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Left Atrial Decompression during Veno-Arterial Extracorporeal Membrane Oxygenation Support by Advancing Venous Cannula to Left Atrium after Balloon Atrial Septectomy

Hung-Chang Jong, Ngoh Kexuan, Tze-Ying Lu and Ta-Jung Wang

Abbreviations

ASD	Atrial septal defect
BAS	Balloon atrial septectomy
FiO_2	Fraction of inspired oxygen
FO	Fossa ovalis
LA	Left atrial
LAD	Left anterior descending
LAVA	Left atrial veno-arterial
LCX	Left circumflex
LMCA	Left main coronary artery
LV	Left ventricular
LVEF	Left ventricular ejection fraction
SaO_2	Oxygen saturation
VA-ECMO	Veno-arterial extracorporeal membrane oxygenation
VC	Venous cannula

INTRODUCTION

Veno-arterial extracorporeal membrane oxygenation (VA-ECMO) is usually used in high-stage cardiogenic shock to restore systemic perfusion. However, VA-ECMO retrograde blood flow can increase aortic root and left ventricular (LV) pressure, increase LV end-diastolic and systolic volume, and decrease stroke volume.[1,2] When LV end-diastolic pressure exceeds 25 mmHg, it can deteriorate LV systolic function and decrease antegrade stroke volume. This phenomenon is known as LV overload. LV overload is a critical condition that can cause severe pulmonary edema, refractory ventricular arrhythmia, and significant LV stasis. When LV overload occurs, LV decompression should be performed immediately to prevent irreversible myocardial injury, multiorgan failure, and embolic stroke. LV and atrial decompression can be accomplished through percutaneous intervention, including catheter base venting, percutaneous transseptal venting, and transaortic ventricular assist device (IMPELLA).[1,3] Percutaneous transseptal venting has a good unloading effect and can reverse LV overload within a few minutes. To prevent LV overload after ECMO activation, some operators insert the ECMO venous cannula to the left atrial (LA) through the fossa ovalis (FO) after atrial septectomy. This technique is called left atrial veno-arterial (LAVA)-mode ECMO. LAVA-mode ECMO has an excellent LV unloading effect, which has been documented in several case reports.[4,5] However, the LAVA venous cannula should be inserted in the LA before ECMO activation; LAVA can only be a preventive therapy. Therefore, we conducted balloon atrial septectomy (BAS) to create a small atrial septal defect (ASD) in the FO and advance the original ECMO venous cannula (VC) to the LA while VA-ECMO was being conducted. This technique renders LAVA-mode ECMO not only as a preventive treatment but also as a rescue therapy.

CASE

A 53-year-old healthy man suffered from refractory chest pains and was diagnosed with acute myocardial infarction in our emergency department. The electrocardiogram revealed significant ST segment elevation in the precordial lead and lateral lead and ST segment depres-

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Division of Cardiovascular Medicine, Department of Internal Medicine, Shuang Ho Hospital, Taipei Medical University, New Taipei City, Taiwan.
Corresponding author: Dr. Ta-Jung Wang, Division of Cardiovascular Medicine, Department of Internal Medicine, Shuang Ho Hospital, No. 291, Zhongzheng Rd., Zhonghe District, New Taipei City 23561, Taiwan. Tel: 886-2-2249-0088; Fax: 886-2-2249-0088; E-mail: 16302 @s.tmu.edu.tw

sion in the inferior lead (Figure 1A). As anterior and lateral wall ST-elevation myocardial infarction was suspected, emergent coronary angiography was performed, which revealed left main coronary artery (LMCA) total occlusion with massive thrombus (Figure 1B). To restore the left coronary artery flow, we used a coronary aspiration microcatheter for thrombectomy and a balloon catheter to dilate the left anterior descending (LAD) artery and left circumflex (LCX) coronary artery. To maintain the left coronary artery blood flow, a coronary stent was positioned from the LMCA to the LAD to fully cover the lesion and was then deployed at 12 atm. After stent implantation, a few residual thromboses were noted in the LCX orifice without extension to the LM and LAD; tirofiban was prescribed for thrombolysis. The final result of the LAD and LCX arteries was acceptable, with TIMI III flow being achieved (Figure 1C). The intra-aortic balloon pump was implanted to improve coronary blood flow. However, refractory cardiogenic shock and respiratory failure occurred after 3 h. High-dose inotropic agents (15 μg/min/kg dopamine, 15 μg/min norepinephrine) were prescribed to maintain mean blood pressure. Echocardiography revealed LV anterior wall and lateral wall akinesia and severe LV systolic dysfunction [left ventricular ejection fraction (LVEF): 20-25%]. Arterial oxygen saturation (SaO_2) was only 80% under 100% of the fraction of inspired oxygen (FiO_2). To improve systemic perfusion, we sent the patient to the catheter laboratory for VA-ECMO implantation. The ECMO system was Terumo Capiox EBS. We chose a 15-cm, 16.5-Fr EPS arterial cannula and 50-cm, 21-Fr VC for cannulation. After ECMO activation, ECMO flow was gradually titrated to 3000 mL/min, and the patient's mean blood pressure increased to 100 mmHg. However, arterial oxygen saturation was only 88% under 100% FiO_2. Pulse pressure (Figure 2A) decreased to 7 mmHg after 5 min of observation. Echocardiography revealed LV dilatation with severe LV systolic dysfunction (LVEF: 15%-20%), incomplete opening of the aortic valve, and "smoke" sign in LV; thus, LV overload was indicated. To unload LV, we switched the ECMO system to the LAVA mode.

First, we performed transseptal puncture through the FO and delivered a 0.35-inch guidewire to the left superior pulmonary vein. To create a route to advance the VC to the LA, we performed BAS with a 12-mm peripheral balloon catheter (Figure 1D). The guidewire was kept in the LA to provide a roadmap. After BAS, pulse pressure (Figure 2B) increased to 20 mmHg, which re-

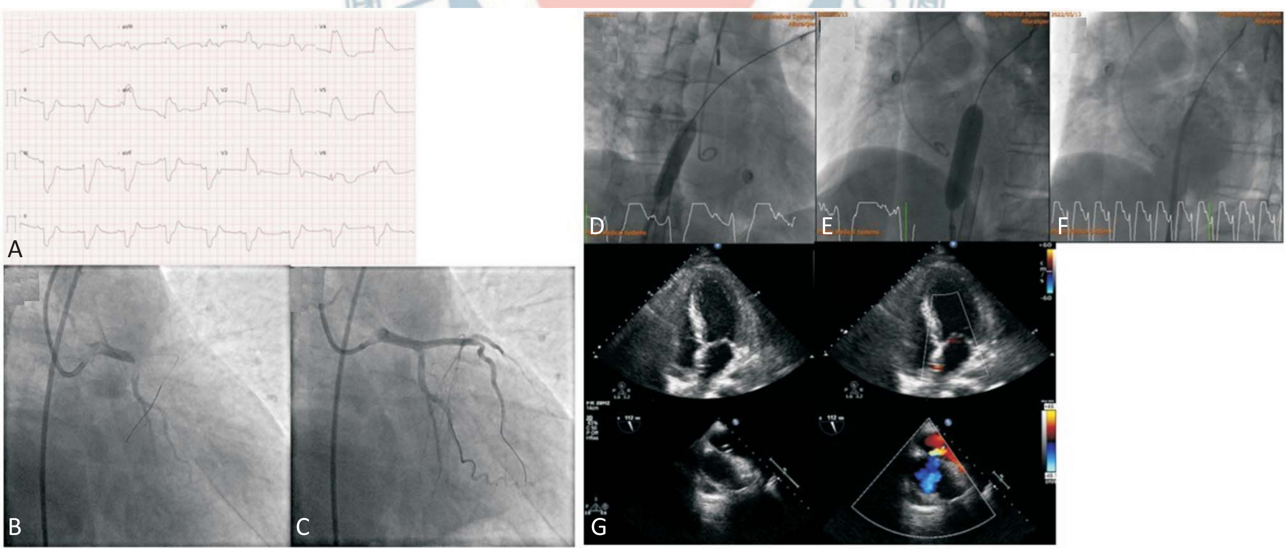

Figure 1. Electrocardiogram (A) before primary percutaneous transluminal coronary angioplasty suggests the anterior wall and lateral wall transmural myocardial infarction. Coronary angiography (B) shows the left main coronary artery total occlusion with massive thrombus. A coronary stent was deployed from the left main to left anterior ascending coronary artery. The angiography (C) indicates strong results with TIMI 3 flow after intervention. Procedure of LAVA-ECMO: (D) Balloon atrial septectomy was performed with a 12-mm peripheral balloon catheter. (E) Following the interspace of the balloon catheter, the venous cannula advanced to the left atrium through the atrial septal defect. (F) Left atrial angiography shows the tip of the venous cannula located in the left atrium. (G) Echocardiography documented the venous cannula tip located in the left atrium. ECMO, extracorporeal membrane oxygenation; LAVA, left atrial veno-arterial.

flected stroke volume elevation. Then, we used the balloon catheter to adjust the direction of the VC and gently pushed it to the LA (Figure 1E). LA angiography showed that the tip of the VC was correctly inserted into the LA (Figure 1F). Transthoracic and transesophageal echocardiography also indicated that the VC tip was located in the LA (Figure 1G), and that the aortic valve fully opened during the cardiac cycle. Compared with the pulse pressure contour after BAS (Figure 2B), the dicrotic notch elevation during LAVA-mode ECMO (Figure 2C) indicated further improvement of stroke volume.[6] The ECMO pump ran during the entire procedure. The result of LA unloading in this case was excellent, and pulmonary edema (Figure 2D-E) was reversed after 6 h. Moreover, the patient was successfully weaned from ECMO after 10 days.

DISCUSSION

In this decade, adequate LV unloading has been regarded as a key component of successfully managing cardiogenic shock.[7] However, conservative LV unloading therapy includes continual renal replacement therapy, a vasodilator, an inotropic agent, diuretics, and an intra-aortic balloon pump, all of which are sometimes insufficient to reverse LV dilatation.[8,9] LA/LV venting should be considered in patients with risk factors for LV overload or in patients with no response to conservative therapy. The risk factors for LV overload include severe LV failure, aortic insufficiency, high ECMO flow, and intravascular volume overload. Early LA/LV venting after ECMO implantation can be provided as preventive therapy. No guidelines exist that specify when LV venting should be performed. In our hospital, indications or timing of LV decompression include aortic valve closure, refractory pulmonary edema, and refractory ventricular arrhythmia. In this case, pulse pressure contours and echocardiographic findings after ECMO suggested poor LV function. Additionally, intravascular volume overload due to poor SaO_2 might have already occurred. Therefore, we switched the ECMO sys-

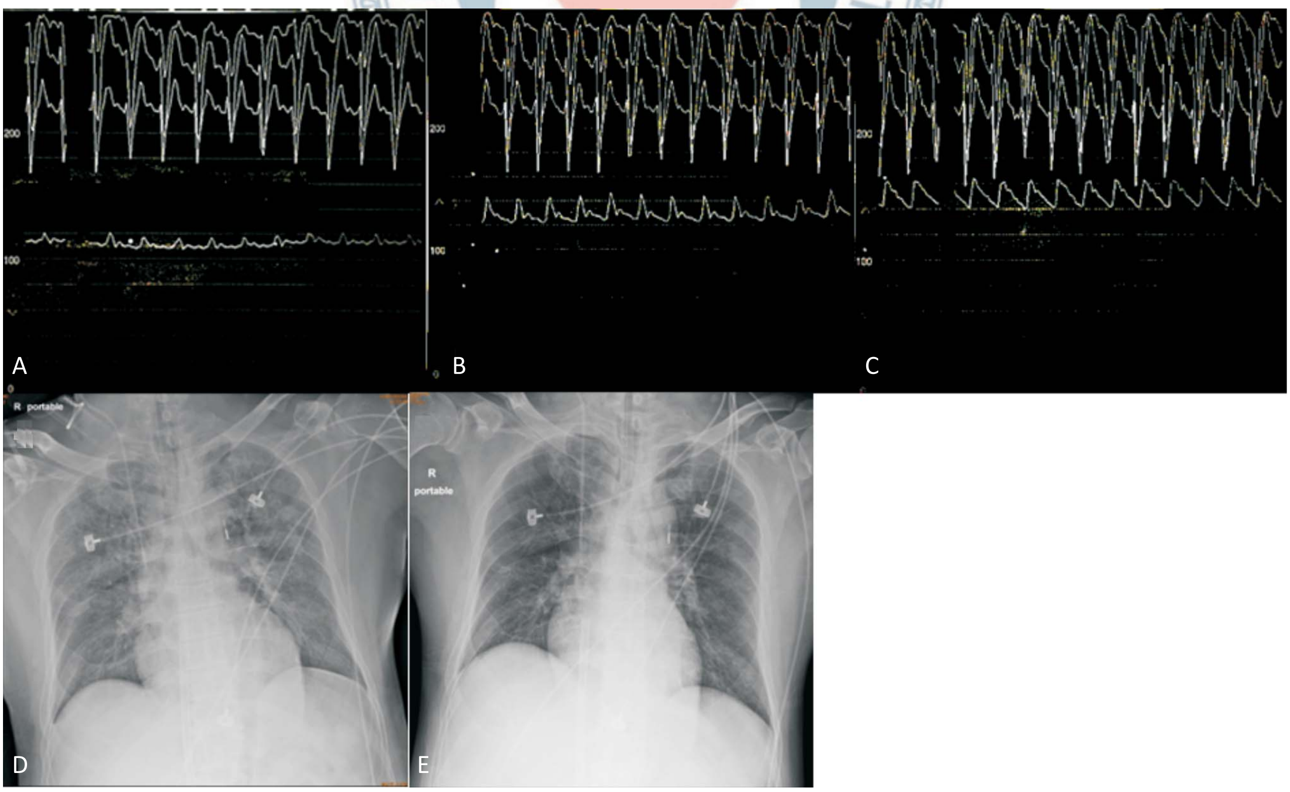

Figure 2. *Periprocedural central blood pressure was obtained from 6-Fr Pigtail catheter: (A) Pulse pressure is 7 mmHg after veno-arterial extracorporeal membrane oxygenation (VA-ECMO) activation. (B) After balloon atrial septectomy, pulse pressure elevates to 20 mmHg. (C) The dicrotic notch elevation is shown after venous cannula tip enters the left atrium. Chest plain film revealed pulmonary edema reversed after 6 h. (D) Chest plain film just after left atrial veno-arterial (LAVA)-ECMO implantation, (E) after 6 h.*

tem to the LAVA mode to prevent LV overload.

Compared with surgical venting, percutaneous venting has several advantages in the acute phase of post-myocardial infarction cardiogenic shock. For example, percutaneous venting can be performed in a catheter laboratory without sternotomy and general anesthesia and is suitable for patients after primary percutaneous transluminal coronary angioplasty. Compared with conventional VA-ECMO plus BAS, LAVA-ECMO has a better LV unload effect. However, VC deployment must be performed after atrial septectomy, which is difficult to accomplish in patients in a critical condition, such as those with refractory ventricular arrhythmia. Our technique allows surgeons to insert the VC to the LA after ECMO activation; thus, LAVA-ECMO is more suitable in patients in critical conditions. Additionally, this procedure is not difficult. The right atrium is small during the acute phase of myocardial infarction. Surgeons can insert the VC to the LA after BAS without adjusting its direction. When the VC is not directed toward the ASD, surgeons can insert a 10-15-mm balloon catheter across the ASD using a transseptal guidewire. Then, the transseptal sheath can be used to adjust the balloon catheter above the tip of the VC. Consequently, the VC can follow the interspace of the balloon to enter the LA.

In a patient in a critical condition, we do not use the Swan-Ganz catheter to monitor cardiac output and pulmonary capillary wedge pressure. Therefore, we could not provide complete hemodynamic data for this case. Only a 6-Fr Pigtail to monitor ascending aortic blood pressure and a pulse pressure contour to estimate the variation of the cardiac output were used. Dicrotic notch elevation suggests that LAVA-mode ECMO may provide a better unload effect than conventional ECMO plus BAS.

LEARNING POINTS

LAVA-ECMO is a cost-effective, convenient, and efficient procedure for hemodynamic support in patients with high-stage cardiogenic shock. Because of the unload effect, LAVA-mode ECMO is suitable for patients with risk factors for LV dilatation. Compared with conventional VA-ECMO, in the LAVA mode, more time is required to perform atrial septectomy before venous cannulation. This may be the reason that LAVA-ECMO has not been widely utilized. In this case report, we present a technique that allows VC insertion to the LA after ECMO activation, which expands the potential of LAVA-ECMO application in emergency situations.

DECLARATION OF CONFLICT OF INTERESTS

All the authors declare no conflict of interest.

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