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 2018;155:643-9)

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 Commentaries pages 650 and 651.

See Editorial page 641.

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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; available ahead of print Oct 18, 2017.

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0022-5223/\$36.00

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

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

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

Abbreviations and Acronyms

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

artery branches, leading to an instant reduction of right 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 $1000 \text{ dynes} \cdot \text{s} \cdot \text{cm}^{-5}$.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 venovenous¹¹ or a venoarterial¹² 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, $>250 \text{ mL}$) 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

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/article/S0022-5223\(17\)31962-1/fulltext](http://www.jtcvsonline.org/article/S0022-5223(17)31962-1/fulltext).

TABLE 1. Hemodynamic characteristics of all patients undergoing pulmonary endarterectomy

Characteristics	
n	396
Age, y	60 ± 18
Male, n (%)	216 (54.5)
Pre-CPB sPAP, mm Hg	70 ± 23
Pre-CPB mPAP, mm Hg	45 ± 13
Pre-CPB dPAP, mm Hg	29 ± 16
Pre-CPB PVR, dynes·s·cm ⁻⁵	620 ± 320
Pre-CPB SVR, dynes·s·cm ⁻⁵	1220 ± 440
Pre-CPB CVP, mm Hg	10.9 ± 4.7
Pre-CPB CO, L·min ⁻¹	4.8 ± 2.0
Jamieson type	I (34.5%), II (34.2%), III (31.3%)

Values shown are n (%) or mean ± SD. CPB, Cardiopulmonary bypass; sPAP, systolic pulmonary arterial pressure; mPAP, mean pulmonary arterial pressure; dPAP, diastolic pulmonary arterial pressure; PVR, pulmonary vascular resistance; SVR, systemic vascular resistance; CVP, central venous pressure; CO, cardiac output.

has an overall filling volume of 600 mL. A crystalloid solution (Jonosteril; Fresenius, Bad Homburg, Germany) was used for system priming. The oxygenator and the tubes are coated with phosphorylcholine.

Statistical Analysis

All continuous variables are expressed as mean ± standard deviation. Univariate comparisons between patients were performed with a χ^2 test or Fisher exact test, where appropriate, for dichotomous variables; the Student *t* test or Mann-Whitney *U* test was applied for continuous variables. Statistical tests were 2-sided; differences in which *P* was less than .05 were considered significant. GraphPad Prism version 6.00 for Windows was used for the data and statistical analyses (GraphPad Software, La Jolla, Calif; www.graphpad.com).

RESULTS

Table 1 shows demographics, hemodynamic characteristics, and Jamieson classification of all 396 patients who underwent PEA. The mean age was 60 ± 18 years with a near-equal sex distribution of 216 men (54.5%) and 180 women (45.5%). Mean pulmonary arterial pressure was 45 ± 13 mm Hg, cardiac output 4.8 ± 2.0 L/min, PVR 620 ± 320 dynes·s·cm⁻⁵, and central venous pressure 12.3 ± 4.2 mm Hg. Regarding the thromboembolic disease type, 34.5% of the patients had type I, 34.2% type II, and 31.3% type III.

In-hospital mortality of the overall cohort was 2.3% (9/396 patients). A total of 16 patients needed ECMO support after surgery (4.0%). Of those, 8 patients (2.0%) developed severe endobronchial bleeding during the first weaning attempt and required venoarterial ECMO support. The mean age of the 6 women and 2 men was 67 ± 11 years, which was slightly older than the non-ECMO patients (60 ± 16 years) (Table 1). The ECMO group had a lower cardiac output of 3.7 ± 1.1 L/min and greater PVR of 857 ± 553 dynes·s·cm⁻⁵.

TABLE 2. ECMO postpulmonary endarterectomy (short-term venoarterial ECMO)

Characteristics	
n	8
Age, y	67 ± 11
Male, n (%)	2 (25)
Jamieson Classification I, n (%)	3 (38)
Jamieson Classification II, n (%)	1 (13)
Jamieson Classification III, n (%)	4 (50)
Cardiopulmonary bypass time, min	308 ± 45
Aortic crossclamp time, min	103 ± 32
Circulatory arrest time, min	38 ± 8
Lowest core temperature, °C	18.6 ± 1.2
Duration of va ECMO, min	49 ± 13
Weaned, n (%)	8 (100)
Discharged from hospital, n (%)	7 (88)
Blood products	
pRBCs, U	7.0 ± 3.2
FFP, U	7.9 ± 3.8
Platelets, U	1.7 ± 1.3

Values shown are n (%) or mean ± SD. va ECMO, Venoarterial extracorporeal membrane oxygenation; pRBCs, packed red blood cells; FFP, fresh-frozen plasma.

CPB time was 308 ± 45 minutes, aortic crossclamp time 103 ± 32 minutes, and total circulatory arrest time 38 ± 8 minutes. The lowest body core temperature was 18.6 ± 1.2°C.

One of these 8 patients died as the result of multiple-organ failure. The procedural characteristics of the ECMO group are given in Table 2. In all of these patients, the ECMO circuit was connected intraoperatively after severe endobronchial bleeding was confirmed by bronchoscopy. The average ECMO support time was 49 ± 13 minutes (range 20-113 minutes). All 8 patients with venoarterial ECMO were successfully weaned intraoperatively from the circuit, and 1 patient needed venovenous ECMO support for poor oxygenation 6 hours postoperatively.

All patients with venoarterial ECMO support had a significant blood transfusion requirement. The necessary support was provided with multiple units of packed red cells

TABLE 3. Complications in patients undergoing ECMO

Complication	
Atrial fibrillation	2
Pericardial tamponade	1
Temporary acute renal failure with continuous venovenous hemofiltration	1
Pneumonia	1

TABLE 4. Clinical course of patients undergoing ECMO

Variable	Patient 1	Patient 2	Patient 3	Patient 4	Patient 5	Patient 6	Patient 7	Patient 8
Age, y	71	54	70	81	75	75	61	50
Sex	Female	Female	Male	Female	Male	Female	Female	Female
WHO FC	III	III	III	III	III	III	III	III
Duration of ECMO support, min	29	50	70	35	20	36	25	104
Ventilator support, h	206	113	43	27	102	335	34	146
Bronchus block (fibrin glue)	X		X					X
Parenchymal lesion in CT	S8 RLL		S2 RUL, S8/S9 RLL	S5 lingula	S5 ML, S9 RLL, S1 LUL	S5 ML		S2, S5, S6
ICU, d	11	10	9	9	8	16	2	12
Hospital stay, d	22	22	16	13	15	19	26	14
pRBCs, U	8	6	7	4	9	12	2	10
FFP, U	14	6	10	3	6	12	6	4
Platelets, U	0	2	4	2	2	0	2	2
Discharged from hospital	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes

WHO FC, World Health Organization functional class; ECMO, extracorporeal membrane oxygenation; CT, computed tomography; S, segment; RLL, right lower lobe; RUL, right upper lobe; ML, middle lobe; LUL, left upper lobe; ICU, intensive care unit; pRBCs, packed red blood cells; FFP, fresh-frozen plasma.

(6.8 ± 3.0), fresh-frozen plasma (8.1 ± 3.7), and platelets (1.7 ± 1.3) (Table 2). The additional complications after PEA were atrial fibrillation, pericardial tamponade (requiring reoperation), renal failure requiring continuous venovenous hemofiltration, and pneumonia (Table 3).

Details of the individual patients supported by ECMO are listed in Table 4. All patients with endobronchial bleeding were preoperatively in World Health Organization functional class III, and computed tomography scans showed in some cases parenchymal lesions that were most likely remnants of pulmonary infarctions. Table 5 shows operative and postoperative time lines. Operation time (489 ± 36 vs 416 ± 65 minutes, $P < .0001$), ventilation time (164 ± 139 vs 52 ± 76 hours, $P < .0001$), intensive care unit stay (9.4 ± 1.1 vs 3.6 ± 3.1 days, $P < .0001$), and hospital stay (15 ± 5 vs 12 ± 20 days, $P = .0102$) were significantly longer in the venoarterial ECMO group. Seven patients were discharged from the hospital. One patient who needed venovenous ECMO support for poor oxygenation died on postoperative day 12 due to multiple-organ failure. Currently, all 7 patients are alive and in functional class

I ($n = 3$), II ($n = 3$), or III ($n = 1$) with a mean follow-up of 2.6 years. One year after surgery, these patients showed significant improvements in functional class from (3.1 ± 0.4 to 1.7 ± 0.8), in mean pulmonary arterial pressure from (45 ± 14 to 24 ± 10 mm Hg), and in PVR from (671 ± 272 to 296 ± 211 dynes $\cdot$ s $\cdot$ cm $^{-5}$) (Table 6).

Figure 1 depicts the survival of patients with severe endobronchial bleeding during 2 periods: (1) between 2009 and 2013 with 2 survivors and 6 nonsurvivors and (2) between 2014 and 2016 with 7 survivors and 1 nonsurvivor. In the latter period with short-term ECMO support mortality was significantly lower ($P = .0406$).

DISCUSSION

In this article, we describe our experience with the novel, short-term use of venoarterial ECMO in combination with restored coagulation to manage intraoperative endobronchial hemorrhage after PEA. To our knowledge, this is the first documentation of the reversal of anticoagulation during short-term, intraoperative ECMO support followed by successful weaning.

TABLE 5. Postoperative course in patients with and without short-term venoarterial ECMO support

Variable	Non-ECMO group (n = 388)	Short-term va ECMO group (n = 8)	P
Operation time, min	416 ± 65	489 ± 36	<.0001
Ventilation time, h	52 ± 76	164 ± 130	<.0001
ICU time, d	3.5 ± 3.1	9.4 ± 1.1	<.0001
Postop hospital stay, d	12 ± 20	15 ± 5	.0102

ECMO, Extracorporeal membrane oxygenation; ICU, intensive care unit; postop, postoperative.

TABLE 6. Hemodynamic changes and pre- and postoperative WHO FC in patients with short-term venoarterial ECMO

Characteristics	Preoperative	1-year postoperative	
WHO FC	3.1 ± 0.4	1.7 ± 0.8	($P = .0027$)
mPAP, mm Hg	45 ± 14	24 ± 10	($P = .0424$)
CI, L/min/m 2	2.3 ± 0.3	2.5 ± 0.2	($P = .3236$)
PVR, dynes $\cdot$ s $\cdot$ cm $^{-5}$	671 ± 272	296 ± 211	($P = .0242$)

Values shown are mean $\pm$ SD. WHO FC, World Health Organization functional class; mPAP, mean pulmonary arterial pressure; CI, cardiac index; PVR, pulmonary vascular resistance.

FIGURE 1. Comparison of survival between 2 different concepts of venoarterial ECMO support. Depicted are long-term ECMO support between 2009 and 2013 and short-term ECMO support between 2014 and 2016. Short-term venoarterial ECMO support resulted in a significant reduction in mortality ($P = .0406$). Green indicates survivor; blue indicates nonsurvivor.

PEA is the treatment of choice for chronic thromboembolic pulmonary hypertension. Rare but serious complications are reperfusion edema, persistent pulmonary hypertension, and endobronchial bleeding. All of these complications are potentially fatal.⁵ With increasing experience and extended indications for PEA surgery, all major PEA centers (centers with more than 100 PEA procedures per year) have to deal with these complications to save the lives of their patients. In this article, we focus on massive endobronchial hemorrhage and its management.

During the PEA procedure, surgeons have the unique opportunity for early anticipation of possible airway bleeding and may treat intraoperative defects to avoid this complication. If during endarterectomy denuded vessels or only a thin layer of adventitia or perforation is detected, endobronchial bleeding must be considered. In some cases, perforated vessel layers can be repaired with fibrin glue. In particular, disruptions of a distal pulmonary artery can be detected intraoperatively using the “bubble” technique, as reported by Morsolini and colleagues¹⁰: if a pulmonary arterial branch shows bubbles during gentle ventilation of the lung, this branch should be blocked with topical application of a surgical sealant such as fibrin glue.

During rewarming of the patient to the normal core temperature, we routinely perform a bronchoscopy. If small amounts of blood are visible but there is no blood ascending from the bronchi, weaning from CPB can be carried out in the routine manner. In the majority of cases, endobronchial bleeding commences during the weaning phase due to increased pulmonary arterial pressures. It can be detected early, however, by monitoring tidal or minute volume during pressure-controlled ventilation. Decreasing values are the earliest signs of a reduced ventilatory space that might be caused by endobronchial bleeding before blood is detected in the endotracheal tube. Immediate assessment by bronchoscopy is then warranted.

In dealing with this complication the bronchoscopic diagnosis is usually clear, but it is often difficult to discern whether bleeding is localized or diffuse. Because of the spilling of blood into the entire bronchial system, blood can be aspirated from multiple locations during bronchoscopy. As evident from Table 4, however, in 2 of 8 patients we had the impression that the blood predominately came from one segmental bronchus. Consequently, we also blocked this bronchus with fibrin glue, administered with the aid of a bronchoscope. There are also descriptions of the use of endobronchial blockers or double-lumen endobronchial tubes in cases of severe endobronchial bleeding,¹⁶ but they all have the disadvantage that the amount of blocked lung area is considerably greater compared with a blocked lung segment treated with fibrin glue.

In cases of severe and diffuse airway bleeding, a conservative approach (eg, bronchus blocking) is not sufficient to handle this complication. Increasing experience in extracorporeal support has led to 2 ECMO techniques that are currently in use: for reperfusion edema or impaired lung function of other origin, venovenous ECMO is the preferred support¹¹; otherwise, if hemodynamic compromise is a factor, venoarterial ECMO support with central or peripheral cannulas is preferable.¹²

One of the first reports describing venovenous ECMO support for patients after PEA came from a group in San Diego.¹¹ During a period of 15 years, 1790 patients underwent PEA at this center. Twenty patients (1.1%) had to be supported with venovenous ECMO due to severe respiratory failure. Of these 20 patients, 6 survived. In this report, endobronchial hemorrhage did not play a role.¹¹ Another article was published 2 years later by a group in Cambridge who reported 127 consecutive patients who underwent PEA.¹² In 7 patients (5.5%), venoarterial ECMO support was required postoperatively, 5 patients were weaned successfully from the circuit, and 4 were discharged from hospital. In this report, also, endobronchial bleeding was not the reason for ECMO support.¹²

Pulmonary hemorrhage remains a rare complication after PEA (prevalence of 0.5%-2%) that has been treated historically almost entirely without ECMO support.^{17,18} More recently, however, a number of case reports have been published in which the use of ECMO support is described to manage this serious complication.^{13,14,16,19} The individual management of these cases was different and depended on the type of ECMO connection (venovenous or venoarterial). In some instances, the ECMO circuit was connected intraoperatively before weaning from CPB; in other patients, ECMO support was initiated after weaning from CPB. In all cases the mean duration of ECMO support was 3.5 days, ranging from 2 to 4 days. Long-term venoarterial ECMO support, however, that bypasses the lungs for several days may lead to blood stasis in the pulmonary vasculature with the hazard of rethrombosis of the

freshly endarterectomized pulmonary arteries. This fatal complication had occurred in one of our patients in the previous year and led us think about an alternative approach to manage this problem.

In severe endobronchial hemorrhage, the coagulopathy must be reversed, but in this situation the patient cannot be weaned from CPB. Therefore, we decided to switch the circulatory support immediately to a venoarterial ECMO circuit, because there all components have a heparinized lining. This allows for complete restoration of the coagulation system by administering the full dose of protamine during extracorporeal perfusion, and with an increased positive end-expiratory pressure value of 15 cm H₂O we were able to wean all patients from the venoarterial ECMO support in the operating theater. The risk of clotting within the heparin-coated oxygenator is minimal, but it is important to provide pulsatile flow to the pulmonary arteries to avoid clotting in the newly endarterectomized vessels.

The reason for the 8 incidents of severe endobronchial bleeding (2%) that occurred within the 3-year study time frame at our center is not clear. The mechanism of pulmonary hemorrhage remains obscure. Surgical trauma resulting in disruption of the pulmonary arterial vessel and/or a markedly increased capillary permeability after the reperfusion of nonperfused pulmonary parenchyma, similar to ischemia–reperfusion lung injury after transplantation, are possible mechanisms. In 6 of our patients, some parenchymal lesions (possibly remnants of pulmonary infarctions) were detectable that could have conceivably served as foci of pulmonary hemorrhage (Table 4). In addition, the fact that our center treats a large number of patients with distal pulmonary vascular disease might be an explanation. Moreover, compared with other cohorts,⁴ our patients are approximately 10 years older, which might lead to a greater rate of endobronchial hemorrhage. In our series, most of the patients (5 of 8) were older than 70 years of age. The fact that weaning was possible after restoration of the coagulation system suggests that the vasculobronchial connections were of small caliber. In addition, administered blood products such as fresh-frozen plasma and platelets were effective in sealing the bleeding sites. Thus far, we can only speculate on the true cause of bleeding in the individual patient and are not able to recommend different treatment options for different types of bleeding. Our concept of short-term ECMO has proven to be very effective for all patients with potentially different causes of hemorrhage.

In this case series of patients with endobronchial bleeding, the success of weaning from venoarterial ECMO support is very encouraging and demonstrates that this devastating complication is manageable in the majority of patients in the operating theater and that the operation can be concluded in the usual manner. Furthermore, this

concept avoids ECMO-related long-term complications and is resource-saving.

There are some limitations to our study: (1) our small sample size of only 8 patients with endobronchial hemorrhage; and (2) the decision to use ECMO support is subjective and bronchoscopic blocking might be equally feasible in some cases. Because of the success of this approach in a life-threatening situation, however, we have made this our standard procedure.

This is not the first report to describe ECMO support for managing endobronchial bleeding,^{13,14,16,19} but to our knowledge, it is the first small case series that describes the short-term management of this bleeding complication in the operating theater. In all other case reports the duration of ECMO support ranged from 2 to 4 days and ECMO support was almost always initiated after weaning from CBP.

CONCLUSIONS

Severe endobronchial bleeding is a feared complication of PEA for which different concepts of management have been reported. With our new concept of short-term venoarterial ECMO support, successful weaning from the extracorporeal support in the operating theater is feasible.

Conflicts of Interest Statement

Dr Guth: speaking fees from Actelion, Bayer, and Pfizer. Dr Ghofrani: speaking fees from Actelion, Bayer, Actelion, GSK, Pfizer, Merck, Novartis, Takeda Pharmaceuticals, Eli Lilly, Bellerophon, and Pulse Technologies. Dr Mayer: speaking and consulting fees from Actelion, Bayer, GSK, Pfizer, and MSD. Dr Wiedenroth: speaking fees from Actelion, Bayer, BTG, and MSD. Dr Richter: speaking fees from Actelion, Bayer, Mundipharma, OMT, Roche, and United Therapeutics. All other authors have nothing to disclose with regard to commercial support.

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Key Words: CTEPH, pulmonary endarterectomy, ECMO, endobronchial hemorrhage

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