ARTICLE IN PRESS

American Journal of Emergency Medicine xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

American Journal of Emergency Medicine

journal homepage: www.elsevier.com/locate/ajem

Original Contribution

Use of extracorporeal membrane oxygenation in severe traumatic lung injury with respiratory failure☆,☆☆,★

Shih-Chi Wu, MD, Msc [a,b,*], William Tzu-Liang Chen, MD [b,c], Hui-Han Lin, MD [d], Chih-Yuan Fu, MD [e], Yu-Chun Wang, MD [a,b], Hung-Chieh Lo, MD [a,b], Han-Tsung Cheng, MD [a], Chia-Wei Tzeng, MD [a]

[a] Trauma and Emergency Center, China Medical University Hospital, Taichung, Taiwan
[b] School of Medicine, China Medical University, Taichung, Taiwan
[c] Division of Colorectal Surgery, Department of Surgery, China Medical University Hospital, Taichung, Taiwan
[d] Department of Cardiovascular Surgery, China Medical University Hospital, Taichung, Taiwan
[e] Department of Trauma and Emergency Surgery, Chang Gung Memorial Hospital, Linko, Taiwan

ARTICLE INFO

Article history:
Received 28 June 2014
Received in revised form 3 February 2015
Accepted 4 February 2015
Available online xxxx

ABSTRACT

Objectives: The use of extracorporeal membrane oxygenation (ECMO) in managing acute respiratory distress syndrome had been accepted. Severe lung injury with respiratory failure is often encountered in trauma patients. We report our experience with the use of ECMO in severe traumatic lung injury.
Methods: Patients with severe traumatic lung injury that met the following criteria were candidates for ECMO: (1) severe hypoxemia, Pao_2/fraction of inspired oxygen (1.0) less than 60, and positive end-expiratory pressure greater than 10 cm H_2O in spite of vigorous ventilation strategy; (2) irreversible CO_2 retention with unstable hemodynamics; and (3) an initial arterial Pao_2/fraction of inspired oxygen (1.0) less than 60, where the pulmonary condition and hemodynamics rapidly deteriorated despite vigorous mechanical ventilation strategy.
Results: Over 60 months, a total of 19 patients with severe traumatic lung injury who received ECMO management were retrospectively reviewed. The median age was 38 years (25-58 years), the median injury severity score was 29 (25-34), the median admission Acute Physiology and Chronic Health Evaluation II (APACHE II) score was 25 (21-36), and the median blood transfusion volume was 5500 mL (3500-13 000). There were 9 venovenous and 10 venoarterial types. The survival rate was 68.4% (13/19). The survivors were younger (30 vs 53 years; 21-39 vs 48-63).
There were 6 mortalities (3 pneumonia, 2 coagulopathy, and 1 cardiac rupture with cardiac tamponade). There were 5 of 19 patients with pre-ECMO traumatic brain hemorrhage (3 survived and 2 mortalities). A total of 16 patients received heparinization with 5 mortalities.
Conclusions: The use of ECMO may offer an additional treatment modality in severe traumatic lung injury with respiratory failure that is unresponsive to optimal conventional ventilator support. Timely ECMO intervention is of value.

1. Introduction

Severe trauma is one of the leading causes of death in young adults [1,2], and approximately 50% of cases are associated with chest injury in multiple trauma [3]. Most lung injury patients with mild to moderate respiratory failure respond well to noninvasive respiratory support. However, a small number of lung injury patients may develop severe respiratory failure and progress from hypoxia with systemic inflammatory response syndrome to acute lung injury or acute respiratory distress syndrome (ARDS). Intubation and mechanical ventilation in these patients may become mandatory to correct hypoxia and hypercapnia. Generally, management with a lower tidal volume and higher positive end-expiratory pressure (PEEP) is recommended in such respiratory distress [4-6]. However, there were patients who progressed to lung failure even with vigorous ventilation support. The hospital survival rates of patients with severe lung dysfunction have ranged from 26% to 58% [7-10]. In cases when most treatment options, including invasive ventilation, have failed, the use of extracorporeal membrane oxygenation (ECMO) may be used as a temporary replacement for the injured lungs; it serves to reduce ventilator settings and prevent further barotrauma [11,12]; provide adequate ventilation, oxygenation, and improvement of hypercapnia; and provide the effect of "lung rest" and buy time for recovery of lungs [13].

☆ Conflicts of interest: The authors declare no conflicts of interest related to this study.
☆☆ Author contributions: Wu SC did the study conception and design, initial draft of manuscript, interpretation, and manuscript drafting and revision. Chen WT participated in the study design and conception; Lin HH performed the procedure of extracorporeal membrane oxygenation. Fu CY, Wang YC, Lo HC, Cheng HT, and Tzeng CW did the data collection.
★ Guarantor of the article: Shih-Chi Wu, MD.
* Corresponding author at: Trauma and Emergency Center, China Medical University Hospital, No. 2 Yuh-Der Road, Taichung, Taiwan 404, R.O.C. Tel.: +886 4 22052121x5043; fax: +886 4 22334706.
E-mail addresses: rw114@mail.cmuh.org.tw (S.-C. Wu), wtchen@mail.cmuh.org.tw (W.T.-L. Chen), d10760@mail.cmuh.org.tw (H.-H. Lin), drfu5564@yahoo.com.tw (C.-Y. Fu), traumawang@yahoo.com.tw (Y.-C. Wang), carfishcat@yahoo.com.tw (H.-C. Lo), howardcheng324@gmail.com (H.-T. Cheng), D11814@mail.cmuh.org.tw (C.-W. Tzeng).

http://dx.doi.org/10.1016/j.ajem.2015.02.007
0735-6757/

Please cite this article as: Wu S-C, et al, Use of extracorporeal membrane oxygenation in severe traumatic lung injury with respiratory failure, Am J Emerg Med (2015), http://dx.doi.org/10.1016/j.ajem.2015.02.007

The use of ECMO in severe neonatal respiratory failure has been previously reported [14]. Recently, there were reports regarding the use of ECMO as a therapeutic option for ARDS in adults [11,12,15].

Massive blood loss and massive transfusion often resulted in "coagulopathy" in multiple trauma patients, which limited the use of ECMO in severe traumatic lung injury because of systemic heparinization. Thus, the use of ECMO in patients with severe traumatic lung injury remains controversial due to the risk of bleeding complications [16,17]. However, Arlt et al [18] reported the use of ECMO in 10 patients with severe trauma and hemorrhagic shock with a 60% survival rate, indicating that there might be a role for ECMO in severe traumatic lung injury patients with coagulopathy.

We were interested in the role of ECMO in severe traumatic lung injury and performed this retrospective study. We report our experience with the use of ECMO in severe traumatic lung injury and respiratory failure.

2. Materials and methods

We retrospectively reviewed the charts of patients who had severe traumatic lung injury that was refractory to conventional therapy and received extracorporeal lung support (ECMO) and were admitted to our intensive care unit (ICU) at the Trauma and Emergency Center from January 2008 to January 2014.

The data abstracted from the chart contained no identifying patient information. Those abstracting data were trained in the use of standardized data collection forms and were periodically monitored for accuracy. An assessment of interrater reliability was performed.

Institutional review board approval was not required for this type of retrospective research in our institution.

2.1. Inclusion criteria for ECMO in severe traumatic lung injury

Patients with traumatic lung injury who received conventional management initially were considered candidates for ECMO when they met one of the following criteria:

1. Arterial PaO_2/fraction of inspired oxygen (1.0) less than 60 and PEEP greater than 10 cm H_2O for 2 hours in spite of optimized mechanical ventilation strategy and conservative treatment.
2. Irreversible CO_2 retention with unstable hemodynamics.
3. The initial arterial blood gas PaO_2/fraction of inspired oxygen (1.0) less than 60, where the pulmonary condition and hemodynamics rapidly deteriorated despite vigorous mechanical ventilation strategy.

2.2. Indications for venovenous and venoarterial ECMO

The indication for venovenous (VV) ECMO was persistent hypoxemia despite vigorous ventilation and PEEP management, blood transfusion, and/or chest tube thoracotomy. Indications for venoarterial (VA) ECMO support were coexistent cardiopulmonary injury as well as profound shock despite vigorous resuscitation and vasopressor support.

2.3. Technique and access for ECMO

The VV ECMO was established via bilateral femoral vein or internal jugular vein and femoral vein using the Seldinger technique. The VA ECMO was done via exploring femoral artery and vein or right subclavian artery and femoral vein (if the subclavian artery was used, an 8-mm Dacron grafting was done first, then a cannula inserted).

2.4. Establishing and operating the ECMO device

Before establishing ECMO, the body surface area was first calculated to choose an appropriate cannula size. For VV ECMO, first, the pump speed was set at 3000/bpm and gas flow/blood flow at 1:1; then, it was adjusted according to blood gas data. For VA ECMO, the blood flow/body surface area was set at approximately 2, and the gas flow/blood flow, at 1:3 initially, and this was adjusted according to blood gas data. The speed setting, blood flow rate, and gas flow rate were then tailored to the patient.

The activated clotting time was maintained between 180 and 200 seconds. In patients with coagulopathy and bleeding, a heparin-free strategy may be adopted, and the activated clotting time range is allowed to be within 140 to 160 seconds.

2.5. Post-ECMO management in the ICU

Patients received regular intensive care after the establishment of ECMO.

Patients who developed an acute kidney injury, according to the risk injury failure loss end-stage kidney disease criteria [19,20], received early continuous renal replacement therapy/continuous VV hemofiltration (CVVH) in circuit. The CVVH machine (DF-080, HF 400; Informed SA, Geneva, Switzerland) was connected to the ECMO circuit for hemodialysis in the case of renal insufficiency.

Patients who developed sepsis and/or septic shock were managed according to the guidelines from the Surviving Sepsis campaign [21].

The demographics, mechanism of injury, Abbreviated Injury Score (AIS), Injury Severity Score (ISS), APACHE II scores, length of stay, amount of blood transfused, and survival rate were collected.

The relation between survivors and nonsurvivors as well as ECMO types (ie, VA and VV) and the use of CVVH during ECMO were evaluated. The bacteremia rate, use of heparin, causes of death, and special characteristics of some patients were also collected.

3. Statistical analyses

SAS software version 9.1 (SAS, Cary, NC) was used for the statistical analyses. Continuous data were reported as medians and interquartile ranges (IQRs) when the data were not normally distributed. Continuous data with a normal distribution were reported as mean and SD. Discrete variables were expressed as counts and percentages. Fisher exact tests were used to compare categorical variables. The Wilcoxon rank sum test and *t* test were used for continuous variables. Tests for statistical significance were 2 sided with a level of significance of $P < .05$.

4. Results

During this 60-month period, there were 19 patients with severe traumatic lung injury who received ECMO management and were enrolled in this study. There were 17 males and 2 females. The most common mechanism of injury was blunt injury after a motor vehicle crash.

The mean age was 40.7 years (SD, 18.7), the median injury severity score was 29 (25-34), the mean admission Acute Physiology and Chronic Health Evaluation II score was 28.7 (SD, 8.10), and the median blood transfusion volume was 5500 mL (3500-13 000). There were 9 patients (47.4%) who received VV-type ECMO, and 10 patients (52.6%) received VA-type ECMO. Of 19 patients, 13 survived; the survival rate was 68.4% (Table 1). There were 6 patients who died, including 3 due to pneumonia, 2 due to coagulopathy, and 1 due to cardiac rupture with cardiac tamponade.

The significant differences between the survivors and nonsurvivors were age and ICU stay; the survivors were much younger than nonsurvivors (55.8 vs 33.8 years), and there was a longer ICU stay in survivors (20.5 days vs 8.97 days) (Table 1). There were no other significant differences between the groups.

There were no significant differences between those who received VV-type ECMO and those who received VA-type ECMO among multiple factors. There was also no difference in the survival rate (Table 2).

Among multiple factors, there were no significant differences between the group who received CVVH during ECMO and those who did not, and there was no significant difference in the survival rate between the 2 groups (Table 3).

Please cite this article as: Wu S-C, et al, Use of extracorporeal membrane oxygenation in severe traumatic lung injury with respiratory failure, Am J Emerg Med (2015), http://dx.doi.org/10.1016/j.ajem.2015.02.007