Reprint of: Continuous renal replacement therapy and mild hypothermia for acute left heart failure after cardiovascular surgery*

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See related commentary on page 606.

Management of severe heart failure with high doses of inotropes and vasopressors and increased ventricular volume will result in a high work load for the failing heart, with progressive decompensation. Recovery of heart function as a result of a period of rest for a failing heart has been well documented. However, few hospitals in China currently have the resources to provide extracorporeal membrane oxygenation or left ventricular assist device services. Management has continued to be a major challenge for cardiovascular surgical teams. We report a new strategy of combined continuous renal replacement therapy (CRRT) and mild hypothermia (MHT) to provide a period of rest for the severely failing heart to achieve recovery of cardiac function adequate for survival.

CASE REPORT

A 31-year-old man with Marfan syndrome underwent an emergency Bentall procedure for acute aortic dissection with aortic insufficiency. The preoperative left ventricular ejection fraction was 32%, and he was in New York Heart Association class IV. The cardiopulmonary bypass time was 75 minutes, and the crossclamp time was 45 minutes. Postoperative acute left heart failure was diagnosed from the clinical manifestations, hemodynamic data, and ultrasound findings. It was initially managed with high doses of inotropes and vasopressors (eg, dopamine,

epinephrine, norepinephrine) to maintain a mean artery pressure >70 mm Hg. The cardiac index (CI) was <2.2 L/min/m². The pulmonary artery wedge pressure (PAWP) was >20 mm Hg, and the left ventricular ejection fraction was $<30\%$. The urine output was <0.5 mL/kg for 6 hours, and the arterial lactate was >3.0 mmol/L. A pulmonary artery catheter was used to continuously monitor the cardiac output and core temperature. At 21 hours after surgery, CRRT was started with a Prisma automatic continuous renal replacement system (Gambro Dasco SpA, Medolla, Italy). During CRRT, the extracorporeal circulation lines were submerged in ice water to maintain the core body temperature at 34°C. His core body temperature was 38.8°C before CRRT/MHT and decreased to 34.2°C after 3 hours of treatment. The fluid intake and output were adjusted such that the fluid output was greater than his intake, and the PAWP was 10 to 12 mm Hg. The PAWP decreased from 23 to 13 mm Hg after 10 hours of treatment and was maintained at 10 to 12 mm Hg during the entire period of CRRT/MHT. The dosages of inotropes and vasopressors were gradually reduced to maintain the mean artery pressure at 60 to 70 mm Hg and CI at >1.0 L/min/m². An intravenous heparin infusion was used to maintain the activated whole blood clotting time at 120 to 140 seconds. Replacement therapy included maintaining the plasma albumin at >35 g/L and platelet count at $>5.5 \times 10^9$ /L. During CRRT/MHT, the doses of inotropes and vasopressors were substantially decreased (Figure 1). By the fifth day of CRRT/MHT, his cardiac function had gradually recovered. When the CI had increased to 1.8 to 2.2 L/min/m², with the PAWP stable at 10 to 12 mm Hg and the echocardiogram showed improved contractility of the myocardium with a left ventricular ejection fraction $>45\%$, the core body temperature was gradually increased to 37.3°C. Also, the dose of inotropes and the volume load were adjusted to maintain the mean artery pressure at 80 to 85 mm Hg. CRRT was gradually discontinued. The total CRRT period was 136 hours. With the institution of CRRT/MHT, the CI had decreased from 2.0 to 1.7 L/min/m². After CRRT/MHT was discontinued, the CI had increased to 3.4 L/min/m². During the CRRT/MHT period, he had had nearly no urine output, and serum creatinine was controlled at 98 to 130 mmol/L using CRRT. The urine output had recovered to normal by 48 hours after the CRRT had been discontinued, and his renal function had recovered to normal without additional

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FIGURE 1. Dosages of dopamine, epinephrine, and norepinephrine before continuous renal replacement therapy (column a), during CRRT (column b), and after CRRT discontinuation (column c). Black triangle indicates the amount of norepinephrine was 0.

renal replacement therapy. The patient survived in the intensive care unit and hospital.

DISCUSSION

The primary goal of the CRRT/MHT strategy was to reduce the work of the heart to facilitate recovery of myocardial function. Catecholamine use was substantially decreased and could well have importantly contributed to the reduction in cardiac oxygen consumption and survival of the patient. Myocardial recovery and the reduction of catecholamine drugs could have been facilitated by the positive inotropic effect of mild hypothermia,¹ the increased systematic vascular resistance contributed by the mild hypothermia,² and the correction of acidosis by CRRT. As the temperature decreases by 1°C, the overall metabolic rate will decrease by about 8%. When the temperature has decreased to 32°C, the overall metabolic rate will decrease

by about 50% to 60%, and, accordingly, oxygen consumption and carbon dioxide production will be reduced.³ With the decreased metabolic demand, mild hypothermia will result in an important decrease in the work of the heart. A new metabolic balance will be reached under mild hypothermia, and organ perfusion can better supply the metabolic needs in the presence of acute heart failure and gain time for recovery of cardiac function adequate for survival. CRRT reduces the cardiac preload promptly by ultrafiltration.⁴ When this has been accompanied by a reduction in the use of inotropes and vasopressors, the work of the heart and overall oxygen consumption will decline, achieving “unloading” of the heart. CRRT controls the body temperature rapidly and accurately and has also been effective in avoiding the chills and pressure sores seen with surface cooling. In our clinical practice, an additional 11 patients have experienced acute left heart failure after cardiac surgery

TABLE 1. Data from another 11 patients with acute left heart failure after cardiac surgery who underwent CRRT/MHT strategy

Pt. no.	Age (y)	Gender	Primary illness	Procedure	Preoperative EF (%) / NYHA class	Interval to initiation of CRRT/MHT postoperatively (h)	Total CRRT/MHT duration (h)	Survived in ICU*	Survived in hospital†
1	39	F	AD + AI + MR	Bentall + TS + MVR	47/III	8	164	Yes	Yes
2	27	M	AD + AI + MR	Bentall + MVR	71/II	15	155	Yes	Yes
3	37	F	AD	ATS	67/II	22	105	Yes	No
4	65	F	CHD	CABG	65/II	17	170	Yes	Yes
5	54	F	MR	MVR	59/III	25	135	Yes	Yes
6	41	F	AD	ATS	70/II	32	116	Yes	Yes
7	40	F	AD	ATS	54/III	14	111	Yes	Yes
8	57	M	MS + MR	MVR + TVP	41/IV	16	183	Yes	Yes
9	17	F	TOF	TOF correction	51/II	20	179	No	—
10	25	F	MS	MVR	52/III	10	163	Yes	Yes
11	55	M	MS + MR + AS	MVR + TVP	63/III	22	143	No	—

No persistent renal failure occurred that required dialysis. *Pt. no.*, Patient number; *EF*, ejection fraction; *NYHA*, New York Heart Association; *CRRT*, continuous renal replacement therapy; *MHT*, mild hypothermia; *ICU*, intensive care unit; *F*, female; *AD*, aortic dissection; *AI*, aortic insufficiency; *MR*, mitral regurgitation; *TS*, total arch replacement combined with stented elephant trunk implantation; *MVR*, mitral valve replacement; *M*, male; *ATS*, ascending aorta and total arch replacement combined with stented elephant trunk implantation; *CHD*, coronary heart disease; *CABG*, coronary artery bypass grafting; *MS*, mitral stenosis; *TVP*, tricuspid valveplasty; *TOF*, tetralogy of Fallot; *AS*, aortic stenosis. *Two patients died in the ICU of refractory heart failure. †One patient died of rupture of a residual aortic dissection 20 days after cardiac and renal function had recovered to normal.

and were treated with the CRRT/MHT strategy with good outcomes (Table 1). Similar reports of hypothermia combined with intra-aortic balloon pump support after heart surgery have also been published, with good outcomes.^{5,6} Randomized clinical studies are needed to evaluate the efficiency and safety of the CRRT/MHT strategy in acute left heart failure after cardiovascular surgery.

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EDITORIAL COMMENTARY

Innovative strategy for severe left ventricular failure without use of a left ventricular assist device

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See related article on pages 604-6.

The report from Du and colleagues¹ at the Fu Wai Hospital in Beijing, China, describes an innovative approach to manage acute severe left ventricular failure without the use of a left ventricular assist device. Hypothermia is now recognized as a valuable technique to allow cerebral recovery after a period of cardiac arrest. With the approach described in this report, the concept is extended to allow myocardial recovery in the postcardiotomy patient with severe acute cardiac failure.

With this strategy, moderate hypothermia permits the reduction of cardiac preload, afterload, and inotrope and vasopressor support, thereby reducing cardiac workload and facilitating myocardial recovery. The management with

hypothermia includes renal replacement therapy and full ventilator support to reduce overall metabolic requirements. The goal is to facilitate cardiac recovery without the development of multi-organ system failure.

Although the experience reported is limited to 12 patients, and it is not a prospective, randomized trial, the favorable survival results in these patients with severe acute heart failure are encouraging. In this era of limited hospital and financial resources, this innovative approach may well see application in a variety of situations, especially in hospitals without access to advanced cardiac support technology.

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