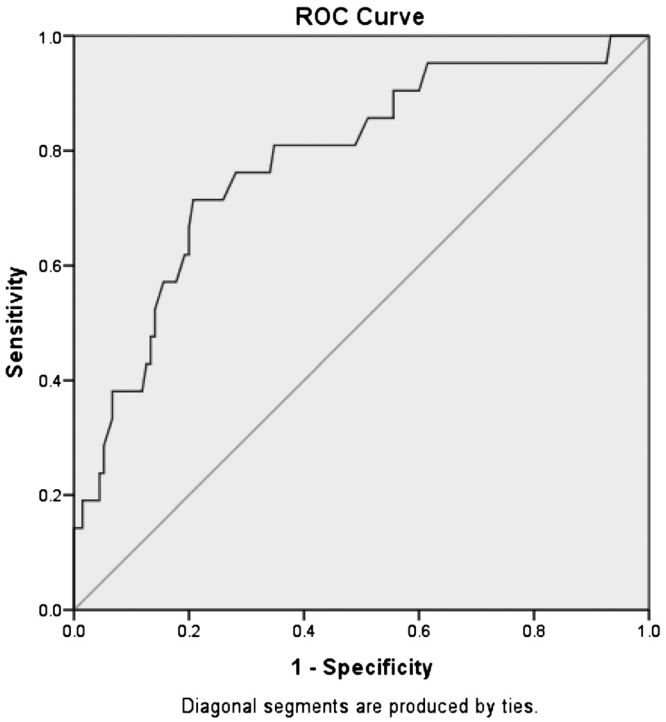

Figure 3. Increasing A-a difference versus likelihood of reintubation.

The mean values for P/F ratio and A-a difference associated with reintubation (Table 1) were 279 and 120 mm Hg, respectively ($p < 0.0001$). The inflection points on each receiver operating characteristic curve with the maximum sensitivity and specificity for reintubation were P/F ratio of 289 or less and A-a difference of 100 mm Hg or greater. ORs were used to compare P/F ratios and A-a differences associated with reintubation (Table 2). P/F ratio less than 290 (OR, 8.7; $p < 0.001$) and A-a greater than or equal to 100 mm Hg (OR, 9.2; $p < 0.001$) were associated with failed extubation in this population of patients.

Positive-predictive value (PPV) was also calculated using the same cutoff P/F ratio (≥290) and A-a difference (≤99 mm Hg) associated with successful extubation. PPV for P/F ratio of 290 or greater was 94%; PPV for A-a difference of 99 mm Hg or less was 95% (Table 2).

DISCUSSION

Endotracheal intubation with mechanical ventilator support is a common indication for admission to the ICU and the trauma ICU specifically. Blunt pulmonary contusion occurs in approximately 17% to 27% of patients with multiple injuries with ISS of greater than 15 and can lead to life-threatening complications such as adult respiratory distress syndrome and pneumonia.[17] Weaning from mechanical ventilation, including patients with unplanned endotracheal extubation, has been studied in the literature with the goal of successfully predicting those patients who will wean successfully and remain off the ventilator.[1–3,5–12,18–20] A number of predictive criteria have been used, including vital capacity, tidal volume, minute ventilation, negative inspiratory force, rapid shallow breathing index (RSBI), and P/F ratio.[1–3,5–12,18,20] Despite this, extubation failure rates of 2% to 25% are reported.[2,3] Failed extubation, whether elective or unplanned, has multiple adverse consequences, including increased mortality, increased length of hospital and ICU stay, increased need for tracheostomy, and higher hospital costs.[2,3] These complications also increase with the duration of invasive mechanical ventilation, emphasizing the need for successful and timely extubation.[3,4]

Blunt pulmonary contusion represents a special subset of injury not only because evolution of lung damage may be delayed but also because contusion is associated with other injuries and abnormal radiographic findings such as rib fractures, hemothorax, and pneumothorax.[13,17] Despite the large amount of literature examining weaning criteria, none has specifically addressed patients with pulmonary contusion. P/F ratio seems to be helpful in ventilator weaning, but the reported threshold values vary from 150 to 300.[2,6,9,18] In our institution, P/F ratio of 200 or greater is used as one of the weaning criteria by respiratory therapists for evaluation of readiness to wean intubated ICU patients. Our respiratory therapists use a checklist when assessing mechanically ventilated trauma patients for spontaneous breathing trial before extubation: evidence of sedative reversal, P/F of 200 or greater, positive end-expiratory pressure of 5 or less, FIO_2 less than 0.5, pH greater than 7.25, hemodynamic stability, use of vasopressors, and inspiratory effort. Spontaneous breathing trial then requires a minute ventilation of less than 10 L/min as well as limits on hemodynamic and respiratory parameters. RSBI is not used. The elective extubations were performed using this protocol at our institution. The mean P/F ratio for successful extubation in this study was 370, while the mean for patients who failed was 279. This value contrasts not only with the previously cited P/F range of 150 to 300 but also with our own institutional standard for extubation. RSBI has been useful in predicting successful weaning in medical ICU patients.[1,5,21,22] RSBI, however, does not seem to be helpful in evaluating trauma patients.[2,6]

A-a difference has not previously been described as an adjunct criteria for extubation in the ICU. Furthermore, A-a difference has rarely been used in clinical application other than for helping evaluate the physiologic degree of initial respiratory failure[23] or in the diagnosis of pulmonary embolus.[24] We hypothesized that using the A-a difference would

TABLE 2. Likelihood of Successful Extubation if A-a difference Less Than 100 mm Hg or P/F Ratio Greater Than 289

Variable	Successful Extubations, n	Failed Extubations, n	PPV, %	OR	95% CI	χ^2	*p*
A-a difference ≤ 99 mm Hg	108	6	95	9.2	3.5–24.7	22.8	<0.001
A-a difference ≥ 100 mm Hg	39	20					
PF ratio ≥ 290	112	7	94	8.7	3.4–22.4	22.7	<0.001
PF ratio ≤ 289	35	19					

be a helpful adjunct because it reflects the state of ventilation-perfusion in the lungs and represents an imbalance when significantly elevated.[16,25] The value of 1 / RQ is usually designated as 1.25 (using RQ of 0.8).[23,24,26] We chose to use 1.2 as the value of the inverse of the respiratory quotient (1 / RQ) not only because it is an acceptable value for the calculation of A-a difference[16,25,26] but also because it lends to the simplicity of a bedside calculation. The RQ value can also vary between 0.7 and 0.9 in normal human subjects.[26]

Our data show that in addition to greater age, both P/F ratio and A-a difference are significant, independent variables in predicting extubation failure. Patients with blunt pulmonary contusion were chosen because they represent a homogeneous trauma population. Indeed, only 163 patients met clinical and radiographic criteria for the study during a 10-year period. There was no significant difference in ISS, chest AIS score, the presence of rib fractures, hemothorax, and pneumothorax between the failed and successful extubation groups. The literature reports reintubation within a range from 24 hours to 72 hours to define extubation failure.[3,5,6,20,27] We chose reintubation within 72 hours after extubation as the inclusion criteria for our study to broaden the spectrum of patients.

Reported rates of extubation failure in the literature range between 2% and 25%.[2,3] Our reintubation rate falls within this range at 15%. Since, for this study, postextubation failure did not include patients with acute changes in GCS score or stridor, the patients that failed did so as a result of progressive respiratory distress, hypoxia, tachypnea, failure to clear secretions, hypercarbia, or a combination thereof.

Limitations of the study include its retrospective nature. We were able to collect 163 patients with 173 extubations during a 10-year period. We chose to include the data from all extubations in the patients with multiple extubations. Although, at face value, this may seem suboptimal, we argue that the physiology of P/F ratio and A-a difference should apply to any patient and his or her physiology when specific criteria are met. Limiting the inclusion to only blunt pulmonary contusion patients also limited the number of patients in the study during the 10-year period, but doing so also resulted in a more homogeneous population with less confounding variables. Many of the patients were intubated for reasons other than pulmonary contusion alone (adult respiratory distress syndrome, severe traumatic brain injury, shock, etc.). However, A-a difference and P/F ratio with the inclusion criteria (e.g., GCS score > 9T before extubation, no stridor, no quadriplegia, etc.) were calculated at one point in time before extubation regardless of the reason(s) for initial intubation. This is one of the reasons why patients with pulmonary contusion were studied. It is a major, common denominator in all of the study patients. We are advocating P/F ratio and A-a difference as adjuncts in ventilator weaning and selecting patients for successful extubation because they are easily calculable and have clinical application at the bedside. As with all clinical criteria, we do not suggest that these measurements are infallible and clearly must be used in conjunction with sound clinical judgment.

Using the cutoff of P/F of less than 290, 19 of the 26 failed extubations would have been prevented. Using an A-a difference of 100 mm Hg or greater would have prevented an additional three failed extubations. This would have altered management for 22 of 26 or 85% of the failed extubations in the study.

P/F ratio has already been shown to be a useful variable in predicting extubation failure and success in the trauma population.[6] However A-a difference has not been studied in this context. We hypothesized that A-a difference would be a useful adjunct in selecting successful extubation since it involves both oxygenation and ventilation and reflects shunt and V/Q (ventilation-perfusion) mismatch.[23] Normal A-a difference is age dependent and normally increases with age.[25] We did not expect A-a difference to be normal in any intubated ICU trauma patient with pulmonary contusions, but it seems that it is the magnitude of the A-a difference that correlates with extubation failure. Calculation of A-a difference requires measurement of both Pa_{O_2} and Pa_{CO_2}. However, the study by Brown et al.[2] showed that by themselves, Pa_{O_2} and Pa_{CO_2} do not correlate with extubation failure or success. It seems that the relationship of both values in the same arterial blood gas measurement correlates with successful extubation or its failure.

CONCLUSION

P/F ratio and A-a difference are easily calculated values that are useful adjuncts to predicting successful extubation in trauma patients with pulmonary contusions. P/F less than 290 and A-a greater than or equal to 100 mm Hg were independently and significantly associated with failed extubation in this population of patients. Successful extubation of individual patients, however, is best driven by clinical judgment.

AUTHORSHIP

J.F.B. contributed the original idea; performed the literature search, data collection, data analysis, data interpretation; and wrote the manuscript. J.W.D. contributed in the data analysis, critical revision, data interpretation. K.M.C. contributed in the data analysis, data interpretation, statistical analysis. K.L.L. contributed in the critical revision and data analysis.

DISCLOSURE

The authors declare no conflicts of interest.

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