Short-term venoarterial extracorporeal membrane oxygenation for massive endobronchial hemorrhage after pulmonary endarterectomy

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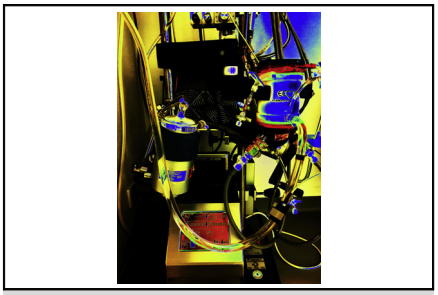
ABSTRACT

Objectives: Pulmonary endarterectomy (PEA) is the only curative treatment option for patients with chronic thromboembolic pulmonary hypertension. Massive endobronchial bleeding that precludes weaning from cardiopulmonary bypass is an often-fatal complication of PEA. The aim of this study was to determine whether short-term extracorporeal membrane oxygenation (ECMO) is a safe and feasible procedure in patients with severe endobronchial bleeding.

Methods: From January 2014 to December 2016, 396 patients (mean age 60 ± 18 years, 54.5% male) underwent PEA in our department. Patients with severe endobronchial hemorrhage at the time of weaning from cardiopulmonary bypass (CPB) were switched to a heparin-coated venoarterial ECMO circuit. After full-dose protamine administration to restore normal coagulation, weaning from ECMO was attempted in the operating room.

Results: In-hospital mortality was 2.3% (9/396 patients). Eight patients (2.0%) developed severe endobronchial bleeding classified as diffuse (n = 6) or localized (n = 2) by bronchoscopy. After reinstitution of CPB and subsequent switch to ECMO, the mean duration of ECMO support was 49 ± 13 minutes, and all 8 patients were weaned successfully from ECMO in the operating theater without further signs of endobronchial bleeding. One patient needed venovenous ECMO support for poor oxygenation 6 hours after surgery. Seven patients were discharged after a prolonged postoperative stay of 17.6 ± 4.1 days. One patient died. This new concept significantly reduced mortality compared with previous (2009-2013) ECMO support ($P = .0406$).

Conclusions: For patients with massive endobronchial bleeding after PEA, the intraoperative switch from CPB to venoarterial ECMO support with full-dose protamine administration is a new and potentially life-saving treatment concept. (J Thorac Cardiovasc Surg 2017;■:1-7)



Extracorporeal membrane oxygenation.

Central Message

Short-term venoarterial extracorporeal membrane oxygenation support is a new and feasible concept for the successful treatment of severe endobronchial bleeding in the operating theater.

Perspective

Pulmonary endarterectomy is the only curative treatment for chronic thromboembolic pulmonary hypertension. Severe endobronchial bleeding is a feared complication of pulmonary endarterectomy. Short-term venoarterial extracorporeal membrane oxygenation support was implemented successfully as a new concept for addressing this serious complication and reducing mortality. This short-term solution avoids further complications linked to longer periods of extracorporeal circulatory support.

See Editorial Commentary page XXX.

MCS

Pulmonary endarterectomy (PEA) is the most successful treatment option for chronic thromboembolic pulmonary hypertension,[1-3] and with growing experience, favorable results have been reported.[4-7] The aim of surgery is a complete removal of fibrotic material from pulmonary artery branches, leading to an instant reduction of right

Scanning this QR code will take you to a supplemental video for the article.

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Read in part at the 36th Annual Meeting and Scientific Sessions of the International Society of Heart and Lung Transplantation, Washington, DC, April 27-30, 2016.

Received for publication April 28, 2017; revisions received July 16, 2017; accepted for publication Sept 6, 2017.

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0022-5223/$36.00

https://doi.org/10.1016/j.jtcvs.2017.09.045

Abbreviations and Acronyms
CPB = cardiopulmonary bypass
ECMO = extracorporeal membrane oxygenation
PEA = pulmonary endarterectomy
PVR = pulmonary vascular resistance

ventricular afterload and improving right heart function, gas exchange, exercise capacity, and survival. A major risk factor for mortality after PEA is the degree of pulmonary vascular resistance (PVR), especially when it is greater than 1000 dynes·s·cm^{-5}.[8] Patients with predominantly distal disease (thromboembolic disease classification type III) also have a greater mortality due to a greater risk of postoperative residual pulmonary hypertension.[9]

Severe complications of PEA surgery include reperfusion injury of the lungs with poor oxygenation capability, persistent pulmonary hypertension, right ventricular failure, and endobronchial bleeding.[10] These complications early after surgery account for most of the in-hospital deaths, whereby intraoperative endobronchial bleeding is one of the most critical and fatal complications.

Extracorporeal membrane oxygenation (ECMO) is a well-established technique for providing emergency gas exchange and circulatory support for patients with respiratory and/or circulatory failure. ECMO is provided as a venovenous[11] or a venoarterial[12] system. Particularly for endobronchial bleeding complications during PEA, ECMO support is reported to be a life-saving tool that can be used for several days until bleeding stops followed by weaning from the system.[13,14] Prolonged venoarterial ECMO support, however, fosters further complications, such as thrombocytopenia, systemic embolization, and rethrombosis of the pulmonary vasculature due to the reduced pulmonary arterial flow. Therefore, to reduce these complications, short-term ECMO support is preferable.

One benefit of using ECMO systems with heparin-coated circuits instead of conventional extracorporeal circulatory support during PEA surgery is the fact that blood coagulation can be completely restored with protamine with a minimal risk of clot formation inside the oxygenator. In 2014, we changed our treatment concept for severe endobronchial bleeding to one that uses short-term venoarterial ECMO support with immediate restoration of normal coagulation. Here we report the first use of short-term venoarterial ECMO support for the treatment of severe endobronchial bleeding after PEA (Video 1).

PATIENTS AND METHODS

Patients

From January 2014 to December 2016, 396 patients underwent PEA at our center. This collective consisted of 216 men (54.5%) and 180 women (45.5%) with a mean age of 60 ± 18 years. All data were collected prospectively in a dedicated database. The data collection was approved by the institutional ethics committee and conducted in keeping with the Declaration of Helsinki. All patients provided written informed consent.

Surgical Techniques

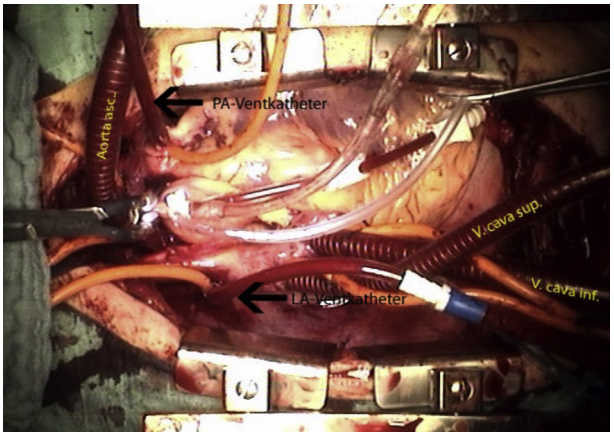
PEA was performed via the standard technique described by the San Diego group using median sternotomy with deep hypothermic circulatory arrest.[15] Bronchoscopy was performed after rewarming of the patient, who was subsequently slowly weaned from the cardiopulmonary bypass (CPB); the operation was concluded in the usual manner.

ECMO Management

The decision for venoarterial ECMO support was made immediately after severe endobronchial hemorrhage (ie, >250 mL) was confirmed by bronchoscopy. After the detection of endobronchial bleeding, the patient was returned immediately to CPB and the switch to venoarterial ECMO was planned. If localized bleeding was present, the affected bronchus was blocked by the application of fibrin glue under bronchoscopy (this occurred in 2 cases). Units of fresh-frozen plasma, platelets, and red blood cells were ordered. The patients were switched directly from CPB to venoarterial ECMO support by clamping the arterial and venous cannulas, disconnecting the CPB tubes, and connecting the tubes of the ECMO system. The flow of the venoarterial ECMO system was restored immediately to the calculated cardiac output, and, if necessary, additional volume (crystalloids and fresh-frozen plasma) was added. Under ECMO support, the patients received a full dose of protamine to restore normal blood coagulation. Positive end-expiratory pressure was increased to 15 mm Hg, and the ventilation frequency was increased to 15 to 20/breaths per minute. After a short stabilization period, the next attempt to wean the patient from the ECMO support was initiated.

The ECMO Circuit

The circuit consists of a preassembled tubing set including the oxygenator and an additional centrifugal pump head. In all cases, the ECMO ADULT oxygenator (Eurosets, Medolla, Italy) was used, and the centrifugal pump head was a Revolution 5 (Sorin S.p.A., Milan, Italy). The oxygenator has a filling volume of 225 mL and a gas exchange area of 1.81 m^2. The maximum blood flow rate is 7 L/min. The pump has a filling volume of 57 mL and can operate at up to 5 L/min blood flow. Including the tubes, the ECMO system has an overall filling volume of 600 mL. A crystalloid



VIDEO 1. Presentation of the short-term extracorporeal membrane oxygenation concept including a video of pulmonary endarterectomy surgery. Video available at: http://www.jtcvsonline.org.