Outcomes of Extracorporeal Life Support in Trauma

Keywords: Trauma; Extracorporeal life support; ECLS; ECMO

Abstract

Background: Extracorporeal life support (ECLS) is a life-saving treatment for critically ill trauma patients with refractory cardiopulmonary failure. The purpose of this analysis is to use a large national trauma database to characterize the use and outcomes of ECLS in trauma.

Methods: Patients from centers that performed ECLS were identified from the 2007-2009 National Trauma Data Bank (NTDB). Demographic, clinical, and outcome data were abstracted. Univariate analyses were performed using chi-square, Mann-Whitney U-test, and regression analyses. Propensity score analysis and multiple regression models were developed using backwards stepwise logistic regression to identify risk factors for ECLS and predictors of mortality; p≤0.05 was considered significant.

Results: Forty-two centers of 682 (6%) performed ECLS on 78 of 245,950 patients (0.03%). ECLS patients were younger, more severely injured, had a longer ICU and hospital length of stay, and a higher mortality. Univariate analysis showed that ECLS patients had a significantly increased risk of death (OR 28; 95% CI 18-43; p<0.001). Among patients receiving ECLS, predictors of mortality included injury severity score (ISS) (OR 1.06; 95% CI 1.01-1.11; p=0.03) and cardiac arrest (OR 7.57; 95% CI 1.58-36.2; p=0.01). After propensity score adjusted logistic regression, ECLS was still a significant predictor of mortality (OR 6, 95% CI 2.76-13.1, p<0.01). Patients receiving ECLS at a center that performed 5 or more ECLS runs trended towards a lower mortality rate (27% vs. 73%, p≤0.10).

Conclusions: ECLS is infrequently used in the trauma setting. When compared to other trauma patients, ECLS patients are more critically ill and are at increased odds of death. Further study is required to determine which patient and hospital characteristics predict improved survival.

Introduction

The role of extracorporeal life support (ECLS) in the management of acute respiratory failure of the trauma victim is not well defined. Several case reports and small case series describe the use of ECLS in the management of pediatric and adult traumatic respiratory failure including blunt and penetrating parenchymal and tracheobronchial injuries [1-10], cardiac contusions [11-13], traumatic brain injury [14-17], and shock [18-20]. Retrospective cohort studies of trauma patients cared for at tertiary care referral centers report survival after ECLS ranging from 50-79% [21-24]. These case reports, small case series, and retrospective reviews suggest a potential role for ECLS in the management of traumatically injured patients.

The National Trauma Data Bank collects and maintains a large, detailed registry of de-identified trauma data voluntarily submitted from participating trauma centers. The purpose of this analysis is to use a large national trauma database to characterize the use and outcomes of ECLS in trauma patients.

Methods

This study was approved by The University of Texas Health Science Center Institutional Review Board (IRB# HSC-MS-10-0215).

longer intensive care unit (ICU) and hospital length of stay and were considered more likely to die. Patients receiving ECLS at a center that performed 5 or more ECLS runs had a lower mortality rate, although the difference was not statistically significant (27% vs. 73%, \( p = 0.10 \)).

Univariate analysis showed that ECLS patients had a significantly increased odds of death (OR 28; CI 18-43; \( p < 0.001 \)). In patients that received ECLS, injury severity score (OR 1.06; CI 1.02-1.11; \( p = 0.027 \)) and cardiac arrest (OR 7.57; CI 1.58-36.2, \( p = 0.011 \)) were independent predictors of mortality on logistic regression analysis.

There was sufficient overlap in propensity scores to match 53 ECLS patients to 212 controls. Following propensity score matching, there were no significant differences between patients who received ECLS and those that did not with respect to patient demographics and clinical characteristics (Table 2). There were also no differences found between the matched groups with regard to complications. However, mortality amongst patients receiving ECLS remained higher (50% vs. 31%, \( p = 0.01 \)). The propensity score adjusted multivariate logistic regression identified ECLS use, injury severity score, age, systolic blood pressure and GCS on admission as independent predictors of mortality (Table 3).

**Discussion**

Review of the National Trauma Data Bank shows that the utilization of ECLS in the management of critically ill trauma patients is rare. Not surprisingly, patients that receive ECLS are more critically ill and are at increased risk of complications and death. However, ECLS has become a powerful tool for managing acute cardiorespiratory failure in critically ill patients. Significant advances in critical care such as advanced lung protection strategies along with major advances in extracorporeal technology (catheters, oxygenator, heparin bonded circuitry, improvements in pump design, etc.) have led to a surge in the use of ECLS for the management of adult cardiorespiratory failure. In 2009, the results of a randomized, prospective trial of ECLS in critically ill adult patients with acute respiratory failure...
Several case reports and small case series illustrate the utility of ECLS in carefully selected traumatically injured patients. With respect to blunt and penetrating thoracic trauma, venoarterial (VA) ECLS has been successfully used in managing postoperative cardiopulmonary failure following pneumonectomy for penetrating thoracic trauma [27]. Both venoventricular (VV) and VA ECLS have been employed for perioperative management of patients who sustained traumatic tracheobronchial rupture to enable successful operative repair [3,8,13]. VV ECLS has been used in several patients to manage respiratory failure from extensive traumatic pulmonary contusion and hemorrhage [1,2,6,13,28]. VA ECLS has also been successfully employed in the management of cardiac failure from traumatic cardiac contusion and hemorrhagic shock [11,12,18,20].

Several experienced ECLS centers have retrospectively reported their single center experience with traumatically injured patients. The University of Michigan reviewed 30 adult trauma patients who received ECLS between 1989 and 1997 [21]. Their patients had an average age of 26 years, were 50% male and had predominately blunt mechanism of injury. The survival to discharge in this cohort was 50%. They found that fewer days of pre-ECLS ventilation and more normal venous oxygen saturation were associated with survival. Acute renal failure and the need for vena-arterial support were more common in those who died. Bleeding complications were common (59%) but not associated with mortality. Early implementation of ECLS was associated with increased odds of survival. The United Kingdom experience was described in a single center retrospective review of 28 patients from 1992 to 2000 [22]. The predominant mechanism was blunt road traffic crashes with multisystem traumatic injury. Direct pulmonary contusion and fat-emboli were common contributing factors to refractory acute respiratory failure and the need for ECLS. Overall, 71% of patients were successfully weaned from ECLS support. Patient age, duration of ECLS, and duration of pre-ECLS ventilator support did not differ between survivors and non-survivors. Patients with lower ISS and isolated long bone fractures had a worse outcome on ECLS, perhaps illustrating different physiologic recovery from fat emboli syndrome when compared to other etiologies of acute respiratory failure. More recently, a retrospective analysis of

<table>
<thead>
<tr>
<th>Variable</th>
<th>ECLS (n=53)</th>
<th>No ECLS (n=212)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Age (years)</td>
<td>27.5</td>
<td>29.5</td>
<td>0.59</td>
</tr>
<tr>
<td>Mean ISS</td>
<td>25.9</td>
<td>27.1</td>
<td>0.67</td>
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<tr>
<td>Mean SBP (mmHg)</td>
<td>117</td>
<td>119</td>
<td>0.86</td>
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<tr>
<td>Mean Pulse</td>
<td>112</td>
<td>115</td>
<td>0.56</td>
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<tr>
<td>Mean GCS Total</td>
<td>9.7</td>
<td>9.6</td>
<td>0.95</td>
</tr>
<tr>
<td>Mortality (%)</td>
<td>50</td>
<td>31</td>
<td>0.01</td>
</tr>
<tr>
<td>Mean ICU LOS, days</td>
<td>23</td>
<td>23</td>
<td>0.91</td>
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Comorbidities

<table>
<thead>
<tr>
<th>Comorbidities</th>
<th>ECLS (n=53)</th>
<th>No ECLS (n=212)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Respiratory failure (%)</td>
<td>13</td>
<td>15</td>
<td>0.78</td>
</tr>
<tr>
<td>Alcoholism (%)</td>
<td>15</td>
<td>17</td>
<td>0.79</td>
</tr>
<tr>
<td>Ascites within 30 days (%)</td>
<td>2</td>
<td>1</td>
<td>0.68</td>
</tr>
<tr>
<td>Hypertension requiring medication (%)</td>
<td>9</td>
<td>12</td>
<td>0.64</td>
</tr>
<tr>
<td>Impaired sensorium (%)</td>
<td>6</td>
<td>9</td>
<td>0.52</td>
</tr>
<tr>
<td>Bleeding disorder (%)</td>
<td>11</td>
<td>11</td>
<td>0.94</td>
</tr>
</tbody>
</table>

Complications

<table>
<thead>
<tr>
<th>Complications</th>
<th>ECLS (n=53)</th>
<th>No ECLS (n=212)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abdominal compartment syndrome (%)</td>
<td>4</td>
<td>2</td>
<td>0.68</td>
</tr>
<tr>
<td>Abdominal fascia left open</td>
<td>6</td>
<td>4</td>
<td>0.74</td>
</tr>
<tr>
<td>Acute renal failure</td>
<td>34</td>
<td>34</td>
<td>0.96</td>
</tr>
<tr>
<td>Acute respiratory distress syndrome</td>
<td>45</td>
<td>50</td>
<td>0.60</td>
</tr>
<tr>
<td>Base deficit</td>
<td>13</td>
<td>16</td>
<td>0.68</td>
</tr>
<tr>
<td>Bleeding</td>
<td>11</td>
<td>11</td>
<td>0.94</td>
</tr>
<tr>
<td>Cardiac arrest with cardiopulmonary resuscitation</td>
<td>25</td>
<td>25</td>
<td>1.00</td>
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<tr>
<td>Coagulopathy</td>
<td>15</td>
<td>12</td>
<td>0.68</td>
</tr>
<tr>
<td>Deep vein thrombosis / thrombophlebitis</td>
<td>4</td>
<td>3</td>
<td>0.79</td>
</tr>
<tr>
<td>Myocardial infarction</td>
<td>4</td>
<td>4</td>
<td>1.00</td>
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<tr>
<td>Pneumonia</td>
<td>21</td>
<td>25</td>
<td>0.61</td>
</tr>
<tr>
<td>Pulmonary embolism</td>
<td>8</td>
<td>4</td>
<td>0.48</td>
</tr>
<tr>
<td>Stroke/cerebrovascular accident</td>
<td>4</td>
<td>1</td>
<td>0.45</td>
</tr>
<tr>
<td>Systemic sepsis</td>
<td>11</td>
<td>14</td>
<td>0.67</td>
</tr>
<tr>
<td>Unplanned intubation</td>
<td>8</td>
<td>9</td>
<td>0.73</td>
</tr>
</tbody>
</table>

(Conventional ventilatory support versus extracorporeal membrane oxygenation for Severe Adult Respiratory failure; CESAR) were published. This trial showed improved outcome in those patients who were managed at an ECLS center [26]. This trial only enrolled a small proportion (12/180 or 7%) of trauma patients, which included patients undergoing surgery. Nonetheless, given these results, the use of ECLS has become more widely utilized in critically ill patients with cardiopulmonary failure of various etiologies, including those with traumatic injuries.

Several experienced ECLS centers have retrospectively reported their single center experience with traumatically injured patients. The University of Michigan reviewed 30 adult trauma patients who received ECLS between 1989 and 1997 [21]. Their patients had an average age of 26 years, were 50% male and had predominately blunt mechanism of injury. The survival to discharge in this cohort was 50%. They found that fewer days of pre-ECLS ventilation and more normal venous oxygen saturation were associated with survival. Acute renal failure and the need for vena-arterial support were more common in those who died. Bleeding complications were common (59%) but not associated with mortality. Early implementation of ECLS was associated with increased odds of survival. The United Kingdom experience was described in a single center retrospective review of 28 patients from 1992 to 2000 [22]. The predominant mechanism was blunt road traffic crashes with multisystem traumatic injury. Direct pulmonary contusion and fat-emboli were common contributing factors to refractory acute respiratory failure and the need for ECLS. Overall, 71% of patients were successfully weaned from ECLS support. Patient age, duration of ECLS, and duration of pre-ECLS ventilator support did not differ between survivors and non-survivors. Patients with lower ISS and isolated long bone fractures had a worse outcome on ECLS, perhaps illustrating different physiologic recovery from fat emboli syndrome when compared to other etiologies of acute respiratory failure. More recently, a retrospective analysis of

Table 2: Difference between groups after propensity score matching.
Propensity score matched ECLS and no-ECLS patients were compared using student’s t-test. Patient characteristics and complications were similar between groups.
prospectively collected, single-center, registry data of 52 consecutive trauma patients receiving ECLS from 2002 through 2012 for post-traumatic respiratory failure was conducted [24]. Like previous studies, the predominant mechanism was automobile crash (73%) and the patients were severely injured with a mean ISS of 58.9±10.5 and a mean lung injury score of 3.3±0.6. Their series is notable for utilizing both pump-less and pump-driven ECLS, 98% percutaneous cannulation, and minimal complications. Their overall survival was 79% and compares favorably to the proposed ISS-related mortality of 59%. These studies conclude that ECLS is feasible in the critically ill, traumatically injured population and may have a role for patients who develop severe respiratory distress associated with trauma.

Our current study provides a snapshot of the number of centers in the United States that provide the option of ECLS in the management of their severely injured trauma population and their outcomes. The mortality of 51% is comparable to the mortality seen in other studies. Patients at these centers that received ECLS as part of their clinical course were more critically ill and would be expected to have an increased odds of poor outcome. Not surprisingly, predictors of mortality using propensity score matching showed that receiving ECLS, as well as injury severity and physiological derangement were related to increased odds of death. The data suggests that less injured, critically ill trauma patients are more likely to benefit from ECLS.

There are several limitations to this study that may impact the results and conclusions. Due to the nature of the NTDB, the true primary indication for ECLS is unknown. The dataset does not enable analysis of the timing of ECLS and the temporal relationship of various complications in clinical outcome. Second, there may be additional unmeasured confounders; traditional regression analyses and propensity score analyses can only account for observed confounders. Thus, ECLS patients may have been more critically ill than non-ECLS patients, even after propensity score matching. However, the reduction in the odds ratio for the association between ECLS and mortality from 28 to 6 after propensity score matching suggests a reduction in selection bias with this statistical method. Lastly, the lack of pertinent clinical data such as clinical physiologic variables, mechanical ventilation parameters, cardiac function, and renal function makes it difficult to clinically apply these results.

Like many aspects of critical care, providing ECLS requires multidisciplinary coordination across many medical, nursing, and respiratory therapy subspecialties. The design, implementation, maintenance, and experience of ECLS teams are important to delivering the highest quality of ECLS care. In this context, hospital experience and regional ECLS referral patterns may play a role in outcome [29,30]. As with most complex technologies and procedures, increased experience, over time, should improve outcome and this trend is observed in this study. Unfortunately, this type of data is also unavailable from the NTDB but might be reflected in the fact that survival was improved in sites that performed more ECLS runs.

As with most papers, this study generates more questions than answers. Further investigation is required to identify which patients are most likely to benefit from ECLS, the optimal management (sedation and analgesia, mechanical ventilator “rest” settings, nutrition, systemic anticoagulation, etc.) of trauma patients on ECLS, the role of specialized trauma centers for ECLS, and the metrics by which these centers should be judged. This issue is partially addressed in this study but a more complete and robust clinical data set and analysis is required to provide more definitive conclusions, particularly with respect to timing of potential transfer or initiating ECLS. However, the success documented in this review, multiple case reports, case series, and small retrospective reviews suggest an important role of ECLS in the management of critically ill trauma patients and that these are questions worth answering. Additional investigations and trials are needed to determine which patient and hospital characteristics will allow for optimal utilization of this resource-intensive intervention to achieve maximal benefit in critically injured trauma victims.

References


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