Chest tube placement in children during extracorporeal membrane oxygenation (ECMO)

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ABSTRACT

Background: Pleural collections of air and fluid are frequent in infants and children treated with extracorporeal membrane oxygenation (ECMO). In this anticoagulated population, chest tube placement is potentially hazardous, and catastrophic hemorrhage has been reported. We sought to define the risks associated with chest tube placement in a large population of children managed with ECMO.

Methods: The records of 189 consecutive children managed with ECMO at two children's hospitals were reviewed. Demographics, indications for ECMO, and ECMO courses were reviewed. In particular, the occurrence of pleural collections and the frequency and technique of chest tube placement were evaluated. The incidence of complications and mortality were determined.

Results: The median age of the subjects was 2 days. The overall mortality was 26.5%. A pneumothorax was found in 19 (10.1%), a pleural effusion in 26 (13.8%), and a hemothorax in 2 (1.0%). A chest tube was placed in 27 (19 by a needle-guide wire technique and 8 by cut-down). Major bleeding complications occurred in 6 subjects (22%).

Conclusions: There was a significant incidence of major bleeding complications and death in subjects in whom chest tubes were placed. The placement of a chest tube during ECMO should be done only if it is likely to improve pump flow or promote weaning of support.

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Extracorporeal Membrane Oxygenation (ECMO) allows for temporary cardiopulmonary bypass in patients with severe but reversible respiratory or cardiac dysfunction who have not responded to maximal conventional ventilatory support and medical treatment. ECMO allows for the oxygenation of blood while the lungs and/or heart recover [1,2]. Bartlett and colleagues [3] described ECMO in 45 neonatal respiratory patients in 1982 and since then, the number of ECMO centers has increased throughout the world and ECMO has become a mainstay in many pediatric hospitals. The conditions most commonly associated with the need for ECMO are congenital diaphragmatic hernia (CDH), meconium aspiration (MA), respiratory distress syndrome (RDS), primary pulmonary hypertension, and sepsis [4].

While neurologic injury, air embolism, renal failure, infection, and bleeding are common complications in infants and children managed with ECMO, pleural collections of air and fluid are also frequent [5]. Fluid accumulates in the pleural space if the rate of filtration increases, if the rate of lymphatic clearance decreases, or if both of these processes occur, which is common in the presence of inflammation, infection and organ dysfunction [6]. Pneumothorax and hemothorax occur in up to 10% of patients on ECMO [7,8]. Management of pleural collections can be particularly complicated as systemic heparinization is required while on ECMO and otherwise minor bleeding due to chest tube placement can become catastrophic [9]. As there are only anecdotal reports of severe complications following chest tube insertion in this population, we sought to more specifically define the outcome of chest tube placement in pediatric patients managed with ECMO as well as assess whether the incidence of complications is influenced by placement technique (percutaneous vs. open cut-down).

1. Methods

This was a retrospective review of the records of 189 consecutive pediatric patients managed at two large pediatric ECMO centers between March, 1997 and June, 2012. Institutional Review Board approval was obtained at both sites (LLUCH: 5120044, CNMC: 00003720). Demographics, the indications for ECMO, details of the ECMO courses, and the incidence of complications and mortality were reviewed. Specifically, the occurrence of pleural collections and the frequency and technique of chest tube placement were evaluated.

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Chi-Square analysis was used to evaluate the significant differences in mortality and hemorrhage between subjects who did and did not have chest tubes placed and between those who had a percutaneous or cut-down technique.

Neither ECMO center had a protocol that specified indications for chest tube placement. The overall ECMO management strategies for infants and children, including ventilator management, anticoagulation, and weaning of support were similar at the two sites.

2. Results

The median age of the subjects was 2 days (range, birth–14 years) and the most frequent indications for ECMO were meconium aspiration (28.6%) and congenital diaphragmatic hernia (24.3%), followed by cardiac failure (12.7%) and sepsis (9%). Mean ECMO duration was approximately 9 days and the overall mortality was 26.5% (Table 1).

Forty-seven patients (24.8%) were found to have pleural collections (effusion, pneumothorax, hemothorax) (Table 2). Chest tubes were used to manage 27 of these patients (57.4%). These subjects included 20 neonates and 7 children (age 1 month to 14 years) with a median age of 2 days, similar to the overall study population.

Major bleeding complications occurred in 6 subjects (22%) and half of these died. Three of these subjects were neonates and three were infants or children (age 4 months to 14 years). Chest tube placement was performed for a pneumothorax in five of these patients and for a non-bloody effusion in one. Three required a thoracotomy for control of hemorrhage after placement of the chest tube. In two of these there was bleeding from lung parenchyma (Figs. 1 and 2) and in another there was a left ventricular injury that required repair. Two had bleeding at the chest tube site that required multiple transfusions and one died prior to delineation of the etiology of the bleeding. There were no significant differences in bleeding complications between the percutaneous and cut-down techniques (21% vs. 25% respectively).

In six subjects, a chest tube was placed on the day of ECMO decannulation and in three a tube was placed within two days of decannulation. In two patients, the stated indication for chest tube placement was a pleural collection that was causing circuit flow to cut out. In neither of these cases did flow improve after resolution of the pleural collections until more blood was transfused.

Children with a pneumothorax who had been managed with a chest tube had a 48% mortality versus a 25% mortality when no chest tube was placed (p = 0.15). There was no difference in mortality among those patients with an effusion who were managed with and without a chest tube (p = 1). Both subjects with hemothoraces were managed with chest tubes. Overall mortality was 37% with chest tube placement and 25% without tube placement (p = 0.15) (Tables 3 and 4).

3. Discussion

This is the first multicenter study to examine the incidence of bleeding complications after chest tube placement in pediatric patients managed with ECMO. We have demonstrated that there was substantial morbidity, including multiple transfusions, requirement for operative intervention, and death in children on ECMO in whom a chest tube was placed. The study was underpowered to

Table 1
Demographics. LLUCH = Loma Linda University Children’s Hospital, CNMC = Children’s National Medical Center.

<table>
<thead>
<tr>
<th></th>
<th>Number of Subjects</th>
<th>Mean/Median Age at time of ECMO</th>
<th>Mean Duration of ECMO</th>
<th>Mode of ECMO</th>
<th>Mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>189 Total → 138 LLUCH, 51 CNMC</td>
<td>1.03 years/2 days (Range: Newborn to 14 years)</td>
<td>9d (Range: 9–39 days)</td>
<td>VA: 125 (66.4%) VV: 64 (33.6%)</td>
<td>50 (26.5%)</td>
</tr>
</tbody>
</table>

Table 2
Incidence and management of pleural collections. (P = percutaneous, C = cut-down).

<table>
<thead>
<tr>
<th>Incidence</th>
<th>Chest Tube Placed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pneumothorax</td>
<td>19 (10.1%)</td>
</tr>
<tr>
<td>Effusion</td>
<td>26 (13.8%)</td>
</tr>
<tr>
<td>Hemothorax</td>
<td>2 (1.0%)</td>
</tr>
<tr>
<td>All Pleural Collections</td>
<td>47 (24.8%)</td>
</tr>
</tbody>
</table>
The incidence of pleural collections in our study was approximately 25%. Overall mortality was not significantly different in subjects with pleural collections who did and did not have chest tubes placed. Among those who received a chest tube for any indication, there were frequent, major bleeding complications (22%) that required either multiple transfusions or a thoracotomy for control of hemorrhage. Operative interventions in such critically ill patients increase the risk of additional complications and it is well established that multiple transfusions can place patients at risk for immunomodulation and acute lung injury [10–12]. Although some of these bleeding complications may also have occurred in the absence of systemic anticoagulation, particularly that associated with a ventricular laceration, bleeding from intercostal vessels or lung parenchyma, which is probably relatively frequent and self-limited in patients who are not heparinized, can be very difficult to control on ECMO.

Nagaraj et al. reviewed surgical procedures performed during ECMO, including 11 chest tube placements, but did not associate this procedure with hemorrhagic complications [13]. The results of the present study provide the first quantitative corroboration of anecdotal reports of morbidity and mortality with chest tube placement in children on ECMO.

It is difficult to determine, in retrospect, whether a chest tube placed in a particular patient was absolutely necessary or whether some subjects with pleural collections in whom a chest tube was not placed could have been taken off of ECMO earlier and potentially avoided other complications such as cerebral hemorrhage. We propose that in children on ECMO, reasonable indications for placement of a chest tube include situations in which pump flow and oxygenation are compromised by a pleural collection, indicating tension physiology, or when a pneumothorax or effusion precludes weaning from ECMO. When a chest tube must be placed, there is no clear indication that either a needle-guide wire or cut-down technique is preferable.

In conclusion, insertion of a chest tube for a pleural air or fluid collection while on ECMO may be unnecessary and can result in life-threatening hemorrhage. The placement of a chest tube on ECMO should be reserved for situations in which all other resuscitative measures have been attempted and the evacuation of a pleural collection has a high likelihood of leading to improved oxygenation and hemodynamics and/or the weaning of ECMO support. When a chest tube must be placed, there is no clear indication that either a needle-guide wire or cut-down technique is preferable.

In order to expand upon our findings, we propose that the ELSO registry data collection instrument include specific queries regarding chest tube placement related to timing, the specific indication, and technique. As the registry already tracks bleeding complications and major procedures performed on ECMO, this would allow for better definition of the appropriate indications and techniques for chest tube placement in infants and children on ECMO.

Table 3
Mortality for subjects with pleural collections with and without chest tubes.

<table>
<thead>
<tr>
<th></th>
<th>Chest Tube</th>
<th>No Chest Tube</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pneumothorax</td>
<td>48%</td>
<td>25%</td>
<td>0.15</td>
</tr>
<tr>
<td>Effusion</td>
<td>28.5%</td>
<td>29.4%</td>
<td>1</td>
</tr>
<tr>
<td>Hemorrhax</td>
<td>50%</td>
<td>0%</td>
<td>–</td>
</tr>
<tr>
<td>Overall</td>
<td>37%</td>
<td>24.7%</td>
<td>0.15</td>
</tr>
</tbody>
</table>

demonstrate any difference in outcome based upon the technique of chest tube placement.

The incidence of pleural collections in our study was approximately 25%. Overall mortality was not significantly different in subjects with pleural collections who did and did not have chest tubes placed. Among those who received a chest tube for any indication, there were frequent, major bleeding complications (22%) that required either multiple transfusions or a thoracotomy for control of hemorrhage. Operative interventions in such critically ill patients increase the risk of additional complications and it is well established that multiple transfusions can place patients at risk for immunomodulation and acute lung injury [10–12]. Although some of these bleeding complications may also have occurred in the absence of systemic anticoagulation, particularly that associated with a ventricular laceration, bleeding from intercostal vessels or lung parenchyma, which is probably relatively frequent and self-limited in patients who are not heparinized, can be very difficult to control on ECMO.

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In one of our subjects, who died after a chest tube was placed for a pneumothorax (Fig. 1), oxygenation had not been compromised by the pneumothorax and it may have resolved with a decrease in ventilator pressures. In another, in whom bilateral pleural effusions were believed to be precluding weaning from ECMO, chest tube placement resolved the effusions, but did not allow ECMO flow to be decreased. A pulmonary laceration from the chest tube insertion eventually led to withdrawal of ECMO and death. In the eight subjects that we identified in whom a chest tube was placed within two days of cannulation it can be speculated that chest tube placement permitted weaning from ECMO support, but the deaths of other patients point out how a chest tube placed for imprecise indications can lead to substantial morbidity and death.

In conclusion, insertion of a chest tube for a pleural air or fluid collection while on ECMO may be unnecessary and can result in life-threatening hemorrhage. The placement of a chest tube on ECMO should be reserved for situations in which all other resuscitative measures have been attempted and the evacuation of a pleural collection has a high likelihood of leading to improved oxygenation and hemodynamics and/or the weaning of ECMO support. When a chest tube must be placed, there is no clear indication that either a needle-guide wire or cut-down technique is preferable.

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References


Discussion

Discussant: Dr. Robert Cowles (New Haven, CT): I notice that you had 47 patients and 27 of them had chest tubes. What was different about the patients who got the chest tubes versus those who did not, just why some did and some did not? Was it that they were sicker to begin with and therefore warranted chest tubes?
Response: Dr. Jake Feldman: The decision to have the chest tubes placed was obviously made by the physicians who were treating these patients and so that is actually one of the questions. The indications are not clearly defined and it is almost a matter of opinion. That’s why we feel that prospective studies and prospective data should be taken to help define these indications more clearly.

Discussant: Dr. Erik Skarsgard (Vancouver, BC): I enjoyed your paper. How did you account for procedures that might have been done that could have been attributable to the source of bleeding? A most obvious example would be a diaphragmatic hernia repair while on ECMO. Did you exclude those patients in consideration of source of bleeding?

Response: Dr. Jake Feldman: No, we did not. We didn’t take that into account.

Dr. Erik Skarsgard: Did any of those patients who were diaphragmatic hernia patients have repair on ECMO?

Response: Dr Jake Feldman: No.