Heart & Lung 45 (2016) 227–231

Contents lists available at ScienceDirect

Heart & Lung

journal homepage: www.heartandlung.org

Retrospective report of contraindications to extracorporeal membrane oxygenation (ECMO) among adults with acute respiratory distress syndrome (ARDS)

J. Kyle Bohman, MD [a,*], Matthew N. Vogt, MD [b], Joseph A. Hyder, MD, PhD [a]

[a] Mayo Clinic, Department of Anesthesiology, Division of Critical Care Medicine, Rochester, MN, USA
[b] Mayo Clinic, Department of Anesthesiology, Rochester, MN, USA

ARTICLE INFO

Article history:
Received 13 December 2015
Received in revised form
23 February 2016
Accepted 4 March 2016
Available online 2 April 2016

Keywords:
Extracorporeal membrane oxygenation
ECMO
Acute respiratory distress syndrome
ARDS
Adult

ABSTRACT

Objectives: To determine the incidence of contraindications to extracorporeal membrane oxygenation (ECMO) among adults with acute respiratory distress syndrome (ARDS) and assess the impact of contraindications on the number of patients receiving ECMO (case volume).
Background: The extent to which contraindications may affect case volumes has not been described.
Methods: Retrospective, observational study at an academic tertiary medical center. The records of 730 consecutive patients with ARDS were queried for respiratory ECMO eligibility and ECMO contraindications.
Results: Of the 730 patients with ARDS, 168 (23.0%) met ECMO inclusion criteria and 515 (70.5%) never met ECMO eligibility due to inadequately severe disease. Among 168 patients who met ECMO inclusion criteria, 1 or more relative contraindications were present in 144 (85.7%) patients. The three most common relative contraindications were immunocompromised state (58.3%), multiorgan dysfunction (29.2%) and contraindication to anticoagulation (16.7%).
Conclusions: Application of relative contraindications may greatly affect ECMO case volumes.

Introduction

ECMO is an emerging rescue therapy for patients with severe ARDS. Application of ECMO requires careful estimation of potential risks and benefits. From the perspective of patients, the therapy often requires transfer to a referral center and a high risk of morbidity. From the perspective of referral centers, ECMO is a high-cost therapy and is labor intensive for nurses, technicians, physicians, blood bank and laboratory staff. The challenges of patient selection for ECMO are made more acute because ECMO referral centers typically have a limited number of ECMO circuits available at any given time, and rationing of the therapy is a possibility. These factors make ECMO centers sensitive to changes in the number of patients receiving ECMO therapy (case volumes), limiting the ability of referral centers to accommodate rapid increases in the number of ECMO patients.

ECMO trials have enumerated inclusion and exclusion criteria for this therapy (Fig. 1). There is limited consensus, however, around the importance of named relative contraindications. Consequently, these relative contraindications are not consistently applied. No studies have described the incidence of these complications, and more importantly, no studies have evaluated the impact of relative contraindications on potential case volumes.

We use retrospective data from a large academic center, during an epoch prior to regular application of respiratory ECMO, to quantify the incidence of relative contraindications to respiratory ECMO in a population of patients with moderate and severe ARDS. We subsequently used these data to demonstrate the potential impact of relative contraindications on potential ECMO case volumes. These data may be valuable to ECMO referral centers that must balance the workload of ECMO therapy with their capacity to provide high-quality ECMO care for patients with ARDS.

Conflict of interest statement: The authors declare that there is no conflict of interest.

Funding source: JAH was the recipient of the Career Development Award from the Anesthesia Patient Safety Foundation and Anesthesia Quality Institute.

* Corresponding author. Department of Anesthesiology, Division of Critical Care Medicine, Mayo Clinic, 200 First St SW, Rochester, MN 55905, USA. Tel.: +1 507 255 5601; fax: +1 507 255 2939.
E-mail address: bohman.john@mayo.edu (J.K. Bohman).

0147-9563/$ – see front matter © 2016 Elsevier Inc. All rights reserved.
http://dx.doi.org/10.1016/j.hrtlng.2016.03.003

Inclusion Criteria	Absolute Exclusion Criteria	Relative Exclusion Criteria
ARDS per Berlin definition, and ≥1 of the following:	Mechanical Ventilation ≥7 days	Immunocompromised state†
-OR- PaO2/FIO2 <80 for ≥3 hours despite Vt 6 ml/kg + PEEP ≥5	CNS Catastrophe*	Age >70 years
-OR- pH <7.25 for ≥3 hours with RR ≥30 while Pplat <32	Irreversible condition and not lung transplant candidate	Chronic CNS deficit or CNS status unknown
	Death within 3 hours of intubation	High risk for anticoagulation
	ARDS not severe enough to meet inclusion criteria	Multiorgan Dysfunction Syndrome

*Significant anoxic brain injury, diffuse axonal injury, massive intracranial hemorrhage or herniation.
†Solid organ or stem-cell transplant, solid organ or hematologic malignancy, chronic immunosuppressive therapy, HIV/AIDS, and inherited immunodeficiency.

Fig. 1. ECMO-eligibility criteria.[9–11] *Significant anoxic brain injury, diffuse axonal injury, massive intracranial hemorrhage or herniation. †Solid organ or stem-cell transplant, solid organ or hematologic malignancy, chronic immunosuppressive therapy, HIV/AIDS, and inherited immunodeficiency.

Material and methods

Human subjects protections and setting

This retrospective study was approved by Mayo Clinic's Institutional Review Board. The study medical center is a large, academic, tertiary hospital. In addition to multiple surgical and medical intensive care units, the hospital cares for a large volume of solid organ and bone marrow transplant patients. Historically, the hospital has performed primarily postcardiotomy ECMO, but in the few years prior to this publication the use of venovenous ECMO for respiratory failure has been applied to limited numbers of cases.

Identification of ARDS patients

The records of all adult intensive care unit (ICU) patients requiring mechanical ventilation from January 1, 2006 to Dec 31, 2010 at Mayo Clinic, Rochester, MN were queried for ARDS using the institutional electronic medical record (EMR) database and the Metric Data Mart.[1] Steps of development of the database, data security and validation of demographics have been published previously.[2,3] Screening of patients was performed by identifying all patients with at least moderate hypoxemia (at least 2 recorded PaO_2/FIO_2 ratios <200 while receiving ≥5 cm H_2O PEEP) requiring mechanical ventilation. From this population of severely hypoxemic patients, each patient was reviewed by 3 critical care physicians to determine if they had ARDS per the Berlin definition.[4] Echocardiographic data was reviewed by a research cardiologist and used to determine a high likelihood of cardiogenic pulmonary edema. In patients without echocardiograms, if the presence of a known ARDS risk factor was noted, ARDS was established as a predominant cause of hypoxia.[4,5] Only those who were identified as ARDS patients were further evaluated for the following variables and outcomes. Baseline patient data was retrieved electronically from the Metric Data Mart. The following variables and outcomes were determined by manual retrospective review of the electronic medical record by a licensed physician.

Determination of ECMO-eligibility

ECMO-eligibility was determined by manual retrospective review of the electronic medical record by a board certified critical care physician. Several institutions with high volume ECMO practices have published recommended inclusion and exclusion criteria for respiratory ECMO (ECMO for ARDS) in guidelines and major clinical trials.[6–8] We integrated these precedents recommendations to yield a set of ECMO inclusion criteria, absolute exclusion criteria and relative exclusion criteria (Fig. 1). If a patient met inclusion criteria and did not have absolute contraindications to ECMO, then they were identified as "ECMO-eligible" and any relative contraindications were recorded for later analysis.

Contraindications to ECMO

The electronic medical record was also manually reviewed for the presence of contraindications to ECMO by a board certified critical care physician. Screening for contraindications to ECMO was performed at the same time point that each patient met inclusion criteria for ECMO-eligibility (Fig. 1). Based on published guidelines and multicenter ECMO trial criteria, a list of absolute and relative contraindications were compiled and are listed in Fig. 1.[6–8] Absolute contraindications included mechanical ventilation for greater than 7 days, death within 3 h of intubation, irreversible underlying condition or not a lung transplant candidate, and a likely or proven central nervous system catastrophe (severe anoxic brain injury, diffuse axonal injury, massive intracranial hemorrhage or massive stroke). Relative contraindications were commonly cited contraindications which would not necessarily preclude ECMO application. These relative contraindications included multiorgan dysfunction syndrome (MODS), contraindication to anticoagulation, immunocompromised state,[9] age >70 years, weight >150 kg, central nervous system deficit other than those listed above as absolute contraindications (chronic deficits with incapacitation). The working definition of MODS (3 or more failing organs) was chosen *a priori* based on previous studies which noted a mortality of 48.5% in patients with at least 3 failing organs compared to only 26.2% in those with 2 failing organs.[10] For the determination of MODS, respiratory dysfunction was defined as PaO_2/FIO_2 <300; cardiovascular dysfunction was defined as the need for vasopressor or inotropic support to maintain mean arterial blood pressure (MAP) > 60 mm Hg; renal dysfunction was defined as the need for new renal replacement therapy or serum creatinine >3× baseline or >4 mg/dL; hepatic dysfunction was defined as total bilirubin >1.0 mg/dL or INR >1.2; and hematologic dysfunction was defined as a platelet count $<150 \times 10^9$/L.[10–12] Neurologic, gastrointestinal and endocrine dysfunctions were not determined due to difficulties with validity in a retrospective study and significant confounding by sedation and analgesic practices.

The rationale for dividing exclusion criteria into absolute and relative contraindications was that invocation of relative