Published in final edited form as:

Am Surg. 2015 March ; 81(3): 245–251.

Outcomes of Pediatric Patients with Abdominal Sepsis Requiring Surgery and Extracorporeal Membrane Oxygenation Using the Extracorporeal Life Support Organization Database

MICHAEL R. PHILLIPS, M.D.*, AMAL L. KHOURY, M.D.*, BRIANA J. K. STEPHENSON, M.P.H.[†], LLOYD J. EDWARDS, PH.D.[†], ANTHONY G. CHARLES, M.D., M.P.H.^{*}, and SEAN E. McLEAN, M.D.*

*Department of Surgery, University of North Carolina, Chapel Hill, North Carolina

[†]Department of Biostatistics, UNC Gillings School of Global Public Health, Chapel Hill, North Carolina

Abstract

No study describes the use of extracorporeal membrane oxygenation (ECMO) in pediatric patients with abdominal sepsis (AS) requiring surgery. A description of outcomes in this patient population would assist clinical decision-making and provide a context for discussions with patients and families. The Extracorporeal Life Support Organization database was queried for pediatric patients (30 days to 18 years) with AS requiring surgery. Forty-five of 61 patients survived (73.8%). Reported bleeding complications (57.1 vs 48.8%), the number of pre-ECMO ventilator hours (208.1 vs 178.9), and the timing of surgery before (50 vs 66.7%) and on-ECMO (50 vs 26.7%) were similar in survivors and nonsurvivors. Decreased pre-ECMO mean pH (7.1 vs 7.3) was associated with increased mortality (odds ratio, 1.49; 95% confidence interval, 1.04 to 2.14). ECMO use for pediatric patients with AS requiring surgery is associated with increased mortality and an increased rate of bleeding complications compared with all pediatric patients receiving ECMO support. Acidemia predicts mortality and provides a potential target of examination for future studies.

Sepsis leads to approximately 1.6 million pediatric deaths worldwide every year. The estimated annual incidence in the United States is 42,000 cases.¹ Mortality among these patients is approximately 10.3 per cent.¹ Sepsis related to complex intra-abdominal infections or abdominal sepsis (AS) is the second most common cause of sepsis-related mortality among all patients.² Treatment of AS consists of fluid resuscitation, antibiotic therapy, surgery, or percutaneous intervention for source control and supportive care to prevent or manage multiorgan failure² and respiratory failure.³

Extracorporeal membrane oxygenation (ECMO) can provide support for patients with cardiac or respiratory failure.⁴ Despite the ability to provide respiratory and cardiovascular support, the mortality rate for pediatric patients with sepsis who receive ECMO support is

greater than 50 per cent.⁵ Currently, recommendations for pediatric patients with sepsis suggest that ECMO support may be provided as rescue therapy for patients who fail conventional therapy. A detailed algorithm is included within the American College of Critical Care Medicine guidelines; however, a brief description includes the use of: antibiotics, intravenous fluid resuscitation, electrolyte correction, inotropic therapy, mechanical ventilation, hydrocortisone supplementation, and invasive hemodynamic monitoring with goal-directed therapy.⁶ Goals of conventional therapy are defined as cardiac index between 3.3 and 6.0 L/min/m² with age-appropriate mean arterial pressure minus central venous pressure.^{5–7} The largest single-institution study of pediatric patients with sepsis receiving ECMO support included 45 pediatric patients with a mean age of 2.5 years old.⁸ In this study, sepsis from any source was examined, and the mortality rate for patients was 53 per cent.⁸ Other studies have focused on small series of pediatric patients with sepsis resulting from bacteremia^{9–11} or case studies of sepsis resulting from bloodstream infections from rare organisms.^{12, 13} However, the use of ECMO for pediatric patients with AS has not been defined.¹⁴ We examine data from the Extracorporeal Life Support Organization (ELSO) registry to investigate the use of ECMO support in pediatric patients with respiratory failure related to abdominal sepsis who require abdominal surgery for presumed source control. The aim of this study is to define the burden of mortality and to compare outcomes and pre-ECMO risk factors in survivors *versus* nonsurvivors. Ultimately the information derived from the study will inform clinical decision-making and guide discussions with patients and caregivers regarding expected outcomes.

Methods

We used the ELSO database to identify patients who underwent ECMO support and abdominal surgery for sepsis. The ELSO database provides laboratory and clinical values that are reported by participating centers as “before ECMO” and “within 24 hours of the initiation or ECMO.” These values are reported without a further indication about their exact timing or whether additional values were obtained around the initiation of ECMO. Based on consistently available data points and limitations of the ELSO registry, the decision was made to search patients based on *Current Procedural Terminology (CPT)* codes for abdominal surgical procedures (Table 1). All patients were between the ages of 30 days to 18 years old. *International Classification of Diseases, 9th Revision* codes were then examined and patients were excluded if abdominal surgery was performed after cardiac, trauma, and burn surgery or after ECMO support for a primary pulmonary diagnosis (i.e., pneumonia or respiratory syncytial virus), abdominal compartment syndrome, or for other nonabdominal sepsis-related conditions. Patients who did not meet exclusion criteria were included in our analysis.

Descriptive statistics (means, frequencies, standard deviations) were conducted to determine the demographics and clinical characteristics of the study sample. Our primary outcome was mortality. χ^2 analysis was conducted on the number of reported bleeding complications, surgical site bleeding complications (differentiated in the database as: cannula site bleeding, intraventricular hemorrhage, hemolysis, disseminated intravascular coagulation, etc.), the type of ECMO support reported (cardiac, respiratory, or external cardiopulmonary resuscitation [ECPR]) to the database, the timing of surgery (as reported by pre-ECMO, on-

ECMO, or after ECMO), and the ECMO circuitry used (venoarterial or venovenous). Differences among survivors and nonsurvivors were examined.

Subset analysis using commonly available demographic data and the clinical data provided by an arterial blood gas at our institution was performed to identify possible predictors of mortality to guide clinical decision-making and design of future prospective studies. The potential predictors of mortality were: age, pH, partial pressure of carbon dioxide (PaCO_2), partial pressure of oxygen (PaO_2), mean arterial pressure (MAP), serum bicarbonate level (HCO_3), and $\text{PaO}_2/\text{FiO}_2$ ratio. As a result of the small sample size and skewness of the data set, nonparametric tests were performed to determine which of these variables individually differ by mortality status. Multiple logistic regression analysis was performed, using the backward elimination approach, to verify which factors are significantly associated with mortality. All statistical analyses were performed with SAS Version 9.3 and the significance level of the tests was set at 0.05 ($P < 0.05$).

The Institutional Review Board of the University of North Carolina approved this study.

Results

Our search of the ELSO database yielded 174 pediatric patients who underwent abdominal surgery in the peri-ECMO period. After removing patients who met exclusion criteria, we identified 61 patients, including 27 with known abdominal sepsis and 34 patients who underwent abdominal surgery for presumed source control for intra-abdominal sepsis.

Patients were then divided into groups based on mortality. Forty-five patients did not survive to discharge (73.8%). The mean age of survivors and nonsurvivors were 7.0 and 4.4 years, respectively ($P = 0.08$; Table 2). There was no statistically significant difference in ventilator hours (VHs) before ECMO cannulation between survivors and nonsurvivors. The VH for survivors and nonsurvivors was 120.0 and 61.1 hours, respectively ($P = 0.25$). Mean ECMO run time for survivors and nonsurvivors is 215.0 and 140.8 hours, respectively ($P = 0.12$).

We then compared the number of reported bleeding complications in survivors and nonsurvivors. Fourteen of the 16 survivors reported complications, and eight patients reported bleeding complications (57.1%). Of the eight patients reporting bleeding complications, five had surgical site bleeding complications (35.7%) with the other bleeding complications occurring at the cannula site, within the ventricles, or manifesting as disseminated intravascular coagulation. Forty-three of 45 nonsurvivors reported at least one complication; of those 43 patients, 21 nonsurvivors had bleeding complications (48.8%). Fifteen of the 21 complications in the nonsurvivor group reported surgical site bleeding complications (34.9%). All other bleeding complications were similar to those in the survivor group (Table 2). The differences in reported bleeding complications between the two groups were not significant.

We also analyzed the timing of surgery, as reported to the database by pre-ECMO, on-ECMO, or after ECMO. We compared the number of patients in the survivor and nonsurvivor groups who had surgery before ECMO or while on ECMO. In the survivor group, eight of 16 patients had surgery before ECMO (50.0%). In the nonsurvivors 30 of the

45 patients (66.7%) reported surgery before ECMO, 12 of 46 patients (26.7%) had surgery on ECMO, and three patients (6.7%) had surgery after ECMO (one patient not reported). The rest of the patients in both groups had surgery while on ECMO. This difference was not significant ($P=0.20$). There were no differences in mortality based on the type of support reported to the database, including: pulmonary, cardiac, or ECPR ($P=0.11$). The number of survivors supported with venoarterial ECMO was 14 of 16 (87.5%) and the number of nonsurvivors supported with venoarterial ECMO was 41 of 45 (91.1%); the remaining patients were supported with venovenous ECMO. There were no differences in mortality based on the use of either venoarterial circuits or venovenous circuits ($P=0.65$; Table 2).

Clinical factors including age, pH, PaCO₂, PaO₂, MAP, HCO₃, and PaO₂/FiO₂ ratio were compared to determine their ability to predict mortality. Mean values for examined clinical parameters are included in Table 3 for comparison between survivors and nonsurvivors. A comparison of these factors revealed statistically significant differences in only mean pH ($P<0.05$). Logistic regression analysis confirmed that mean pH was associated with increased mortality ($P=0.03$). For every 0.1 decrease in mean pH, mortality was 49 per cent more likely to occur (odds ratio [OR], 1.49; 95% confidence interval [CI], 1.04 to 2.14). Other examined variables were not associated with mortality (Table 3). Survival based upon diagnosis leading to abdominal surgery is listed in Table 4. Hepatic/abdominal abscess is the most common abdominal indication for surgery with no survivors.

Discussion

Analysis of all pediatric patients within the ELSO database from January 1, 1999, to December 31, 2008, has shown that the diagnosis of sepsis increases patient mortality.¹⁵ For all pediatric patients with sepsis requiring ECMO support, the mortality rate was 59 per cent compared with an overall mortality rate of 37 per cent.¹⁵ The mortality reported by the ELSO database in other subgroups of pediatric patients placed on ECMO for respiratory failure is between 50 and 34 per cent based on diagnosis.¹⁶ The use of ECMO in patients with abdominal sepsis requiring surgery (presumably for source control) has not been previously examined. Based on the ELSO database, we show that mortality rate in pediatric patients with abdominal sepsis requiring surgery is 73.8 per cent. We also define clinical factors that do not appear to influence mortality in this cohort of patients and pre-ECMO parameters that may be associated with increased mortality.

The risk of bleeding complications is critical to determining the safety of ECMO. In patients requiring abdominal surgery either before cannulation or while on ECMO, there is increased concern for surgical site bleeding and coagulopathy from surgical surfaces. The ELSO International summary from January 2013 for all pediatric patients reports that the risk of bleeding complications is between 4.0 and 16.8 per cent with surgical site bleeding complications at 13.7 per cent.¹⁶ A small case series of pediatric patients placed on ECMO and requiring abdominal surgery for abdominal compartment syndrome reported one bleeding complication related to laparotomy in seven cases (14.3%).^{17–19} Although the rate of reported bleeding complications was similar in survivors and nonsurvivors, the rate of reported bleeding complications in all of our patients was much higher at 45 to 50 per cent overall (including surgical site, cannula site, disseminated intravascular coagulation, etc.)

and 33 per cent for surgical site bleeding when compared with all pediatric patients placed on ECMO support. Because the risk of bleeding complications was not associated with increased mortality, the risk of bleeding complications should not exclude pediatric patients with abdominal sepsis requiring life-saving surgery from consideration for ECMO. However, patients and their families should be counseled regarding the increased risk of bleeding complications associated with laparotomy in the peri-ECMO period.

In patients with an increased risk of bleeding complications, careful titration of anticoagulant therapy based on laboratory studies and clinical factors with implementation of antifibrinolytic therapy is paramount.²⁰ To decrease bleeding complications in patients requiring surgery while on ECMO, we recommend careful handling of tissues and liberal use of cautery and topical procoagulants during surgery. Practitioners may also hold anticoagulation during the procedure and up to two hours postprocedure with slow titrated resumption of anticoagulation after surgery. Practitioners may also reduce goal activated clotting times in the perioperative period, stop heparin therapy, and provide continuous administration of antifibrinolytic therapy before, during, and after the procedure. A backup ECMO circuit must be immediately available in case rapid clot formation leads to circuit malfunction.

An important predictor of mortality in patients on ECMO is the number of pre-ECMO ventilator days.^{21, 22} Currently, ELSO lists increased ventilator days as a guideline for patient selection, but not a strict contraindication to ECMO support. The number of pre-ECMO ventilation days as a determinant of mortality is not clear. Previous studies have shown that increased days of pre-ECMO ventilation correlate with increased mortality.^{15, 21, 22} Recent studies have shown similar mortality in patients during the first 0 to 10 days of pre-ECMO ventilation.²¹ However, greater than 10 days²¹ or greater than 14 days¹⁵ of pre-ECMO ventilation has been shown to be associated with increased mortality in pediatric patients requiring ECMO support. Consistent with recent studies, our data showed no difference between pre-ECMO ventilator hours in survivors *versus* nonsurvivors. However, the mean pre-ECMO ventilation hours (converted to days for sake of comparison) in our cohort were lower than other studies (mean pre-ECMO ventilation days: survivors 2.5; nonsurvivors 5.0) and make the detection of the impact of prolonged pre-ECMO ventilation in this cohort difficult. The short pre-ECMO ventilator time within our cohort and limitations of an administrative database make identifying the factors influencing pre-ECMO ventilation difficult and would likely be better studied in a prospective study.

The ability to identify patients most likely to benefit from ECMO support is important for optimizing its use in critically ill patients. In our study cohort, acidemia was associated with increased mortality. For each decrease in pH of 0.1, there was a 49 per cent increase in the likelihood of mortality. This finding is consistent with a recent study, which retrospectively reviewed all cases of pediatric ECMO at a single institution and demonstrated that serum pH is decreased in pediatric patients who did not survive to discharge.²³ Our results are also consistent with an analysis of all pediatric patients within the ELSO database that showed that decrease mean pH leads to increased mortality regardless of diagnosis.¹⁵ The effect of pH on mortality may provide an important clinical context to the evaluation of pediatric

ECMO candidates. Additional studies examining the use of pH prospectively will be required to confirm the association of pH with mortality.

Our study also showed that the timing of surgery, type of ECMO support reported by practitioners, and the use of venoarterial or venovenous ECMO does not appear to affect mortality. Unfortunately, the exact timing between surgical intervention and ECMO cannulation is not reported and as such we were unable to examine the timing of surgery as a linear variable. However, these findings provide additional clinical parameters to guide decision-making in pediatric patients on ECMO with abdominal sepsis requiring surgery. Because these parameters do not appear to influence outcomes, the practitioner should use their best judgment until a larger cohort of patients can be identified and examined.

Our study is the first to describe outcomes from a large administrative database in pediatric patients on ECMO with abdominal sepsis requiring surgery. We demonstrated increased mortality in this cohort of patients in comparison to mortality rates for other pediatric patients on ECMO. Our results also identify rate of bleeding complications and acidemia as potential predictors of mortality in pediatric patients on ECMO who require abdominal surgery. Given these findings, we recommend selective use of ECMO support in pediatric patients with abdominal sepsis requiring surgery.

Our data was collected from the ELSO database, which is the largest repository of retrospective ECMO case data. The results of this study are limited by the small sample size and the inherent limitations of the data entered into an administrative database. The small sample size increases the likelihood of Type I and Type II errors when drawing conclusions from the data analyzed. Larger sample cohorts will be required to further clarify the findings of our study. The study is also limited to only pediatric patients treated with surgery for source control, and the study is unable to examine patients treated with antibiotics or percutaneous intervention (because these were not searchable by *CPT* code as a result of limitations of the ELSO database). Limitations of the database also do not permit a review of the surgical findings or surgical pathology to confirm the reported diagnosis. The ELSO database is a large administrative database. As such, it frequently provides data that may form the basis for future study questions rather than definitive conclusions or strict clinical guidelines. Thus, the conclusions drawn by our study must ultimately be confirmed through a prospectively designed study.

Despite the limitations of our study, we show that in pediatric patients on ECMO with abdominal sepsis requiring surgery, mortality and bleeding occur more frequently than the overall incidence of mortality and bleeding complications in other pediatric patients requiring ECMO support. Furthermore, the number of pre-ECMO ventilator days, the type of ECMO support, and the timing of surgery, either before cannulation or while on ECMO, do not appear to affect patient mortality. We believe that the results of this study will aid in the identification of pediatric patients with abdominal sepsis requiring surgery most likely to benefit from ECMO support, thereby improving the outcomes in this complex patient population. We also believe that these data will assist pediatric ECMO providers attempting to counsel families regarding the risks, benefits, and alternatives to ECMO support for pediatric patients with abdominal sepsis requiring surgery.

References

1. Hanna W, Wong HR. Pediatric sepsis: challenges and adjunctive therapies. *Crit Care Clin.* 2013; 29:203–22. [PubMed: 23537672]
2. Solomkin JS, Mazuski J. Intra-abdominal sepsis: newer interventional and antimicrobial therapies. *Infect Dis Clin North Am.* 2009; 23:593–608. [PubMed: 19665085]
3. Christiana C, Burt JEA. Respiratory failure. *Surgery.* 2009; 27:475–9.
4. Brodie D, Bacchetta M. Extracorporeal membrane oxygenation for ARDS in adults. *N Engl J Med.* 2011; 365:1905–14. [PubMed: 22087681]
5. Carcillo JA, Fields AI. Clinical practice parameters for hemodynamic support of pediatric and neonatal patients in septic shock. *Crit Care Med.* 2002; 30:1365–78. [PubMed: 12072696]
6. Brierley J, Carcillo JA, Choong K, et al. Clinical practice parameters for hemodynamic support of pediatric and neonatal septic shock: 2007 update from the American College of Critical Care Medicine. *Crit Care Med.* 2009; 37:666–88. [PubMed: 19325359]
7. Maclaren G, Butt W. Extracorporeal membrane oxygenation and sepsis. *Crit Care Resusc.* 2007; 9:76–80. [PubMed: 17352671]
8. Maclaren G, Butt W, Best D, et al. Extracorporeal membrane oxygenation for refractory septic shock in children: one institution's experience. *Pediatr Crit Care Med.* 2007; 8:447–51. [PubMed: 17693912]
9. Luyt DK, Pridgeon J, Brown J, et al. Extracorporeal life support for children with meningococcal septicaemia. *Acta Paediatr.* 2004; 93:1608–11. [PubMed: 15841769]
10. Creech CB, Johnson BG, Bartilson RE, et al. Increasing use of extracorporeal life support in methicillin-resistant *Staphylococcus aureus* sepsis in children. *Pediatr Crit Care Med.* 2007; 8:231–5. quiz 247. [PubMed: 17417114]
11. Beca J, Butt W. Extracorporeal membrane oxygenation for refractory septic shock in children. *Pediatrics.* 1994; 93:726–9. [PubMed: 8165069]
12. Kamath SS, Mason K. Extra-corporeal membrane oxygenation in a patient with fusobacterium sepsis: a case report and review of literature. *Ann Thorac Cardiovasc Surg.* 2011; 17:397–9. [PubMed: 21881329]
13. Minette MS, Ibsen LM. Survival of candida sepsis in extracorporeal membrane oxygenation. *Pediatr Crit Care Med.* 2005; 6:709–11. [PubMed: 16276340]
14. Custer JR. The evolution of patient selection criteria and indications for extracorporeal life support in pediatric cardiopulmonary failure: next time, let's not eat the bones. *Organogenesis.* 2011; 7:13–22. [PubMed: 21317556]
15. Domico MB, Ridout DA, Bronicki R, et al. The impact of mechanical ventilation time before initiation of extracorporeal life support on survival in pediatric respiratory failure: a review of the Extracorporeal Life Support registry. *Pediatr Crit Care Med.* 2012; 13:16–21. [PubMed: 21478791]
16. Extracorporeal Life Support Registry Report: International Summary. Ann Arbor, MI: Extracorporeal Life Support Organization; Jan. 2013
17. Rollins MD, Deamorim-Filho J, Scaife ER, et al. Decompressive laparotomy for abdominal compartment syndrome in children on ECMO: effect on support and survival. *J Pediatr Surg.* 2013; 48:1509–13. [PubMed: 23895964]
18. Nagaya M, Kato J, Niimi N, et al. Extracorporeal membrane oxygenation for newborns with gastric rupture. *Pediatr Surg Int.* 2001; 17:35–8. [PubMed: 11294265]
19. Lam MC, Yang PT, Skippen PW, et al. Abdominal compartment syndrome complicating paediatric extracorporeal life support: diagnostic and therapeutic challenges. *Anaesth Intensive Care.* 2008; 36:726–31. [PubMed: 18853595]
20. Phillips MR, Khoury AL, Ashton RF, et al. The dosing and monitoring of argatroban for heparin induced thrombocytopenia during extracorporeal membrane oxygenation: a word of caution. *Anaesth Intensive Care.* 2014; 42:97–8. [PubMed: 24471670]

21. Nance ML, Nadkarni VM, Hedrick HL, et al. Effect of preextracorporeal membrane oxygenation ventilation days and age on extracorporeal membrane oxygenation survival in critically ill children. *J Pediatr Surg.* 2009; 44:1606–10. [PubMed: 19635313]
22. Moler FW, Palmisano J, Custer JR. Extracorporeal life support for pediatric respiratory failure: predictors of survival from 220 patients. *Crit Care Med.* 1993; 21:1604–11. [PubMed: 8403974]
23. Bembea MM, Lee R, Masten D, et al. Magnitude of arterial carbon dioxide change at initiation of extracorporeal membrane oxygenation support is associated with survival. *J Extra Corpor Technol.* 2013; 45:26–32. [PubMed: 23691781]

Table 1

CPT Codes Used to Search the Extracorporeal Life Support Organization (ELSO) Database to Identify Patients with Abdominal Sepsis Requiring Surgery*

Procedure	CPT Code	ELSO Database (no. of occurrences)	Study Cohort (no. of occurrences)	Survivors (no. of occurrences)
Appendectomy	44950	2	0	0
Exploratory laparotomy	49000	162	55	15
Laparoscopic appendectomy	44970	1	1	1
Partial Hepatectomy	47120	1	1	0
Laparoscopic cholecystectomy	47562	0	0	0
Cholecystectomy	47600	0	0	0
Nephrectomy	50220	1	1	0
Splenectomy	38100	5	2	1
Distal pancreatectomy with or without splenectomy	48140	1	0	0
Enterectomy (pediatric)	44120	5	4	0
Partial colectomy (pediatric)	44140	1	1	0
Partial colectomy with end colostomy	44143	0	0	0
Proctectomy for congenital megacolon	45121	0	0	0
Colectomy with skin level colostomy	44141	0	0	0
Colectomy with ostomy and mucous fistula	44144	1	0	0
Partial colectomy with transanal approach	44147	0	0	0
Total colectomy with ileostomy	44155	0	0	0
Total colectomy with continent ileostomy	44156	0	0	0
Colectomy with ileoanal anastomosis	44157	0	0	0
Colectomy with J-pouch	44158	0	0	0
Ileocectomy	44160	1	0	0
Laparoscopic colon	44212	0	0	0
Laparoscopic colon with ileal reservoir	44211	0	0	0
Laparoscopic colon with ileostomy	44210	0	0	0
Laparoscopic colon with low anastomosis	44207	0	0	0
Laparoscopic colon with low anastomosis and ostomy	44208	0	0	0
Total		181	65	17

* There were 181 occurrences of *CPT* codes within the database and 66 occurrences that met inclusion criteria. These 66 occurrences represented 61 patients with five patients having two of the queried *CPT* codes.

CPT, Current Procedural Terminology.

Table 2

Demographic Factors of Patients with Abdominal Sepsis Requiring Surgery Reporting to the Extracorporeal Life Support Organization Database and Total Number of Patients within the Cohort Reporting Each Factor

Demographics*					
	Total Patients Reporting	Overall Mean	Survivors (n = 16)	Nonsurvivors (n = 45)	P Value
Age (days)	61	153.91 (159.0)	2555.2 (2099.0)	1595.1 (1792.4)	0.08
ECMO duration (hours)	61	160.23 (164.6)	215.0 (141.9)	140.8 (169.2)	0.12
Year of ECMO	61	2005.4 (5.6)	2001.8 (6.0)	2006.7 (4.9)	0.002
Pre-ECMO ventilator time (hours)	57	104.5 (268.9)	61.13 (64.0)	120.0 (310.5)	0.25
Reported support type	61				
Pulmonary (no.)		N/A	13	28	
Cardiac (no.)		N/A	3	7	
ECPR (no.)		N/A	0	10	0.11
Circuit type	61				
V-A		N/A	14	41	
V-V		N/A	2	4	
Timing of surgery	61				
Pre-ECMO		N/A	8 (50%)	30 (66.7%)	
Post-ECMO		N/A	8 (50%)	12 (26.7)	0.20
Bleeding complications	57				
Total			8 (50%)	21 (48.8%)	0.76
Surgical site			5 (35.7%)	15 (34.9%)	0.67

* Standard deviation in parentheses.

ECMO, extracorporeal membrane oxygenation; ECPR, external cardiopulmonary resuscitation; V-A, venoarterial; V-V, venovenous; N/A, not available.

Clinical Factors of Patients with Abdominal Sepsis Requiring Surgery before Initiation of Extracorporeal Membrane Oxygenation as Reported to the Extracorporeal Life Support Organization Database and Total Number of Patients within the Cohort Reporting Each Factor

Table 3

Clinical Parameters*					
Parameter	Sample	Overall Mean	Survivors (n = 16)	Nonsurvivors (n = 45)	P Value
Mean pH	57	7.18 (0.2)	7.30 (0.2)	7.14 (0.2)	0.02
Mean PaCO ₂ (Torr)	58	57.65 (25.5)	47.55 (21.8)	61.18 (26.0)	0.07
Mean PaO ₂ (Torr)	57	84.62 (83.2)	70.37 (35.5)	89.71 (94.5)	0.27
Mean HCO ₃ (mmol/L)	52	23.05 (13.3)	23.50 (7.4)	22.91 (14.7)	0.85
FiO ₂ (%)	54	91.88 (17.7)	95.94 (9.9)	92.05 (17.5)	0.31
PaO ₂ /FiO ₂ ratio	53	93.20 (15.6)	75.18 (40.9)	102.2 (104.5)	0.34
Mean arterial pressure (mmHg)	42	57.02 (20.4)	65.08 (19.8)	53.80 (20.1)	0.11

* Standard deviation in parentheses.

PaCO₂, partial pressure of carbon dioxide; PaO₂, partial pressure of oxygen; HCO₃, serum bicarbonate level.

Table 4

Diagnosis for Intestinal Infections Requiring Abdominal Surgery and Extracorporeal Membrane Oxygenation

Diagnosis	Number	Survivors	Percent Survival
Appendicitis	4	0	0.0
Inflammatory bowel disease	3	0	0.0
Hepatic/abdominal abscess	6	0	0.0
Vascular insufficiency of the intestine	3	1	33.3
Septic shock	10	4	40.0
Gram-negative sepsis	7	1	14.3
Acute respiratory failure	13	8	61.5
Necrotizing enterocolitis	4	0	0.0
Hirschsprung's disease	1	0	0.0
Gastrointestinal hemorrhage	2	0	0.0
Infectious colitis, enteritis, or gastritis	4	1	25.0
Intestinal obstruction	4	0	0.0
Cholangitis	1	1	100.0