Extracorporeal Membrane Oxygenation for Acute Respiratory Distress Syndrome After Pneumonectomy

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Background. **Postpneumonectomy acute respiratory distress syndrome (ppARDS) is a life-threatening condition with a disastrous prognosis. This study assessed the efficacy of venovenous extracorporeal membrane oxygenation (VV-ECMO) in adult patients with unresponsive severe ppARDS.**

Methods. **We retrospectively reviewed data of all patients treated with VV-ECMO for ppARDS from January 2009 to December 2015. We calculated the Sequential Organ Failure Assessment score before ECMO insertion and monitored the subsequent mechanical ventilation settings. The primary end point was hospital survival. The secondary end point was the ability to achieve a protective ventilatory strategy allowing lung recovery on ECMO.**

Results. **VV-ECMO was indicated in 8 ppARDS patients for refractory hypoxemia (median partial pressure of arterial oxygen/fraction of inspired oxygen: 68 [range, 60 to 75] mm Hg). Median Sequential Organ Failure Assessment before ECMO was 15 (range, 12 to 17), predicting a mortality rate greater than 80%. Median duration of ECMO was 9.5 (range, 5 to 16) days. Tidal volumes and plateau pressures both decreased on ECMO (pre-ECMO tidal volume: 412 [range, 250 to 450 mL] vs ECMO tidal volume: 277 [range, 105 to 367 mL], $p = 0.0156$; pre-ECMO plateau pressure: 34 [range, 32 to 40] cm H_2O vs ECMO plateau pressure: 24.5 [range, 23.3 to 27.3] cm H_2O, $p = 0.0195$). ECMO could be weaned in 7 patients (87.5%). Hospital survival was 50%.**

Conclusions. **Hospital survival was better than predicted before ECMO insertion. In severe and refractory ppARDS, VV-ECMO allows lung recovery and therefore increased survival.**

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Acute respiratory distress syndrome (ARDS) is a rare but a life-threatening complication after pneumonectomy. ARDS was first described in 1967 and consensually defined 27 years later by the American-European Consensus Conference definition as an acute onset of hypoxemia (partial pressure of arterial oxygen–to–fraction of inspired oxygen ratio [Pa_{O_2}/F_{IO_2}] $\leq$200 mm Hg) with bilateral infiltrates on frontal chest roentgenogram without evidence of associated heart failure [1, 2]. In 2012 the definition of ARDS was revised by a task force in Berlin, which proposed three categories according to the degree of hypoxemia: mild (Pa_{O_2}/F_{IO_2} <200 to 300 mm Hg), moderate (Pa_{O_2}/F_{IO_2} <100 to 200 mm Hg), and severe (Pa_{O_2}/F_{IO_2} $\leq$100 mm Hg) ARDS. These stages of mild, moderate, and severe ARDS are correlated with increasing hospital mortality of 27%, 32%, and 45%, respectively [3]. Prognosis of ARDS after lung resection, and particularly after post-pneumonectomy ARDS (ppARDS), seems even more pessimistic. The hospital mortality rates of ppARDS ranged from 33% to 88% in small cohort studies [4–10].

Venovenous extracorporeal membrane oxygenation (VV-ECMO) is an extracorporeal life support technique that allows for the substitution the failing respiratory function. VV-ECMO is frequently associated with a protective ventilation strategy in severe ARDS with the dual rationale (1) to ascertain gas exchanges and (2) to promote lung recovery by resting the lungs [11, 12]. Some case reports describe the successful use of VV-ECMO in ppARDS associated with fistula [13–15]. To the best of our knowledge, no cohort study has been specifically devoted to VV-ECMO in ppARDS. The aim of this study was to assess the efficacy of VV-ECMO in adult patients with severe ARDS after pneumonectomy.

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Abbreviations and Acronyms

ADC = adenocarcinoma
ANOVA = analysis of variance
ARDS = acute respiratory distress syndrome
ASA = American Society of Anesthesiologists
BMI = body mass index
COPD = chronic obstructive pulmonary disease
DLCO = diffusing capacity of the lung for carbon monoxide
ECMO = extracorporeal membrane oxygenation
FEV_1 = forced expiratory volume in 1 second
FF = femoral-femoral
FIO_2 = fraction of inspired oxygen
FJ = femoral-jugular
ICU = intensive care unit
MM = malignant mesothelioma
MOF = multiorgan failure
NA = not applicable
NSCLC = non-small cell lung cancer
$PaCO_2$ = partial pressure of arterial carbon dioxide
PaO_2 = partial pressure of arterial oxygen
PEEP = positive end-expiratory pressure
ppARDS = postpneumonectomy acute respiratory distress syndrome
RBC = red blood cells
RIJ = right internal jugular vein
SCC = squamous cell carcinoma
SOFA = Sequential Organ Failure Assessment
TV = tidal volume
VO_2max = maximal oxygen consumption
VV = venovenous

Patients and Methods

The French Society of Thoracic and Cardio-Vascular Surgery Ethical Committee approved this study and waived the need for informed consent.

Study Design

We retrospectively reviewed all patients treated with VV-ECMO for severe and refractory ARDS after pneumonectomy or completion pneumonectomy between January 2009 and December 2015.

Pre-ECMO Management

All pneumonectomies or completion pneumonectomies were performed as planned curative operations for non-small cell lung cancer or pleural malignancy. All patients were preoperatively assessed by the British Thoracic Society's guidelines for the selection of patients with lung cancer for resection [16]. The anesthetic management protocol of the pneumonectomy was based on sufentanil, propofol or etomidate, and curare. Thoracic epidural analgesia was performed for every patient of the cohort. The ventilation settings before pneumonectomy were (1) positive end-expiratory pressure (PEEP) 8 cm H_2O, (2) tidal volume (TV) 5 to 6 mL/kg, (3) respiratory ratio depending on the end tidal CO_2 (target = 30 to 55 mm Hg), and (4) FIO_2 enough to ensure an oxygen saturation of 90% or higher.

All patients with ARDS had been receiving optimal conventional management at the time when the decision for ECMO was made in a multidisciplinary discussion.

ECMO Initiation

Patients were eligible for ECMO in case of severe ARDS according the Berlin Definition of ARDS [3]. Patients were considered for VV-ECMO if they were unresponsive to optimal medical treatment and hemodynamically stable (mean arterial pressure >60 mm Hg; normal left- and right-sided heart functions and sizes) with minimal vasopressive support. Optimal medical therapy was defined by a combination of (1) protective mechanical ventilation (TV: 4 mL/kg ideal body weight, plateau pressure: ≤30 cm H_2O, PEEP titrated according to pressure-volume loops or recruited lung volume), (2) a reduction of instrumental dead space by avoiding heat-moisture exchangers, (3) empiric broad-spectrum antibiotics in case of clinical suspicion of ventilator-associated pneumonia or positive Gram stain on bronchoalveolar lavage, (4) prone positioning, (5) repeated bronchoscopic sanitation, followed by recruitment maneuvers in case of clinical or radiologic suspicion of atelectasis, (6) neuromuscular blocking agent (curare) for at least 6 hours, and (7) inhaled nitric oxide (20 ppm) more or less combined with almitrine therapy (Fig 1) [17]. VV-ECMO was used as a first-line technique because of its higher efficiency in lungs, heart, and brain oxygenation compared with other extracorporeal life support techniques [11, 12].

The overall status and predicted death of the patients before the ECMO insertion was estimated using the Sequential Organ Failure Assessment (SOFA) score, which quantifies the severity of illness with the degree of hypoxemia, platelet level, liver function (bilirubin), level of the cardiovascular support (mean arterial pressure and vasopressor requirement), kidney function (creatinine level or urine output), and Glasgow Coma Score [15]. SOFA scores of 15 and above are correlated with mortality rates exceeding 80% and 90%, respectively [18].

Insertion of VV-ECMO

VV-ECMO was implanted in the intensive care unit (ICU) using the Seldinger technique. Cannula size depended on the site of cannulation. For double-site cannulation, the outflow cannula was sized 21F to 25F, and the inflow cannula was 18F to 24F. In this setting, the drainage sites were the right or the left femoral veins, and the injection site was preferentially the right internal jugular vein [19]. Accurate positioning of the 2 cannulas was evaluated clinically and by chest roentgenogram.

Single-site cannulation was achieved with a 27F Avalon Elite double-lumen catheter (Maquet Cardiopulmonary GmbH, Rastatt, Germany) implanted into the right