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Influence of different blood flows through a pumpless lung assist system on transpulmonary thermodilution-derived variables

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Dear Sir: Extended hemodynamic monitoring by the transpulmonary thermodilution technique, which has been shown to be sufficiently accurate when compared to the double-indicator technique [1], has the potential for reduced length of mechanical ventilation and stay in the ICU [2]. However, reliability of this technique has been questioned, i.e., during extracorporeal circulation. Previously, it was shown in patients with preserved cardiac output (CO) that running renal replacement therapy has no clinically relevant impact [3]. Here, data are provided on the influence of a pumpless extracorporeal lung assist system on transpulmonary thermodilution-derived variables.

A 70-year-old woman (162 cm, 60 kg) underwent uneventful elective upper lung sleeve resection for cancer. Unfortunately, she developed acute respiratory distress syndrome (ARDS) 5 days after surgery. She was re-admitted to the ICU and underwent intubation of the trachea for mechanical ventilation. For extended hemodynamic monitoring, a 5F-thermistor catheter (PV20L15, Pulsion Medical Systems, Munich, Germany) was placed into the left A. femoralis, which was connected to a PiCCOplus monitor (Pulsion Medical Systems AG, Munich, Germany). Furthermore, a right femoral 12F-dialysis double-lumen catheter (BCDL2000, Bionic Medizintechnik, Friedrichsdorf, Germany) was placed for continuous veno-venous hemofiltration (Edwards bm11 and bm14, Unterschleißheim, Germany). Unfortunately, she developed severe respiratory acidosis ($PaCO_2$ 101 mmHg, pH 7.12) and therefore was treated by a pumpless extracorporeal lung assist system (iLA Membrane Ventilator, Novalung, Hechingen, Germany). For this, a 13-F catheter was placed into the right A. femoralis and a 15-F catheter into the left V. femoralis. Flow in the extracorporeal circuit Q(ELA) was assessed by novalung flow c (Novalung, Hechingen, Germany). Hemodynamic variables based on thermodilution were obtained in triplicate by central venous (V. cava superior) injections of 15 ml 0.9% NaCl < 8°C. For CO_2 elimination, O_2 flow via the membrane was 12 l/min throughout. At all time points (Table 1), ventilator settings (Evita 2 dura, Draeger, Lübeck, Germany) remained unchanged: BiPAP, FiO_2 0.8, PiP 30 mbar, PEEP 12 mbar, respiratory rate 20/min, tidal volume ca. 280 ml, minute volume 3.3 l/min and compliance 10 ml/mbar.

So far, studies on the effects of extracorporeal systems on the accuracy of cardiac output measurement are limited. In general, the higher the flow of the extracorporeal circuit, the higher the overestimation of cardiac output by the thermodilution technique [4]. From theory, any extracorporeal circuit with partially removing the indicator from the system may result in a more or less

Table 1 Hemodynamic variables (body surface area 1.64 m^2). CO, GEDVI and EVLWI were each measured in triplicate (each 15 ml 0.9% NaCl) at each time point, and mean values are presented

No.	Time	HR (1/min)	RR_{sys} (mmHg)	RR_{dia} (mmHg)	MAP (mmHg)	SpO_2 (%)	Q(ELA) (l/min)	Q(CVVH) (ml/min)	CO (l/min)	SVI (ml/m^2)	GEDVI (ml/m^2)	EVLWI (ml/kg)	SVV (%)	PPV (mmHg)	NEPI (μg/kg min)
1	9:40	87	120	60	78	93	1.02	160	4.03	28	517	9.8	23	17	0.1
2	10:00	84	127	62	82	93	1.10	160	4.92	36	626	9.1	18	10	0.1
3	10:15	88	152	72	96	93	1.29	160	4.81	33	588	9.6	14	8	0.15
4	10:30	87	118	58	74	93	1.03	160	4.38	30	577	9.4	16	11	0.1
5	11:30	99	142	76	92	97	1.22	160	3.65	23	470	10.3	22	19	0.1
6	11:45	96	169	79	105	97	1.39	–	4.13	26	526	9.8	13	9	0.1
7	12:00	83	123	65	84	95	1.00	–	4.12	30	585	9.8	19	12	0.05

At all time points, dobutamine was administered in a dosage of 1.2 μg/(kg min)

No. 1: Baseline, no. 2: after fluid challenge (250 crystalloid infusion), no. 3: increase in norepinephrine dosage to increase Q(ELA), no. 4 reduction in norepinephrine dosage to baseline level, no. 5: prior to re-infusion (ca. 250 ml) of blood from the CVVH circuit, no. 6: after re-transfusion and end of CVVH treatment, no. 7: reduction in norepinephrine dosage

HR heart rate, RR_{sys} systolic blood pressure, RR_{dia} diastolic blood pressure, *MAP* mean arterial pressure, SpO_2 oxygen saturation (pulse oximetry, finger clip), *Q(ELA)* blood flow through the extracorporeal lung assist system, *Q(CVVH)* flow through the continuous veno-venous hemofiltration system, *CO* cardiac output, *GEDVI* global end-diastolic volume index, *EVLWI* extravascular lung water index, *SVV* stroke volume variation, *PPV* pulse pressure variation, *DOB* dobutamine, *NEPI* norepinephrine, *ELA* extracorporeal lung assist

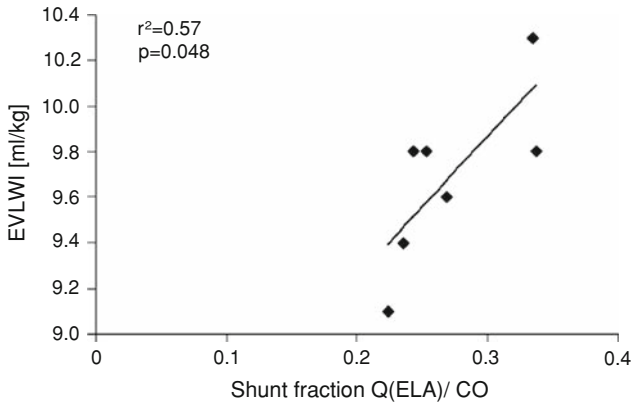

Fig. 1 *EVLWI* extravascular lung water index, *Q(ELA)* blood flow through the pumpless lung assist system, *CO* cardiac output

pronounced error in the determination of cardiac output [5].

In this case, fluid loading increased global end-diastolic volume index (GEDVI) and CO (difference 0.89 l/min, 18%) according to Frank-Starling (decrease in dynamic preload variables), and Q(ELA) increased for 0.08 l/min (7.3%). Noteworthily, extravascular lung water index (EVLWI) slightly decreased from 9.8 to 9.1 ml/kg. Increasing Q(ELA) by perfusion pressure (norepinephrine, no. 3) was associated with nearly unchanged EVLWI. As reported earlier [3], CVVH (here with a blood flow of 160 ml/min) (see nos. 5 and 6) had no influence on thermodilution-derived variables. In summary, we found variables changes in CO (up to +25%) and relative stability (less than 10% changes) of EVLWI. However, due to lack of reference techniques, we do not know the true changes in both variables.

In general, two aspects need to be considered: (1) loss of indicator will be proportional to the shunting fraction (quotient between arterial blood through the extracorporeal membrane and total blood flow). In this case, the relationship between the EVLWI and shunt fraction was significant ($r^2 = 0.57$, $p = 0.048$, which is borderline probably due to the small number of observations) (Fig. 1). Consequently, EVLWI varies with the amount of indicator loss, being greater with greater loss of indicator. However, (2) loss of indicator may also induce errors in CO measurements, and thus maybe also in shunt computation. Unfortunately, it is impossible to differentiate between these two possibilities in the absence of a reference method.

In conclusion, though we did not obtain data without the extracorporeal circuit, and we have no volumetric data (i.e., from echocardiography) to assess GEDVI, measurement of EVLWI by transpulmonary thermodilution seems not to be markedly affected by an extracorporeal bypass. However, we cannot definitely exclude that validity of transpulmonary thermodilution-derived variables is not affected by an extracorporeal circuit; thus, our findings can primarily be regarded as hypothesis generating.

Conflict of interest statement Dr. Samir Sakka is a member of the Medical Advisory Board of Pulsion Medical Systems AG and has received honoraria from this company and MSD Sharp & Dohme for giving lectures.

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