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IMAGES IN INTERVENTION

First-in-Man Fully Percutaneous Complete Bypass of Heart and Lung

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A 24-year-old man was admitted to a regional hospital after an attempted suicide by taking 9 g of the antidepressant venlafaxine. After initial seizures, overnight progressive cardiogenic shock developed (1,2) and resulted in cardiac arrest from electromechanical dissociation (EMD) 12 h after ingestion.

Femoral venoarterial extracorporeal membrane oxygenation (VA-ECMO) was inserted under continued cardiopulmonary resuscitation. On arrival at our center the patient had persistent cardiac arrest (EMD) on VA-ECMO support (flow, 5.5 l/min). Coronary artery disease was absent on angiography. The left ventricle (LV) was severely dilated (left ventricular end-diastolic pressure, 36 mm Hg) (Online Video 1) with most segments being akinetic. Massive pulmonary congestion caused by functional cardiac arrest and a toxic effect of venlafaxine (3) was present, necessitating repetitive endotracheal suctioning. For re-establishing transpulmonary blood flow (Online Video 2) and unloading the LV, an Impella CP microaxial pump (Abiomed, Danvers, Massachusetts) was inserted (**Figure 1**). However, Impella flow was very unstable because of persistent right ventricular arrest (Online Video 2), and pulmonary gas exchange was almost impossible. Therefore we expanded the system to a novel form of mechanical support.

A flexible 15-F ECMO cannula was introduced via the right internal jugular vein into the pulmonary artery (**Figure 1**) over a stiff Amplatz guidewire and connected to the ECMO outflow (veno-arterial-pulmonary-arterial cannulation [VAPa]) (4). Now the ECMO drained 5.5 l/min from the right atrium and returned 2 to 3 l/min to the pulmonary artery and 2.5 to 3.5 l/min toward the aorta, as adjusted by a clamp. The failing right ventricle was bypassed and preoxygenated blood supplied to the pulmonary artery was consecutively drained from the failing LV by the Impella. As a result, upper and lower body gas exchange was completely taken over by the ECMO, and systemic and pulmonary circulatory function was taken over by the triple cannulated ECMO and the Impella.

The LV consecutively regained pulsatility, catecholamine use decreased, and respiratory function recovered (**Figure 2**). After 6 days ECMO and Impella could be explanted. The patient was weaned from mechanical ventilation, fully mobilized, and ultimately transferred to rehabilitation with normalized cardiac function (Online Video 3), chest radiograph,

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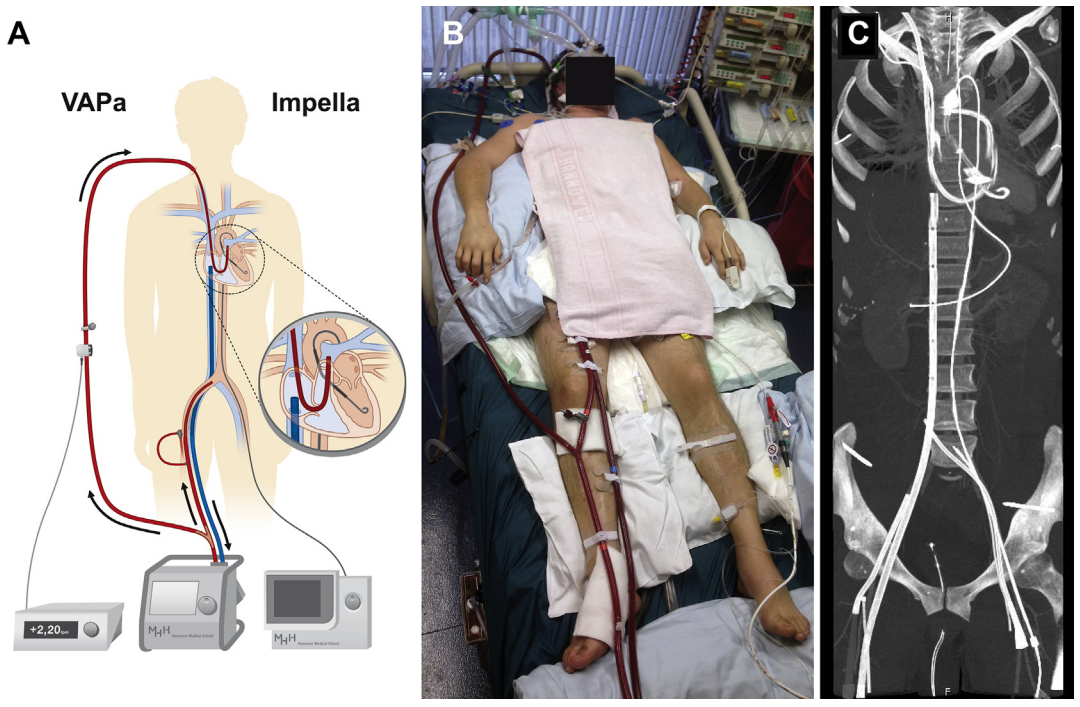
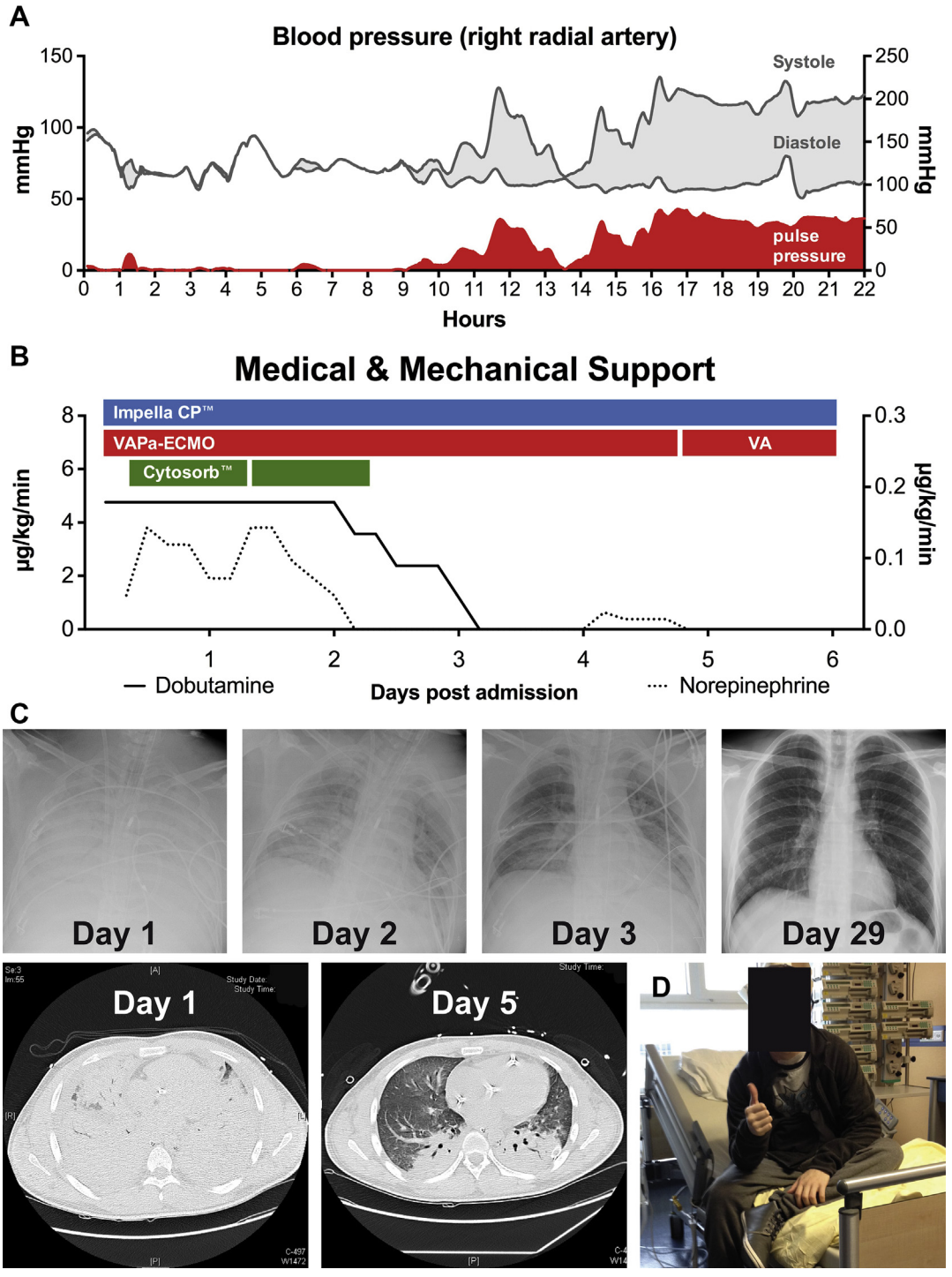
FIGURE 1 Total Percutaneous Mechanical Support of Cardiopulmonary Failure



On arrival the patient had functional cardiac arrest (Online Videos 1 and 2) on veno-arterial (VA) extracorporeal membrane oxygenation (ECMO) support and severe lung failure. An Impella microaxial pump was inserted into the left ventricle and VA-ECMO was escalated to veno-arterial-pulmonary-arterial (VAPa) ECMO by introducing a third cannula into pulmonary artery position. This approach overall resulted in a circulatory bypass of both ventricles and fully extracorporeal gas exchange. **(A)** Schematic. **(B)** Picture of the patient. **(C)** Computed tomography.

FIGURE 2 Clinical Course of the Patient



(A) Over time the left ventricle regained pulsatility as a surrogate of myocardial recovery (right radial artery measurement). Because of mechanical support and cytokine adsorption (Cytosorb, Monmouth Junction, New Jersey) catecholamines (left y-axis dobutamine, right y-axis norepinephrine) could be reduced very early **(B)**, and pulmonary edema progressively improved (**C, top row** radiograph, **bottom row** computed tomography). Both allowed downgrading of veno-arterial-pulmonary-arterial (VAPa) extracorporeal membrane oxygenation (ECMO) **(B, solid line)** to venoarterial (VA) ECMO **(B, dashed line)**. ECMO and Impella were explanted on Day 7. **(D)** The patient was sent to rehabilitation 28 days after admission with normalized systolic cardiac function (Online Video 3) on his own feet. ECMO = extracorporeal membrane oxygenation; VA = venoarterial; other abbreviation as in **Figure 1**.

and full clinical neurological recovery after 28 days of hospitalization (**Figure 2**).

In contrast to conventional single or combined mechanical support, the presented novel strategy truly bypasses biventricular heart and lung failure and maintains antegrade transpulmonary flow.

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KEY WORDS cardiopulmonary arrest, ECMO, Impella, microaxial pump, mechanical support, resuscitation, Takotsubo syndrome

APPENDIX For supplemental videos, please see the online version of this paper.