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Risk factors for extubation failure at a level I trauma center: does the specialty of the intensivist matter?

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ABSTRACT

Introduction Extubation failure in critically ill patients is associated with higher morbidity and mortality. Although predictors of failed extubation have been previously determined in intensive care unit (ICU) cohorts, relatively less attention has been directed toward this issue in patients with trauma. The aim of this study was to identify predictors of extubation failure among patients with trauma in a multidisciplinary ICU setting.

Methods A prospective observational study of extubation failures (EF) was conducted at an American College of Surgeons level I trauma center over 3 years (2011–2013). Case–control patients (CC) were then compared with the study group (EF) with respect to demographic/clinical characteristics and outcomes. Failure of extubation was defined as reintubation within 72 hours following planned extubation.

Results 7830 patients were admitted to the trauma service and 1098 (14%) underwent mechanical ventilation. 63 patients met inclusion criteria for the EF group and 63 comprised the CC group. The overall rate of extubation failure was 5.7% and mean time to reintubation was 13.0 hours. Groups (EF vs CC) were similar for Injury Severity Score (21 vs 21), Glasgow Coma Scale at extubation (11 vs 10), number of comorbidities (1.5 vs 1.7), injury mechanism (blunt 79% vs 74%), and body mass index (27.9 vs 27.2). In addition, groups were similar with respect to weaning protocol compliance (84% vs 89%, p=0.57). EF group had significantly increased ICU length of stay (LOS) (15.7 vs 7.4 days, p<0.001), ventilator days (13.3 vs 4.8, p<0.001), and mortality (9.5% vs 0%, p=0.03). Multiple regression analysis identified that EF was associated with increased odds of: (1) temperature >38°C at time of extubation (OR 5.9, 95% CI 1.7 to 20.8), and (2) non-surgeon intensivist consultation (OR 24.2, 95% CI 5.5 to 105.9).

Conclusions Extubation failure is associated with increased LOS, ventilator days, and mortality in patients with trauma. Fever at time of extubation is associated with extubation failure, and the presence of such should give pause in the decision to extubate. Non-surgeon intensivist involvement increases risk of extubation failure, and a surgical critical care service may be most appropriate for the management of ventilated patients with trauma.

Level of evidence III, Prognostic and epidemiological.

INTRODUCTION

The decision to extubate the intubated and mechanically ventilated patient is one of the more relatively complex judgments made in intensive care units (ICUs) on a daily basis. The benefit of ongoing pulmonary support must be weighed against the recognized time-dependent risks of prolonged intubation and mechanical ventilation. For patients with trauma, this assessment is further complicated by the presence of multiple injuries that may alter cognition, chest wall mechanics, pulmonary function, and mobility, as well as the possible sequelae of severe injury including systemic inflammatory response syndrome, pneumonia, intra-abdominal infection, multiorgan failure, and hospital-acquired delirium. In addition, failure of planned extubation (ie, requiring reintubation within 24–72 hours) is not without risk, as the requirement for reintubation is associated with longer duration of mechanical ventilation, increased likelihood of requiring tracheostomy, prolonged length of stay (LOS), increased cost, and mortality.[1 2] In fact, patients who fail extubation have a relative incidence of mortality that is increased 2.5–10-fold.[1–3]

Risk factors associated with extubation failure have previously been identified, including excess respiratory secretions, cardiac failure, encephalopathy, gastrointestinal bleeding, sepsis, seizures, and need for surgery.[2] However, the majority of research in this area has originated from general ICU patient populations. Data specific to risk factors associated with extubation failure among patients with trauma are relatively sparse.[4–7] In addition, the patients with trauma is often cared for in a diverse clinical setting, whereby a multidisciplinary clinical team is involved in care decisions including the decision to extubate. The purpose of this study was to identify risk factors associated with extubation failure among patients with trauma in a multidisciplinary ICU setting.

METHODS

The study was performed with the approval of the institutional review board at St. Joseph's Hospital and Medical Center in Phoenix, Arizona, USA. We performed a prospective observational study of patients over 14 years of age who failed planned extubation at our urban American College of Surgeons-verified level I trauma center. Patients who self-extubated were not included in the study. This study was conducted during a 3-year period: January 2011 through December 2013. Successfully extubated patients were selected as case–controls on a 1:1 ratio based on next successfully extubated patient of the same gender and Injury Severity Score (ISS) category (mild: 1–8, moderate: 9–15, severe: 16–24, most severe: ≥25). To avoid overmatching and ensure the ability to analyze factors that might influence extubation outcome, no other variables were used in patient selection. Extubation failure was defined as the requirement for reintubation within 72 hours of initial extubation attempt.

Data relative to patient demographics, injuries, clinical characteristics, treatment information, complications, and outcomes were extracted from the medical record. Specifically, continuous variables included patient age, body mass index (BMI), ICU days, LOS, and ventilator days, and were tested using the student's t-test. ISS and Glasgow Coma Scale (GCS) at time of extubation were tested as ordinal variables using the non-parametric Wilcoxon-Mann-Whitney test of medians. Additional nominal variables included blunt versus penetrating injury, attending physician's surgical critical care board certification status, non-surgeon intensivist consultation, presence of fever at time of extubation, sepsis diagnosis, ventilator-associated pneumonia (VAP) diagnosis, and successful completion of spontaneous breathing trial (SBT). The guideline followed by the respiratory therapists at our hospital concerning SBT is outlined in figure 1. Recorded patient comorbidities included substance abuse (tobacco, alcohol, and illicit drugs), hypertension, diabetes, coronary artery disease, pulmonary disease, and morbid obesity. Comorbidities were defined using the definitions of the National Trauma Databank. All nominal variables were tested using the Pearson χ^2 statistic. For those patients who failed extubation, the time to reintubation was recorded.

Variables with a p value of <0.20 during bivariate analysis were included in the development of a multiple logistic regression model assessing predictors of extubation failure. Multicollinearity was measured and adjustments made in the model development process. ORs and 95% CIs were reported. An α of 0.05 was considered significant. All data were analyzed using SPSS (IBM SPSS Statistics, V.24: Armonk, New York, USA).

RESULTS

During the study period, 7830 patients were admitted to the trauma service and 1098 (14%) underwent mechanical ventilation. In total, 63 patients met inclusion criteria for the failed extubation group, and 63 successful extubations comprised the control group. The mean time to extubation was 4.8 days (SD 3.6) overall with failed extubations occurring at 4.9 (SD 3.3) ventilator days and successful extubations 4.7 (SD 3.9) ventilator days (p=0.77). The overall rate of extubation failure was 5.7% and mean time to reintubation was 12.9 (SD 19.6) hours. Of the 65 patients, 35 (56%) who failed extubation underwent subsequent tracheostomy.

Comparing clinical outcomes between groups, the extubation failure group was observed to have a significantly longer ICU stay (15.7±10.6 vs 7.4±4.1, p<0.001). Total number of ventilator days were also significantly greater for the extubation failure group (13.3±10.0 vs 4.8±4.1, p<0.001). The incidence of in-hospital mortality was significantly greater in the extubation failure group versus control (9.5% vs 0%, p=0.03).

Comparison of demographic and clinical factors between the extubation failure and control groups is presented in table 1. Groups were similar for ISS (21 vs 21), GCS at extubation (11 vs 11), number of comorbidities (1.5 vs 1.7), injury mechanism (blunt 79% vs 74%), and BMI (27.9 vs 27.2). In addition, groups were similar with respect to successful SBT (84% vs 89%, p=0.57).

The results of the multiple logistic regression analysis are demonstrated in table 2. The model identified that failed extubation was associated with an increased odds of fever at the time of extubation (OR 5.9, 95% CI 1.7 to 20.8), and non-surgeon intensivist consultation (OR 24.2, 95% CI 5.5 to 105.9).

Testing for multicollinearity identified association between VAP and fever at extubation. The model was run with both VAP and fever included, then alternately with each alone. The resulting model included VAP and fever with a Hosmer-Lemishow goodness of fit p value of 0.216. The Nagelkerke R2 of 0.672 indicated a moderately strong relationship of 67.2% between the predicators and extubation failure was higher than either model with VAP or fever individually.

DISCUSSION

Mechanical ventilation is perhaps the most important advancement in the care of critically ill patients of the 20th century, as the severe pulmonary dysfunction that is common to sepsis, severe trauma, and primary cardiopulmonary disease is essentially non-survivable in the absence of mechanical support. It is well recognized, however, that with mechanical ventilation comes risks, including lung injury, pneumonia, and laryngeal injury from indwelling endotracheal tubes. Recognition of the time-dependent nature of these risks has led to clinical vigilance with respect to discontinuing ventilator support and extubating patients as soon as the clinical condition allows. Whether or not the patient is in fact ready for extubation is a clinical assessment, and naturally, sometimes this assessment will be incorrect in retrospect, and a patient will require reintubation.

Unfortunately, extubation failure is associated with deleterious outcomes including increased duration of mechanical ventilation and mortality.[2] The results of this study further confirm these associations. The mechanisms of the relationship between extubation failure and mortality, however, remain unclear. It is possible that extubation failure is simply a marker of severity of illness—sicker patients are more likely to fail extubation and more likely to die in hospital. However, the contribution of the period of distress between extubation and reintubation, along with the act of reintubation in a distressed patient, likely causes subsequent patient deterioration as well.

A number of causes of extubation failure have been identified, including upper airway obstruction, excessive secretions, cardiac comorbidity, and encephalopathy.[2] The majority of studies that examine this issue have originated from cohorts of primarily medical or mixed cohorts of ICU patients. Patients with trauma represent a unique group, given that the indications for mechanical ventilation are often heterogeneous and multifactorial, including severe brain injury, hemorrhagic shock and the sequelae of resuscitation, thoracic injury, and delirium often associated with recreational drugs and/or alcohol. Relatively few studies have addressed extubation failure in cohorts of patients with trauma. Brown *et al*[5] performed a study of extubation failure among patients with trauma, and observed a failure rate of 6%, similar to the failure rate reported in the present study. In contrast to this study, Brown *et al* identified that spine fracture, initial intubation for airway compromise (present or impending), GCS at extubation, and delirium tremens were independent risk factors for extubation failure. Bilello *et al*[6] performed a similar study at a level I trauma center, focusing specifically on patients with blunt trauma with pulmonary contusion. They observed that PaO2/FiO2 ratio <290 and alveolar-arterial oxygen difference ≥100 mm Hg at time of extubation were predictive of extubation failure.

In both of these studies and in the present study, it is notable that the large majority of patients had successfully completed an SBT. Evidence for the superiority of SBT over other weaning strategies originated in the 1990s, and since that time the SBT has become the foundation for institutional extubation

A. When the order to wean per protocol is written by the physician, the Respiratory Therapist is authorized to initiate alterations in the mechanical ventilation settings for adult patients according to the following protocol.

Step One:
1. Wean FiO2 to <50% keeping oxygen saturation > 92%.
2. Wean PEEP by increments of 2-3 to a goal of 5 after FiO2 is <50%.

Step Two: When all the components of Step One are completed, perform the following assessment of the patient. If the patient meets all of the Step Two criteria, begin Step Three- Spontaneous Breathing Trial.

1. No vasopressors are being utilized to maintain blood pressure (OK to proceed if the patient is hemodynamically stable & physician approval is obtained.)
2. Cough reflex with suctioning of the trachea is present.
3. Swallow reflex appears to be present.
4. Patient is on minimal sedation.
5. PaO2/FiO2 ratio is greater than 200. Obtain a current ABG if the last ABG is greater than 12 hours old.
6. Spontaneous breathing efforts are present.

Step Three- Spontaneous Breathing Trial: The patient should be placed on CPAP 5 and PS 10 with FiO2 of 50% for 30-60 minutes.

Terminate trial prematurely and return to previous comfortable ventilator settings if:
1. Oxygen saturations <90% for 2 minutes.
2. Heart rate >120 or <60 for 2 minutes.
3. Systolic blood pressure >180 or <90 for 2 minutes.
4. Respiratory rate >30 for 15 minutes.
5. Spontaneous tidal volumes < 5cc/kg.
6. Agitation, diaphoresis, or anxiety present for 5 minutes.

If initial spontaneous breathing trial fails, a second attempt to wean may be made at the discretion of the physician if the patient meets Step 2 criteria Coordinate with RN to conduct Spontaneous Breathing Trial every shift during the sedation vacation if the patient meets the Step Two criteria.

If Spontaneous Breathing Trial is tolerated for 30-60 minutes:

1. Perform cuff leak test.
2. Obtain ABG and compare with previous ABG.
3. Notify and inform the physician if the patient is a good candidate for extubation.
4. When approved by the physician, extubate the patient and place on oxygen delivery device, titrating to keep the patient's oxygen saturation >92%.
5. Obtain ABG 30 minutes post extubation.

Figure 1 Adult mechanical ventilation weaning protocol at St. Joseph's Hospital and Medical Center, Phoenix, Arizona, USA.

protocols, including our own. It is instructive, however, that successful completions of SBT does not predict extubation success. As discussed by Brown *et al*,[5] it is important to remember that several factors need to be considered in a patient who has passed an SBT prior to committing to extubation. SBT does not account precisely for a patient's level of cognition, ability to clear secretions, or participate in pulmonary toilet following extubation.

A relatively distinctive observation in the present study was the association between extubation failure and non-surgical intensivist consultation. Over the period of time during which the study was conducted, the trauma service call panel was staffed by surgeons with and without board certification in surgical critical care. However, all trauma surgeons were credentialed to provide surgical critical care by the hospital. The hospital's intensive care units were of the 'open' model, whereby any physician could place a patient in the ICU and intensivist consultation was not mandated. The available intensivist consult service was composed of non-surgeons (primarily certified in critical care via internal medicine pathway), and it was the practice of the trauma service to selectively consult this group for assistance with patient care. However, no specific criteria or guideline for consultation was in place during the study period. Approximately 60% of the patients studied received non-surgical intensivist consultation prior to extubation, including 59 of the 63 extubation failures. In contrast, over one-quarter of the patients in the study were admitted to a trauma surgeon who was board-certified in surgical critical care, and this had no significant bearing on extubation failure versus success.

The explanation for the association between non-surgeon intensivist consultation and extubation failure is not clear. It is possible that patients with intensivist consultation were more likely to fail extubation as a result of underlying comorbidities, severity of illness, and/or time on the ventilator. However, these variables were evaluated and accounted for in bivariate comparison and multivariate regression analysis, and demographic and/or clinical characteristic differences between groups are not apparent. It remains plausible, however, that patients with relatively more complicated clinical issues were more likely to have received intensivist consultation and, in turn, were more likely to have higher risk for extubation failure. This confounding by indication (ie, intensivist consultation) may be present despite the apparent similarities between groups according to the variables that were compared.

It is also possible that the trauma surgeon, privy to an inherent understanding of a patient's injury burden, may be at an advantage with respect to the decision to extubate. Klein *et al*[8] compared the outcomes of patients managed at a regional

Table 1 Comparison of demographic and clinical characteristics between groups

	EF group (n=63)	Control group (n=63)	p Value
Age	44.5±18.7	37.4±14.2	0.02
BMI	27.9±5.3	27.2±6.2	0.50
ISS	21±11.8	20±10.7	0.95
GCS at extubation	11±1.1	10±1.7	0.01
Female gender	13 (20.6)	15 (23.8)	0.67
Hypertension	16 (25.4)	7 (11.1)	0.04
Diabetes	9 (14.3)	3 (4.8)	0.07
CAD	6 (9.5)	3 (4.8)	0.30
Lung disease	5 (7.9)	2 (3.2)	0.24
Smoker	10 (15.9)	14 (22.2)	0.36
Alcohol abuse	22 (34.9)	30 (47.6)	0.15
Drug abuse	15 (23.8)	26 (41.3)	0.04
SCC surgeon	20 (31.7)	13 (20.6)	0.16
Non-surg intensivist	59 (93.7)	19 (30.2)	<0.01
Successful SBT	53 (84)	56 (89)	0.57
Blunt mechanism	50 (79.4)	46 (74.2)	0.49
Thorax injury	34 (54.8)	28 (44.4)	0.28
Head injury	32 (50.8)	21 (33.3)	0.05
Spine injury	37 (58.7)	41 (65.1)	0.46
Fever at extubation	46 (73.0)	21 (33.3)	<0.01
Septic	4 (6.3)	3 (4.8)	0.70
VAP	46 (73.0)	13 (20.6)	<0.01

Continuous variables expressed as mean±SD, categorical variables expressed as n (%). BMI, body mass index; CAD, coronary artery disease; EF, extubation failures; GCS, Glasgow Coma Scale; ISS, Injury Severity Score; SBT, spontaneous breathing trial; SCC, surgical critical care; VAP, ventilator-associated pneumonia.

Table 2 Results of multiple regression analysis

	OR	95% CI	p Value
Age	1.0	0.9 to 1.1	0.28
Head injury	0.4	0.1 to 1.2	0.10
Hypertension	3.3	0.6 to 18.8	0.18
Diabetes	1.2	0.1 to 11.1	0.89
Drug/alcohol	1.2	0.1 to 10.1	0.86
Fever	5.9	1.7 to 20.8	0.01
VAP	3.3	0.8 to 13.2	0.09
GCS at extubation	0.8	0.1 to 8.0	0.83
Non-surg intensivist	24.2	5.5 to 105.9	<0.01
SCC surgeon	3.0	0.8 to 10.9	0.10

GCS, Glasgow Coma Scale; SCC, surgical critical care; VAP, ventilator-associated pneumonia.

trauma center before and after the implementation of a surgical critical care service. Prior to the implementation of the service, the ICU care at their center was provided by a pulmonary medicine intensivist group. The authors identified that following implementation of a surgical critical care service, whereby their patients with trauma received ICU care solely from trauma surgeons on a rotating basis, there were improvements in pulmonary complications (3% vs 6%, $p<0.001$) and fewer ventilator days (3 vs 4, $p=0.002$). Notably, there was also an observed decrease in the rate of failed extubation (4% vs 9%, $p<0.001$). The American College of Surgeons' Committee on Trauma (ACSCOT) has advocated for trauma surgeon-led care of trauma surgeons in the ICU, and in the most recent version of the Resources for Optimal Care of the Injured Patient (the ACSCOT published guidelines for trauma center verification), a surgically directed ICU physician team led by a surgeon boarded in surgical critical care is mandated for level I accreditation/verification.[9] In accordance, we have recently reconfigured our care model to satisfy this requirement, whereby surgeons who are board-certified in surgical critical care provide all intensivist consultation to our trauma service. Whether or not our experience will be similar to that reported by Klein *et al* remains to be determined, but ultimately will help to determine whether the relationship between non-surgeon intensivist and extubation failure was relatively more attributable to provider or patient.

The remaining significant observation of this study was the association between fever and extubation failure. In bivariate analysis, fever and pneumonia were significantly associated with extubation failure. These variables were noted to be collinear; however, including both in the regression proved to provide the best fit, and ultimately fever was observed to be the independent predictor of extubation failure. The presence of fever may or may not have been associated with a pulmonary source. Nonetheless, its presence should signal to the provider that an active infectious or inflammatory process is present, and attempting to extubate the patient in the midst of this process may be ill advised, whether or not the patient had successfully completed SBT.

Limitations of this study include the issue of confounding by indication as described above. The reason for intensivist consultation was not tracked, but indications for consultation likely included the presence of chronic pulmonary comorbid disease, acute pulmonary dysfunction beyond the comfort level of the trauma surgeon, and individual trauma surgeon's interest and comfort with the critical care issues for each patient. Although underlying comorbidities, severity of illness, and/or time on the ventilator were similar between groups, it is possible that there is residual confounding between intensivist consultation and extubation failure explained by additional patient disparities. In addition, the attribution of the decision to extubate to a specific physician was not explicitly captured. In general, the decision to extubate was made by the intensivist if following the patient in consultation, or the trauma surgeon if no intensivist was involved. However, it is possible that in some cases, the trauma surgeon made the decision to extubate despite non-surgeon intensivist consultation. Our center is a teaching institution with surgery and medicine residency programmes, and although decision to extubate is generally an attending-level decision in our facility, it is also possible that some events could have been attributable to resident physician decisions.

CONCLUSION

Among injured ICU patients at an urban level I trauma center, extubation failure was associated with increased LOS, ventilator days, and mortality. Fever at time of extubation was observed to be an independent predictor of extubation failure, and the presence of such should give pause in the decision to extubate. Interestingly, non-surgeon intensivist involvement significantly increased the risk of extubation failure. Whether this finding is all or in part directly attributable to non-surgeon involvement or, in fact, related to unidentified patient factors that are confounding to this association remains undetermined. Nonetheless, a dedicated surgical critical care service may be most appropriate for the management of mechanically ventilated patients with trauma.

Contributors SRP, LRS, and PWG conceptualized and designed the study. PWG and LRS contributed in acquisition of data. JAW, PWG, TMT, JLS, and SRP analyzed and interpreted the data. JAW, JLS, PWG, and SRP drafted the manuscript. JAW, JLS, PWG, SRP, LRS, and TMT critically revised the study.

Competing interests None declared.

Ethics approval The study was approved by St. Joseph's Hospital and Medical Center IRB.

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