



Extracorporeal membrane oxygenation for postoperative complications in general thoracic surgery: a ten-year experience of a university referral centre

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Background: Extracorporeal membrane oxygenation (ECMO) is a rescue therapy that supports gas exchange and hemodynamic parameters in patients with severe respiratory or cardiac failure. In the last ten years, a significant increment in the use of ECMO has been occurred in thoracic surgery for lung transplant, but little is known about the role of ECMO to face severe complications after general thoracic surgery. This study aims: (I) to investigate the incidence of postoperative adverse events, requiring ECMO support, after general thoracic surgery, and (II) to evaluate the intensive care unit (ICU) and hospital survival in patients who received ECMO after general thoracic surgery.

Methods: We retrospectively reviewed the ECMO registry data on patients who received ECMO after general thoracic surgery at Padua University Hospital (Italy) from January 1, 2010 to January 1, 2020. Exclusion criteria were: (I) postoperative prolongation of intraoperative extracorporeal life support, (II) lung transplantation, (III) concomitant heart surgery.

Results: During a ten years period, among 6,837 patients who underwent general thoracic surgery procedures, 7 (0.1%) required ECMO support due to severe postoperative adverse events [acute respiratory distress syndrome (ARDS) in 42.9% of cases and cardiac failure and haemodynamic instability in 57.1% of cases]. Among these patients, 42.8% died in ICU. All patients, discharged alive from ICU, survived to hospital discharge. After 1 year follow-up, only 33.3% of patients was alive.

Conclusions: ECMO support after general thoracic surgery is a lifesaving rescue therapy for the treatment of postoperative cardio-respiratory adverse events in 'complicated' clinical scenarios not manageable with conventional medical approaches. In this specific study cohort, the use of postoperative ECMO was associated with an acceptable survival rate.

Keywords: Extracorporeal membrane oxygenation (ECMO); thoracic surgery; acute respiratory distress syndrome (ARDS); cardiac failure; postoperative complications

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Introduction

Patients undergoing general thoracic surgery are at high risk to develop major postoperative complications, whose incidence and severity are influenced by several factors, such as the medical comorbidities and the performance status at hospital admission, the disease requiring surgery, and the physiologic impact of the procedure (1). Acute respiratory failure (ARF) with acute respiratory distress syndrome (ARDS) and adverse cardiovascular events are the most serious complications after general thoracic surgery, and both events are associated with increased morbidity and mortality (2,3). Extracorporeal membrane oxygenation (ECMO) is a lifesaving technique that supports gas exchange or hemodynamic parameters in patients with severe respiratory or cardiac failure, and thus it can be a rescue therapy for patients developing major complications after general thoracic surgery. In the recent years, a significant increase in the utilization of ECMO has occurred in thoracic surgery, as a growing numbers of centres are using this lifesaving technique mostly in the perioperative period of lung transplantation, either to bridge the patient to transplant or to prevent and treat right ventricular failure and primary graft dysfunction (4). However, little is known about the role of ECMO after general thoracic surgery.

Herein, we present the experience of ECMO after general thoracic surgery in a University Referral Hospital. Our aims are: (I) to investigate the incidence of postoperative adverse events requiring ECMO support after general thoracic surgery, and (II) to evaluate the intensive care unit (ICU) and hospital survival in patients who received ECMO after general thoracic surgery. We present the following article in accordance with the STROBE reporting checklist (available at <https://ccts.amegroups.com/article/view/10.21037/ccts-20-132/rc>).

Methods

We retrospectively reviewed the ECMO registry data on patients who received veno-venous (VV) or veno-arterial (VA) ECMO after general thoracic surgery at Padua University Hospital (Padua, Italy), considering a period of ten years, from January 1, 2010 to January 1, 2020.

Inclusion criteria were: (I) age >18 years, (II) ECMO support as treatment of postoperative complications, (III) general thoracic surgery procedures during the hospital stay. Patients were considered eligible for ECMO according to the Extracorporeal Life Support Organization (ELSO)

guidelines. VV ECMO was chosen if the patient had a ratio of partial pressure of arterial oxygen to the fraction of inspired oxygen ($\text{PaO}_2/\text{FiO}_2$) <100 on FiO_2 >0.9 and/or Murray score 3–4 and/or carbon-dioxide (CO_2) retention, despite optimal care on mechanical ventilation (5). VA ECMO was initiated if hypotension and low cardiac output caused insufficient tissue perfusion, despite adequate volume administration, inotropes and vasoconstrictors (6).

Exclusion criteria were: (I) postoperative prolongation of intraoperative extracorporeal life support, (II) lung transplantation, (III) concomitant heart surgery.

The data collected included: age, sex, body mass index, past medical history, preoperative surgical diagnosis, general thoracic surgery procedure, reason for ECMO therapy, time of ECMO initiation, length of ECMO support and invasive mechanical ventilation (IMV), complications during ECMO, ICU and hospital length of stay, in-ICU and in-hospital survival, 1 year and long term follow-up.

The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The retrospective historical nature of the study waived the need for ethical approval. Informed consent for data publication was routinely obtained from each patient at the time of hospital admission.

Results

From January 1, 2010 to January 1, 2020, 6,837 adult patients underwent general thoracic surgery at our Thoracic Surgery Unit. Surgical procedures included tracheal surgery and resections of lung, mediastinal neoplasms or chest wall malignancies. Among them, 7 patients required ECMO support postoperatively, thus counting for 0.1% incidence of ECMO use after general thoracic surgery over a ten years period.

Patients' preoperative demographic characteristics are listed in *Table 1*. The average age was 60 years (range, 57–67 years). The average BMI was 26.7 kg/m² (range, 22.7–32.9 kg/m²). The most frequent comorbidities included arterial hypertension, heart diseases, and diabetes. The primary surgical diagnoses were non-small cell lung cancer in 3 (42.9%) patients, malignant pleural mesothelioma in 3 (42.9%) patients, and lung metastases from colon cancer in 1 (14.2%) subject. Thoracic surgical procedures included 2 (28.6%) pneumonectomies, 2 (28.6%) pleuro-pneumonectomies with pleural decortications and diaphragmatic resection, 2 (28.6%) bilateral lung lobectomies, and 1 (14.2%) pleurectomy with pleural

Table 1 Patient demographics

| ID | Age (years) | Sex | BMI (kg/m ²) | Surgical diagnosis | Preop CRT | Comorbidities | Surgical procedure |
|----|-------------|-----|--------------------------|-----------------------------------|-----------|---|--|
| 1 | 59 | M | 27.8 | NSCLC relapse | Yes | Arterial hypertension, atrial fibrillation, chronic ischemic heart disease, history of right lung lobectomy for NSCLC | Right thoracotomy: completion of right pneumonectomy + superior vena cava resection + tracheoplasty |
| 2 | 60 | M | 27.0 | NSCLC | No | Crohn disease | Bilateral thoracotomy: left upper lobectomy + right middle lobectomy |
| 3 | 58 | M | 29.4 | NSCLC | No | Congenital deafness | Right thoracotomy: right pneumonectomy |
| 4 | 58 | M | 23.7 | Lung metastases from colon cancer | Yes | Arterial hypertension, paroxysmal supraventricular tachycardia, colon cancer | Right VATS: right lower lobectomy. Left thoracotomy: left lower lobectomy |
| 5 | 67 | M | 22.7 | Malignant pleural mesothelioma | Yes | Arterial hypertension, congenital deafness | Right thoracotomy: right pleurectomy/decortication + right hemidiaphragm resection + right lower lobectomy |
| 6 | 61 | F | 32.9 | Malignant pleural mesothelioma | Yes | Paroxysmal supraventricular tachycardia, type 2 diabetes mellitus | Right thoracotomy: right pleurectomy/decortication + right hemidiaphragm resection + right pneumonectomy |
| 7 | 57 | M | 23.2 | Malignant pleural mesothelioma | Yes | Aortic valve replacement, history of non-Hodgkin lymphoma and colon cancer | Left thoracotomy: left pleurectomy/decortication + left hemidiaphragm resection + left pneumonectomy |

ID, patient identification number. BMI, body mass index; preop CRT, preoperative chemo-radiotherapy; M, male; F, female; NSCLC, non small cell lung cancer; VATS, video-assisted thoracoscopy.

decortication and diaphragmatic resection.

ECMO characteristics are reported in *Table 2*. The average time between surgery and ECMO placement was 8.4 days (range, 0–20 days). The cause for ECMO initiation was ARDS in 3 (42.9%) cases and cardiac failure, followed by haemodynamic instability, in 4 (57.1%) patients. The majority of patients received VA ECMO (85.8%), except for one. The only patient supported by VV ECMO was managed with awake strategy for 2 days before requiring endotracheal intubation followed by IMV. ECMO-related complications occurred in 2 (28.6%) cases.

Patients' clinical outcomes are listed in *Table 3*. The average length of time on ECMO was 5 days (range, 1–11 days). Six patients out of 7 (85.8%) were successfully weaned from extracorporeal support and 4 (57.1%) from IMV. The average length of IMV was 12 days (range, 3–25 days). ICU survival rate was 57.1%, and the average ICU length of stay was 16 days (range, 8–25 days). All patients discharged alive from ICU survived to hospital discharge. The average length of hospital stay was 38 days

(range, 18–71 days). One-year survival was equal to 33.3% and, considering only patients discharged alive from hospital, the overall survival was around 29 months (range, 5–69 months).

Discussion

Postoperative complications requiring ECMO support after general thoracic surgery are usually associated to high mortality. In our experience, during a period of 10 years, 0.1% of patients who underwent general thoracic surgery developed severe postoperative adverse events requiring ECMO treatment. Among these patients, more than 40% died in ICU and only 33.3% was still alive after 1 year.

To our best knowledge, few investigations were previously published on the use of ECMO after general thoracic surgery and most of them were based on quite small sample sizes. Indeed, excluding case-series with less than 3 patients, only seven studies remain to consider.

The first study searched the ELSO registry data from

Table 2 ECMO characteristics

| ID | Cause for ECMO | Surgery to ECMO time (days) | ECMO type | ECMO complications | Other complications |
|----|---------------------------|-----------------------------|-----------|---|--|
| 1 | Cardiogenic shock | 0 | VA | No | Acute kidney injury |
| 2 | ARDS | 12 | VV | No | Atrial fibrillation |
| 3 | ARDS | 5 | VA | No | Deep vein thrombosis |
| 4 | STEMI | 7 | VA | No | Atrial fibrillation, acute kidney failure requiring CRRT |
| 5 | Cardiac arrest | 7 | VA | Venous cannula displacement into the right ventricle | Atrial fibrillation, right hemothorax |
| 6 | ARDS | 20 | VA | Harlequin syndrome, bleeding from cannula insertion sites | Right hemothorax, ventricular arrhythmia |
| 7 | Right ventricular failure | 8 | VA | No | Atrial fibrillation, acute kidney injury |

ID, patient identification number. ECMO, extracorporeal membrane oxygenation; ARDS, acute respiratory distress syndrome; VA, veno-arterial; VV, veno-venous; CRRT, continuous renal replacement therapy.

Table 3 Clinical outcomes

| ID | Length of ECMO (days) | Weaning from ECMO | Length of IMV (days) | Weaning from IMV | ICU length of stay (days) | ICU survival | Hospital length of stay (days) | Hospital survival | Overall survival* (months) |
|----|-----------------------|-------------------|----------------------|------------------|---------------------------|--------------|--------------------------------|-------------------|----------------------------|
| 1 | 1 | Yes | 3 | Yes | 8 | Yes | 18 | Yes | Lost at FU |
| 2 | 9 | Yes | 14 | Yes | 17 | Yes | 64 | Yes | 69 |
| 3 | 6 | Yes | 25 | No | 25 | No | 30 | No | – |
| 4 | 4 | Yes | 12 | No | 13 | No | 18 | No | – |
| 5 | 2 | Yes | 4 | Yes | 14 | Yes | 36 | Yes | 14 |
| 6 | 11 | No | 18 | No | 24 | No | 31 | No | – |
| 7 | 4 | Yes | 8 | Yes | 11 | Yes | 71 | Yes | 5 |

*, overall survival is calculated from ECMO implantation in patients survived to hospital discharged. ID, patient identification number; ECMO, extracorporeal membrane oxygenation; IMV, invasive mechanical ventilation; ICU, intensive care unit; FU, follow-up.

2007 to 2010 and found 21 patients who underwent ECMO for tracheal stenosis, of whom 5 were on VV ECMO and 16 on VA ECMO (7). Although the authors do not specify whether ECMO support was initiated preoperatively or postoperatively, they reported a survival rate of 57%.

The second study analysed VV ECMO for postoperative ARDS. Among 69 patients requiring extracorporeal support for ARDS after surgical procedures during a five years period, 14 (20%) patients underwent general thoracic surgery and only 1 (7%) survived to hospital discharged (8). Interestingly, patients undergone cardiothoracic surgery showed significantly lower survival rates than those who

underwent other operations.

The third study presented 10 patients treated with awake ECMO for postoperative ARDS with a survival rate of 80% (9). In this case-series, 7 (70%) patients experienced thoracic surgery and then developed ARDS either due to postoperative pneumonia (4 patients) or to massive haemoptysis (3 patients).

A more recent retrospective study recorded an incidence of 0.2%, over 8 years, of ECMO placement after general thoracic surgery. Specifically, 29 patients required postoperative extracorporeal life support among 17,185 adults who underwent general thoracic surgical procedures (10).

The indications for ECMO were respiratory failure in 82.8% of cases, and hemodynamic instability in 17.2% of cases. These authors reported a survival to decannulation and a survival to hospital discharge of 34.5% and 24.1%, respectively. Notably, prolonged time between surgery and ECMO placement (>2 days) was a significant risk factor for hospital mortality.

In another recent study, among 232 adult patients who underwent pneumonectomy during a 6 years period, 8 patients (3.4%) required postoperative VV ECMO support due to severe ARDS. Four patients out of 8 survived to hospital discharged, increasing the expected survival rate, based on the Sequential Organ Failure Assessment (SOFA) score, from 20% to 50% before ECMO insertion (11).

Another retrospective review of patients who received extracorporeal support after thoracic surgery over 5 years period identified 6 patients placed on VV ECMO and 2 patients placed on VA ECMO (12). Among these 8 patients, 4 (50%) were successfully weaned from extracorporeal support and 3 (37%) survived to hospital discharge. Remarkably, this study demonstrated that ECMO after general thoracic surgery costs significantly more than in other subgroups of patients, with an average total hospital charge of \$1,053,551 each patient.

Finally, a study on 20 postoperative ECMO applied in non-cardiotomy patients counted 10 cases who underwent general thoracic surgery over an eleven years period. The indications for extracorporeal support were respiratory failure (80%) and cardiogenic shock (20%) with a length of time between surgery to ECMO of 4 days and ECMO length of time of 8 days (13). The survival to hospital discharge was 60%.

In summary, the survival rates reported in these studies are extremely variable, ranging from 7% to 70%. These unclear and heterogeneous results may be ascribable to severe disparities in study design and to heterogeneous surgical populations with different pulmonary pathologies, comorbidities and surgical procedures. Indeed, the survival rate for ECMO patients differs significantly between studies, ranging from 29% at hospital discharge in adult patients requiring VA ECMO for cardiac arrest unresponsive to conventional cardiopulmonary resuscitation (14), to 65% at 60 days in adult patients supported for severe ARDS (15), and up to 95% at 30 days in adult patients prophylactically treated with VA ECMO after bilateral lung transplant (16).

Patients undergoing general thoracic surgery procedures are mainly affected by oncological diseases and present

often numerous comorbidities, which may impair their performance status and cause a significant decline in multiple physiological systems (17). Moreover, frailty is a frequent condition in patients who underwent thoracic surgery, and more than 69% of candidates usually have more than one frailty trait (18). This finding could justify the lower survival rate registered among patients supported with ECMO after general thoracic surgery compared to other ECMO populations. Notably, in our experience, although all the patients had thoracic malignancies and 72% of them underwent preoperative oncological treatments (including chemotherapy and radiotherapy), all patients, except 1, were successfully weaned from ECMO, and only 28% of the patients experienced ECMO-related complications.

When patients develop severe cardiopulmonary complications after general thoracic surgery not manageable with conventional therapy, ECMO appears to be a valid option in order to allow multi-organ recovery and to make better clinical decisions. Indeed, these patients should not be excluded a priori from extracorporeal support. Even if ECMO is an invasive and very resource-consuming treatment, for each case a multidisciplinary risk/benefit balance should be evaluated before ECMO initiation, assessing not only the preoperative comorbidities, but also the type of surgery performed, the patient's postoperative clinical conditions, the timing of the call for initiation of ECMO, and the previously expressed wishes of the patient. Extracorporeal support should be offered if there is a reasonable chance that ECMO will achieve the desired outcome and if the patient would likely benefit from it in a middle-long term perspective (19).

Conclusions

ECMO support after general thoracic surgery is a lifesaving rescue option for the treatment of postoperative cardio-respiratory complications in the rare cases (0.1%) that cannot be managed with conventional therapies. In this highly selected population, postoperative ECMO use is associated with acceptable survival rate (ICU survival rate 57.1%, and 1-year survival rate 33.3%). Further studies, with larger multicentric sample sizes, are needed to determine the effectiveness of ECMO application after general thoracic surgery, and to establish safe prognostic criteria for identifying patients who mostly benefit from a valid postoperative ECMO support.

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Footnote

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