# Abdominal Surgery Needs Extracorporeal Life Support as a Final Back-up

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**Research article**

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# Abstract

Background: There are very limited published data regarding the experience of extracorporeal membrane oxygenation (ECMO) after abdominal surgery. Our objective was to examine the clinical application and outcome of ECMO in patients deteriorating early after abdominal surgery. Methods: Between 1998 and 2018, patients who had ECMO implantation within 30 days after abdominal surgery were enrolled. Clinical outcomes, patient demographics, ECMO types and indications, laboratory findings and other relevant aspects of their medical histories were reviewed. Results: Sixteen patients aged between 20 and 77 years were enrolled, including 11 patients who underwent elective surgery and 5 who underwent emergency laparotomies. Six veno-arterial ECMO (VA-ECMO) and 10 veno-venous ECMO (VV-ECMO) devices were implanted for refractory hypotension or acute respiratory distress syndrome (ARDS) based on the clinical discretion of the attending physician. After timely diagnosis of the aetiology underlying the deterioration, 4 additional salvage interventions were allowed under ECMO support. Three VA-ECMO and 5 VV-ECMO patients were successfully weaned, while 5 patients (31.25%) survived to hospital discharge without significant sequelae. Patients who survived to discharge had a significant inotropic dose taper on day two after ECMO implantation (59.4 versus 1.3 mcg/kg/min, p = 0.0487). ECMO-related complications included 3 implantation wound haematomas, limb ischaemia requiring wound debridement and reperfusion catheter insertion. There was no intra-abdominal bleeding or major thromboembolic event in our series. Conclusions: ECMO gave surgeons additional chances to treat reversible cause of sudden patient collapse after the timely diagnosis of the cause. No patients in our cohort encountered serious ECMO-related complications. Our study demonstrated that ECMO may be used as a final back-up for sudden deterioration after abdominal surgery.


# Background

During post-operative care after major abdominal surgery, rapid patient deterioration leading to critical conditions, such as refractory hypotension or ARDS, may develop and are associated with high mortality rates despite intensive resuscitation [1, 2]. Although ECMO may be used to rescue patients, general surgeons or critical care physicians often fear that ECMO-related complications may result in even more catastrophic consequences, such as massive surgical site bleeding haemorrhage or major thromboembolic events [3]. Therefore, despite many advances in ECMO technology in the past few years [4] and its expanded use in thoracic surgery, ARDS caused by lung infection or fulminant myocarditis [5-7], there are very limited data published regarding the use of ECMO support in catastrophic events after abdominal surgery [8, 9]. In our institute, there are more than 5000 abdominal surgeries performed by 30 general surgeons each year in our institute. In addition, ECMO support is available 24 hours a day. Since the first implantation in 1994, more than 2000 patients have received ECMO in our institute, which is one of the largest ECMO cohorts and collections of peri-implantation care experience in the world [10-12]. This study aimed to investigate the clinical outcomes of patients who had ECMO implantation after abdominal surgery based on 20 years of experience.

# Methods

We reviewed the medical records of patients who received ECMO within 30 days after undergoing abdominal surgery at National Taiwan University Hospital from 1998 to 2018. Patients who underwent simultaneous cardiac or pulmonary surgery in addition to the abdominal surgery, who had intra-abdominal vascular surgery, who had been an organ transplantation recipient and was currently on immunosuppressant or who had been discharged from hospital post-operatively before ECMO device implantation were excluded. All clinical data were reviewed, including history, indication and types of surgical procedure; length of hospital stay; perioperative laboratory study; and the use and doses of inotropes. Clinical results including mortality and its cause, the total length of time on ECMO circulation, the success rate of weaning from ECMO, and pertinent complications were analysed.

For the statistical analysis, the Chi-square or Fisher's exact test was performed for categorical variables, and a t test, paired t test or Mann-Whitney U test was performed for continuous variables. Survival was compared via the Kaplan-Meier method. This study was approved by the institutional review board and was performed in compliance with the standards of the ethical guidelines of the Declaration of Helsinki. All statistical analyses were performed with standard statistical software, including SAS version 9.4 (SAS Institute Inc., Cary, NC) and Stata version 11.2 (StataCorp).

# Results

Over the 20-year period, we identified 16 patients who met the inclusion criteria. The cohort consisted of 13 men and 3 women, with a median age of 56 years (range 20 to 77 years). The detailed patient profiles, including demographics, procedures performed before ECMO setup, indications and type of ECMO, are shown in Table 1. Seven of the eight patients who received VA-ECMO underwent implantation of the device during cardiopulmonary resuscitation for the underlying aetiology, including peri-operative acute coronary disease, massive bleeding, acute pulmonary thromboembolism, and refractory hypotension complicated with severe sepsis. In contrast, the twelve patients who received VV-ECMO underwent implantation of the device mainly for acute respiratory distress syndrome (ARDS), which was primarily caused by severe systemic inflammatory response syndrome (SIRS), aspiration pneumonia, and transfusion-related acute lung injury. The median time from surgery to ECMO implantation was 3 days (range 0-22 days). There was no significant difference in this duration between VV- and VA-ECMO patients.

Patient outcomes and salvage interventions performed are listed in Table 2; 3 VA-ECMO and 5 VV-ECMO patients were successfully weaned, while 5 patients (31.25%) survived to hospital discharge without significant sequelae. The median time on ECMO was 100 hours (ranging from 42 to 306 hours) for VV-ECMO and 32 hours (ranging from 6 to 192 hours) for VA-ECMO (p=0.0827). Under VA-ECMO support, emergent salvage interventions were further necessitated in 2 patients in critical condition, including emergency percutaneous coronary intervention (PCI) and emergency surgical pulmonary embolectomy, which successfully rescued one patient who eventually survived; on the other hand, 3 patients underwent

salvage intervention while receiving VV-ECMO support, including transarterial embolization for post-operative bleeding, surgical debridement and emergency PCI, which successfully rescued 1 patient who survived to hospital discharge. Overall, in VA-ECMO patients, despite the deaths of 3 patients on ECMO due to intractable hypotension within 24 hours of mechanical circulation, 2 out of the other 3 patients (66.7%) were successfully weaned from ECMO, including 1 patient who underwent emergency surgical embolectomy for pulmonary embolism and finally survived to discharge. In the VV-ECMO group, 6 out of the 10 patients (60%) were weaned from ECMO, with 4 patients surviving to hospital discharge. None had early mortality within 24 hours after the establishment of mechanical support. As shown in Figure 1, there was no significant survival difference between the VV- and VA- ECMO groups according to the Kaplan-Meier survival analysis (log rank p = 0.1594).

Table 3 compares the clinical and laboratory data between survivors and non-survivors. The demographic profiles, including age, sex, and pre-existing medical conditions, such as diabetes, chronic kidney disease, or coronary artery disease, were similar in both groups, although compared with non-survivors, survivors had a higher incidence of New York Heart Association (NYHA) function class II heart failure (24.5% versus 0%, p = 0.0239) before surgery. With regard to other clinical and laboratory parameters, we compared the fraction of inspired oxygen ($FiO_2$), serum lactate level, and indexed inotropic doses calculated by the inotropic equivalent (IE = dopamine x1 + dobutamine x1 + epinephrine x 100 + nor-epinephrine x 100 + isoproterenol x 100 + milrinone x 15 (in mcg/kg/min) [10], immediately before the establishment of ECMO circulation and 2 days after ECMO circulation. When comparing survivors to non-survivors before ECMO circulation, there were no significant differences in the $FiO_2$ (100% versus 94%, p = 0.3556), serum lactate level (8.7 versus 6.2 mmol/L, p = 0.4469), or IE (60.06 versus 23.24 mcg/kg/min, p = 0.2199). However, as shown in Figure 2, despite a trend of improvement in the three parameters in both surviving and non-surviving patients on post-implantation day 2, the decrease in IE was the only parameter that showed a consistent and significantly larger degree of improvement among survivors than among non-survivors (59.4 versus 1.3 mcg/kg/min, p = 0.0487).

Regarding the complications related to ECMO use in this early post-abdominal surgery cohort, as shown in Table 4, three patients had complications associated with ECMO cannulation, including two who experienced distal limb ischaemia requiring additional insertion of reperfusion catheters and one who experienced bleeding at the cannulation site that caused a subcutaneous haematoma, necessitating further wound debridement. All four of these cases were associated with the use of VA-ECMO. In our cohort, no surgical site bleeding or clinically significant thromboembolic events were encountered during or after ECMO use.

# Discussion

In this study, we reported the largest cohort of adults who received ECMO due to refractory hypotension or respiratory failure within 30 days after abdominal surgery. Overall, ECMO provided 5 patients with additional time to undergo salvage interventions. ECMO also successfully rescued 8 (50%) patients who were survived ECMO, including 5 (31.25%) patients who even lived to hospital discharge without

significant sequelae. In the context of critical illness, both VV- and VA-ECMO provided surgeons with additional time for acute management of patients who would otherwise have died almost immediately due to a sudden deterioration. Salvage interventions may be able to rescue patients given a correct and timely diagnosis while the patient is receiving ECMO support, providing additional chances for patient survival as well as better communication between the family and physician [13].

The benefits of the use of ECMO in various critical contexts, including cardiogenic shock, refractory septic shock, in-hospital cardiac arrest, ARDS or transplantation, have been reported in other series [1]. Among patients with cardiogenic shock or postcardiotomy syndrome who were receiving ECMO, the reported rate of survival to hospital discharge was between 24% and 45% [3, 12, 14]. A similar survival rate was reported when ECMO support was used as an acute resuscitation tool for in-hospital cardiac arrest [10, 11]. On the other hand, Lee et al. [1] reported that the survival rate of patients with refractory hypotension after liver transplantation who received ECMO was 25%. Enhanced survival after ECMO support was reported among patients who suffered from heart failure due to fulminant myocarditis and those who underwent VV-ECMO for H1N1-related ARDS. The reported rate of survival to hospital discharge in the former report was as high as 70%, while it was reported to be between 64 and 75% in the latter [15-17]. In our series, there was a compatible survival benefit identified in our cohort, indicating a need for extracorporeal life support as an important back-up system for patients who experience rapid deterioration after abdominal surgery, particularly in centres that perform large numbers and complicated types of surgical procedures.

In addition, an interesting finding in our study is that neither VV- nor VA-ECMO led to serious complications, such as surgical site bleeding or thromboembolic events, among patients who had undergone abdominal surgery. Although limb ischaemia occurred in 3 patients who underwent VA-ECMO implantation using the femoral cut-down technique, resolution was achieved after the placement of a distal reperfusion catheter. A previous study also suggested pressure criteria for pre-emptive placement of distal reperfusion catheters to prevent limb ischaemia [18]. However, when ECMO was used for post-cardiotomy or cardiogenic shock, the rates of complications such as cerebrovascular events and major bleeding requiring rethoracotomy were reported to be as high as 17.4% and 58%, respectively, after a mean duration of ECMO support ranging from 47.9 to 132 hours [3]. Similarly, when ECMO was used for heart failure due to fulminant myocarditis or bacterial sepsis, there were elevated rates and increased severity of complications, including 3 out of 14 patients (21%) who had limb ischaemia that required amputation and 14.3% of patients who required re-exploration for haemostasis after a median ECMO duration ranging from 72 to 139 hours, despite a better survival outcome [15, 16, 19-21]. In contrast, a low incidence of complications during ECMO use for refractory septic shock after liver transplantation was reported, with a median of 96 hours of ECMO support, echoing our finding in terms of the complications of ECMO use after abdominal surgery [8, 22]. This discrepancy indicates that the incidence of ECMO-related complications and patient clinical outcomes may vary widely, particularly between patients who underwent cardiothoracic surgery and abdominal surgery. ECMO should be considered relatively safe for use in patients who require extracorporeal life support after abdominal surgery.

Regarding potential prognostic factors, after comparing clinical and laboratory data before and after ECMO implantation, a significant reduction in the inotropic dose within 2 days after ECMO implantation was associated with a significantly higher likelihood of ECMO weaning and survival to hospital discharge. Although age may be one of the most powerful poor prognostic factors in clinical decision making, we did not find age to be a substantial risk factor for poor prognosis. Previous studies reported prognostic factors that were mostly associated with conditions that existed before the initiation of extracorporeal life support, including pre-existing diabetes, chronic kidney insufficiency, acute renal failure requiring renal replacement therapy, elevated lactate level, age more than 70 years, and logistic EuroSCORE greater than 20% [3, 12]. In contrast, our study identified factors that indicate early treatment response to ECMO and can be used to identify patients with a better prognosis at an early stage after ECMO implantation. This index may also be used to facilitate communication between surgeons and families and may potentially reduce futile use of extracorporeal life support.

In a further comparison of the outcomes of patients who required VV- and VA-ECMO, the average duration of VV-ECMO circulation was approximately 5 days, which mostly reflects the disease course of ARDS [23]. Half of the patients in this cohort survived to be weaned off of ECMO, and 40% survived to hospital discharge without significant sequelae and continued to receive further treatment for their underlying diseases, such as malignancies, during follow-up. Thus, when ARDS developed during the early post-operative period after abdominal surgery, the timely utilization of VV-ECMO may avoid prolonged refractory hypoxia and may further reduce the risk of systemic hypotension and multi-organ dysfunction [23, 24]. While some clinicians may be concerned about ECMO-related complications in this context and thus hesitate to employ VV-ECMO in this population, especially those with a diagnosed malignancy, such concerns need to be revised on the basis of the data presented in this study. As a result of limited case availability, we did not demonstrate a survival difference between patients who required VV- and VA-ECMO (40% versus 16%, $p = 0.3630$). This study was also limited by its retrospective design and the fact that the decision to use extracorporeal life support was mainly based on clinical discretion. As this study demonstrated a clear survival benefit and a positive clinical safety profile in this selected patient population, future studies should include a larger cohort with a longer follow-up period to further elucidate the clinical benefits and safety of the use of extracorporeal life support in abdominal surgery patients who develop a critical illness in the postoperative period.

# Conclusions

This study demonstrated that in early post-operative critical situations after abdominal surgery, both VA- and VV-ECMO were associated with survival benefits and a low level of risk of ECMO-related complications. ECMO provided surgeons with additional time to diagnose the aetiology of the sudden deterioration and implement timely interventions. ECMO should be considered an important rescue measure in critical conditions encountered early after abdominal surgery.

# List Of Abbreviations

ECMO, extracorporeal membrane oxygenation

VA-ECMO, veno-arterial extracorporeal membrane oxygenation

VV-ECMO, veno-venous extracorporeal membrane oxygenation

ARDS, acute respiratory distress syndrome

SIRS, systemic inflammatory response syndrome

PCI, percutaneous coronary intervention

NYHA, New York Heart Association

IE, inotropic equivalent

$FiO_2$, fraction of inspired oxygen

# Declarations

### *Ethics approval and consent to participate*

This study was approved by the National Taiwan University Hospital Research Ethics Committee and was performed in compliance with the standards of the ethical guidelines of the Declaration of Helsinki.

***Ethics approval for animal study:*** Not applicable

### *Consent for publication*

Not applicable

### *Availability of data and material*

The datasets used and analysed during the current study are available from the corresponding author on reasonable request.

### *Competing interests*

The authors declare that they have no competing interests.

*Funding*

No funding was received for this study.

*Authors' contributions*

CHL analysed the clinical data and prepared the manuscript. MHW and PDC interpreted the patient data. JMW participated in the conception of the study. MTL designed the study and prepared and edited the manuscript. All authors read and approved the final manuscript.

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## Tables

Due to technical limitations, tables are only available as a download in the supplemental files section.

## Figures

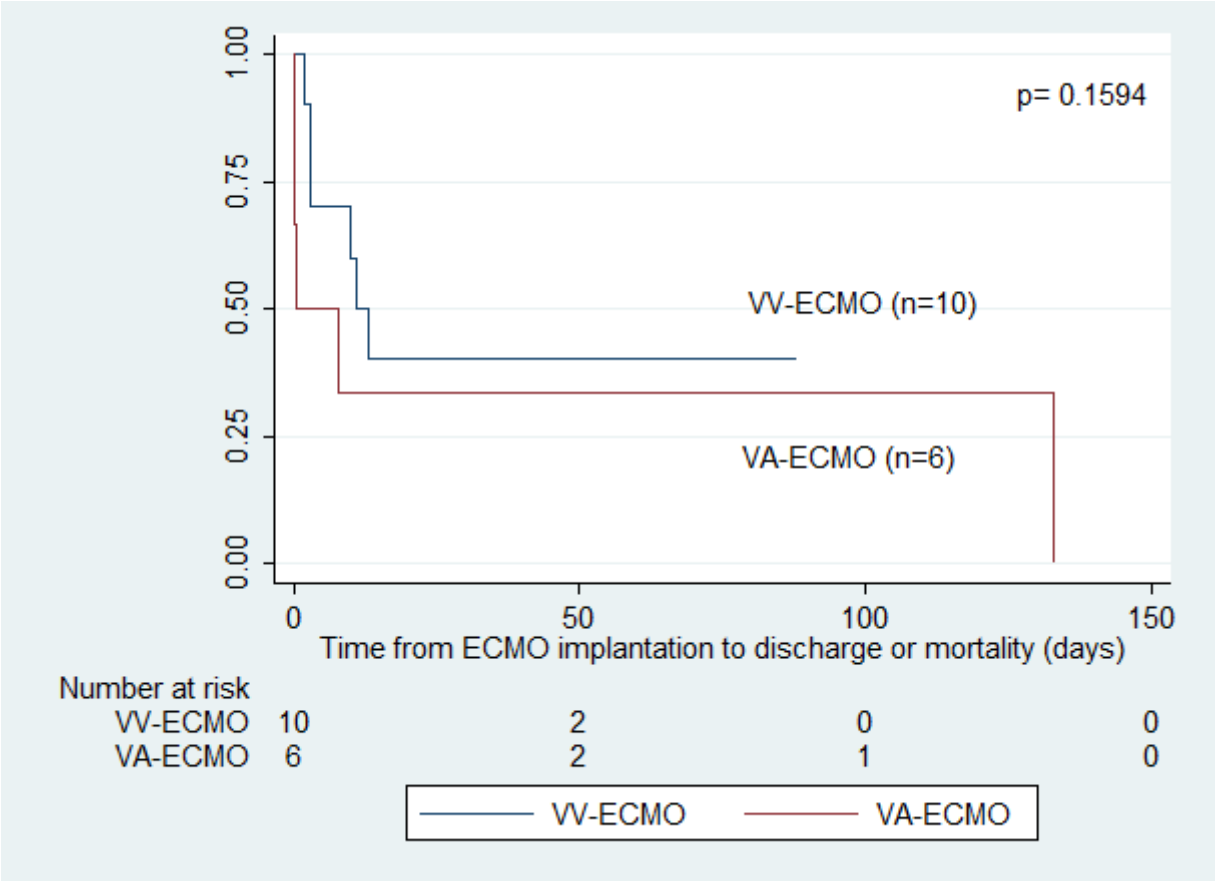


**Figure 1**

Survival difference between VV- and VA-ECMO groups according to the Kaplan-Meier survival analysis.

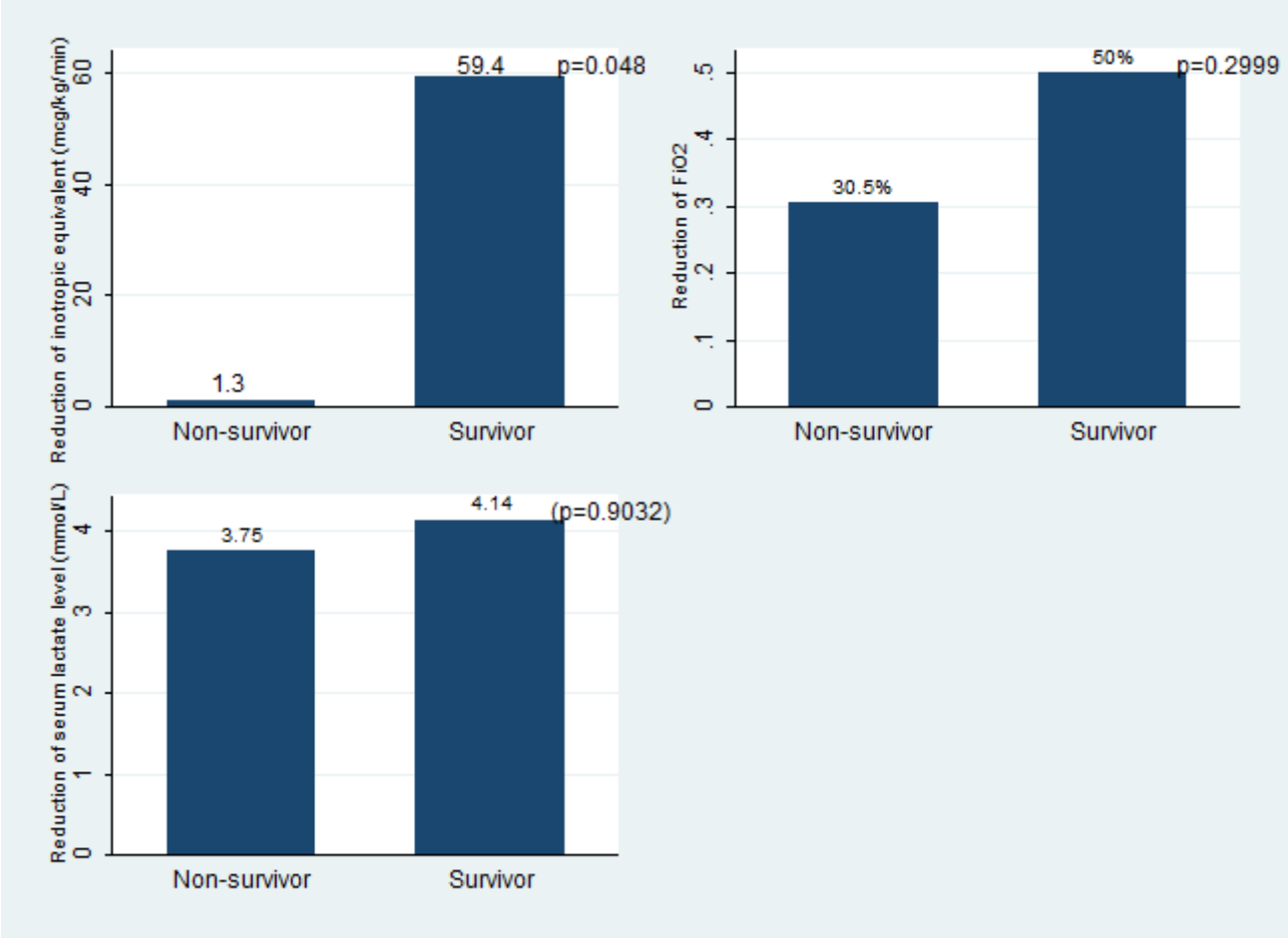


**Figure 2**

Comparison between survivors/non-survivors of changes in IE, FiO2, lactate on the second day of ECMO.

# Supplementary Files

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