Establishing Extracorporeal Membrane Oxygenation in a University Clinic: Case Series

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Objectives: **Although extracorporeal membrane oxygenation (ECMO) is well established for respiratory failure in neonates, application in adults is still considered controversial. The survival of patients with acute respiratory distress syndrome and ECMO therapy is 50% to 70%.**

Design: **A retrospective analysis of 10 patients, who were placed on ECMO from September 2004 to December 2005, was performed.**

Setting: **University clinic.**

Interventions: **Venoarterial ECMO was established in 7 patients, venovenous ECMO in 2 patients, and combined venoarterial and venovenous ECMO in 1 patient.**

Measurements and Main Results: **Indications were pneumonia, acute respiratory distress syndrome, near drowning, pericardial tamponade with shock lung, right-heart failure after heart transplantation, shock lung after cardiopulmonary resuscitation, and right-heart failure in chronic thromboembolic pulmonary hypertension. Median maintenance of ECMO therapy was 56.5 hours (range, 36-240). The median Murray score was 3.3 for survivors and 4 for nonsurvivors. Overall mortality was 30%; 70% were weaned from ECMO and survived until discharge. Median pre-ECMO risk for fatal outcome according to Hemmila was 0.43 for survivors and 0.92 for nonsurvivors ($p < 0.02$). In 2 cases, surgical reintervention was necessary because of bleeding in one, and a side switch of the cannulae had to be performed because of femoral venous thrombosis in the other.**

Conclusions: **ECMO has been shown to be a successful therapy for acute respiratory distress syndrome when conventional strategies have failed. Pre-ECMO risk assessment may be useful in the evaluation of patients.**

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KEY WORDS: extracorporeal membrane oxygenation, acute respiratory failure, acute respiratory distress syndrome, ECMO, ARDS

EXTRACORPOREAL MEMBRANE OXYGENATION (ECMO) has been used for respiratory and circulatory support in infants. Possible indications for ECMO in adults are acute respiratory failure, which can be predominantly hypoxic or hypercarbic, acute right heart failure, and acute global heart failure, when reversibility is expected. ECMO is also used as a bridge to lung or heart transplantation. Acute respiratory distress syndrome (ARDS) occurs with an incidence of 78 to 88 cases/100,000 people per year.[1,2] The overall mortality of ARDS is currently 40% to 60%.[3-5] Among patients with ARDS, there is a group of patients with "severe ARDS" that is characterized by a PaO_2/F_IO_2 ratio $\leq$100 despite optimal conventional treatment.[6,7] Those severe forms occur with an incidence of 1.5 to 13.5/100,000 per year.[1,2,8-11]

The technique of ECMO for patients with severe ARDS includes placing them on a venovenous (VV) or venoarterial (VA) circuit with a membrane oxygenator to temporarily take over the gas exchange function of the lungs. While on ECMO, the mechanical ventilator settings are adjusted to minimize ventilator-induced lung injury and to maximize the recruitment of functional residual lung capacity, without the problems of high-pressure, high-oxygen mechanical ventilation. In the recent literature, the survival rate of patients with ARDS and ECMO therapy is reported as 50% to 70%. The purpose of this report is to describe the authors' initial experience with ECMO in adult patients.

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METHODS AND MATERIALS

The ECMO circuit used consisted of a Medtronic Bio-Medicus console (Medtronic Biomedical, Minneapolis, MN), a Bio-Medicus centrifugal blood pump, and a Medtronic Biocal blood temperature control module (Medtronic Biomedical). The oxygenator was a hollow-fiber membrane oxygenator with integrated heat exchanger. Cannulae were Medtronic Bio-Medicus cannulae (Medtronic Inc., Minneapolis, MN) that are heparin coated and radioopaque. Patients received heparin (initial dosage 100 U/kg) before ECMO therapy. Heparinization was monitored by activated coagulation time (target range, 180-200 seconds, 160 seconds in the weaning phase).

The indication for ECMO was a PaO_2/F_IO_2 ratio $\leq$100 mmHg on positive end-expiratory pressure $\geq$10 cmH_2O for $\geq$2 hours of advanced treatment[2,8] with pressure-controlled mechanical ventilation + positive end-expiratory pressure, permissive hypercapnia, and reduction of pulmonary edema.[12,13] Inhalation of NO was used in most of the patients. Cardiac ultrasound was performed in all cases. In 7 patients, VA-ECMO was used, 2 cases had VV-ECMO, and 1 patient needed combined VA- and VV-ECMO. VA-ECMO was necessary in cases of right ventricular overload with imminent right heart failure, which was determined by a ratio of mean pulmonary arterial pressure/mean systemic arterial pressure of more than 0.4. The setup of VA-ECMO involved cut-down cannulation of the femoral vein and artery. The arterial cannula (17F) was inserted in the common femoral artery by the Seldinger technique and positioned in the distal aorta. Venous drainage was accomplished via a 22F cannula, which was inserted in the same way into the femoral vein, and positioned in the inferior vena cava close to the right atrium. The leg was perfused through an additional 8F cannula in the femoral artery. In VV-ECMO, cannulae were inserted percutaneously by the use of the Seldinger technique. The venous inflow cannula was installed through the femoral vein and positioned in the inferior vena cava, and the oxygenated blood was reinfused through the right internal jugular vein to the superior vena cava. ECMO was started with maximal flow (4-6 L/min). Weaning was performed according to standard protocols.[12,13]

RESULTS

From September 2004 to December 2005, 10 patients (7 men and 3 women) with acute respiratory or circulatory failure were placed on ECMO in this hospital. They were all white and their

Table 1. Respiratory and Laboratory Parameters Before ECMO Initiation

	PaO_2	$PaCO_2$	SO_2	pH	F_IO_2	I:E	Form	Crea	Bili	Ery	Hb	Leuco	Thrombo	CRP	Age	Sex	Diagnosis	Cannulation	Outcome
Pt 1	33.6	57.5	67.6	7.23	1.00	1:1	BIPAP	0.72	3.29	3.50	10.6	23.8	247	198	56	M	MOF	VA	surv
Pt 2	55.2	59.5	88.2	7.19	1.00	1:1	BIPAP	4.1	16.3	3.49	10.2	8	39	225.6	48	M	Pneumonia	VA	surv
Pt 3	56.1	63.8	58.6	7.37	1.00	1:1	BIPAP	0.93	1.8	4.43	12.1	8.9	50.4	424	43	F	SPE	VA	surv
Pt 4	32	58.6	66.7	7.05	1.00	1:1	BIPAP	2.47	0.71	2.72	7.7	6.1	131	545.2	46	F	Aspiration	VA	dec
Pt 5	60	49.1	89.2	7.35	1.00	1:1	BIPAP	1.10	3.43	3.12	9.6	8.2	41	181.9	55	M	Pneumonia	VA	dec
Pt 6	24.5	68.2	31	7.02	1.00	1:1	BIPAP	1.55	1.19	5.09	15.3	1.4	278	2	38	M	Near drowning	VV	surv
Pt 7	75.6	40.4	90.5	7.22	1.00	1:1	BIPAP	3.42	0.69	2.95	8.7	11.5	264	18.3	46	M	Shock lung	VA	surv
Pt 8	55.4	44.9	89.5	7.19	1.00	1:1	BIPAP	1.20	1.26	2.76	8.6	16.2	119	9.7	40	F	Shock lung	VV	surv
Pt 9	93	36.8	99.8	7.46	0.70	1:1	BIPAP	1.48	4.15	3.47	9.5	11.0	63	53.9	41	M	RHF	VA	surv
Pt 10	60.5	106	81.9	7.02	1.00	1:1	BIPAP	3.20	4.25	3.05	8.5	10.5	180	115.6	49	M	MOF	VA/VV	dec

Abbreviations: F, female; M, male; SO_2, arterial oxygen saturation; F_IO_2, fraction of inspired oxygen; I:E, inspiratory to expiratory; BIPAP, biphasic assisted pressure; Crea, creatinine; Bili, bilirubin; Ery, erythrocytes; Hb, hemoglobin; Leuco, leucocytes; Thrombo, thrombocytes; CRP, C-reactive protein; MOF, multiorgan failure; SPE, septic pulmonary embolism; RHF, right-heart failure; Surv, survived; Dec, deceased.

median age was 46 years (range, 41-56). In 3 additional patients, ECMO was considered but not used because of their poor prognosis with or without ECMO.

The first patient to receive VA-ECMO had peritonitis because of biliary leakage after liver transplantation and developed severe ARDS within hours. Patient 2 had ARDS because of pulmonary leptospirosis; VA-ECMO was established in this patient, when the cause of ARDS was unknown. Further indications for VA-ECMO (patients 3-5, 7, and 9) were septic pulmonary embolism, atypical pneumonia, aspiration, pericardial tamponade with shock lung, shock lung after cardiopulmonary resuscitation, and right-heart failure because of acute deterioration in chronic thromboembolic pulmonary hypertension. In 2 cases (patients 6 and 8), VV-ECMO could be established because right ventricular overload was ruled out by hemodynamic investigation before ECMO therapy. Patient 6 had suffered near drowning, and patient 8 had been resuscitated after postpartum bleeding. In 1 patient (patient 10), who developed ARDS because of acute necrotizing pancreatitis, VA-ECMO was established and maintained for 12 hours. To improve oxygenation of the lungs and the upper parts of the body, a venous inflow cannula was installed additionally through the right internal jugular vein (combined VA-VV configuration). Respiratory and laboratory parameters before ECMO initiation are shown in Table 1.

In 2 cases (patients 2 and 4), surgical reintervention was necessary because of bleeding and a switch of the cannulae from the left femoral to the right femoral vein had to be performed because of femoral venous thrombosis. Overall mortality was 30%. Three patients (patients 4, 5, and 10) died from their primary diseases. Seven of the 10 patients (70%) were weaned from ECMO successfully and survived until discharge. In the surviving patients, the median maintenance of ECMO therapy was 65 hours (range, 36-168; mean, 83 hours; standard deviation, 51.7). In nonsurvivors, the median maintenance of ECMO therapy was 48 hours (range, 36-240; mean, 108 hours; standard deviation, 114.4). Pre-ECMO pressure ratios (mean pulmonary arterial pressure/mean systemic arterial pressure) of the patients as decision criteria for VV- versus VA-ECMO are given in Table 2.

The median Murray score was 3.3 (95% lower confidence level [LCL] 2.7 and 95% upper confidence level [UCL] 4) for survivors and 4 (95% LCL 3.7 and 95% UCL 4) for nonsurvivors. The median pre-ECMO risk for fatal outcome according to Hemmila et al[6] was 0.43 (95% LCL 18.6 and 95% UCL 86.3) for survivors and 0.92 (95% LCL 89.1 and 95% UCL 93.2) for nonsurvivors ($p < 0.02$) (Table 3).

DISCUSSION

Patients suffering from ARDS have been treated with ECMO since the 1970s. The number of patients treated with ECMO for

Table 2. Ratio: Pre-ECMO mPAP/mAP

Pt	Age	Sex	Diagnosis	Cannulation	APs	APd	mAP	PAPs	PAPd	mPAP	mPAP/mAP	Outcome
1	56	M	MOF	VA	101	48	65.67	38	22	27.33	0.42	Surv
2	48	M	Pneumonia	VA	106	56	72.67	60	38	45.33	0.62	Surv
3	43	F	SPE	VA	103	60	74.33	53	33	39.67	0.53	Surv
4	46	F	Aspiration	VA	96	46	62.67	NM	NM	NM	NM	Dec
5	55	M	Pneumonia	VA	95	56	69	NM	NM	NM	NM	Dec
6	38	M	Near drowning	VV	103	54	70.33	33	11	18.33	0.26	Surv
7	46	M	Shock lung	VA	65	30	41.67	40	25	30	0.72	Surv
8	40	F	Shock lung	VV	93	58	69.67	31	22	25	0.36	Surv
9	41	M	RHF	VA	92	67	75.33	67	38	47.67	0.63	Surv
10	49	M	MOF	VA/VV	108	55	72.67	53	25	34.33	0.47	Dec

Abbreviations: F, female; M, male; mAP, mean systemic arterial pressure (mmHg); APs, systolic systemic arterial pressure (mmHg); APd, diastolic systemic arterial pressure (mmHg); mPAP, mean pulmonary arterial pressure (mmHg); PAPs, systolic pulmonary arterial pressure (mmHg); PAPd, diastolic pulmonary arterial pressure (mmHg); MOF, multiorgan failure; SPE, septic pulmonary embolism; RHF, right-heart failure; Surv, survived; Dec, deceased; NM, not measured.

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