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BRIEF COMMUNICATION

Massive pulmonary embolism leading to cardiac arrest: one pathology, two different ECMO modes to assist patients

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Abstract Massive acute pulmonary embolism (MAPE) represents a significant risk for morbidity and mortality. The potential for sudden and fatal deterioration highlights the need for a prompt diagnosis and appropriate intervention. Using two cases reports, we describe two different modes of successful ECMO implantation (VA-ECMO vs. VV-ECMO) for MAPE leading to cardiac arrest. A 27-year-old patient with a severe trauma presented with a MAPE leading to cardiac arrest. In this case, which had absolute contraindications of thrombolysis, a VA-ECMO was successfully implanted. Additionally, a 56-year-old patient presented with a MAPE leading to cardiac arrest. Although intravenous thrombolysis allowed for hemodynamic stabilization, the patient remained severely hypoxemic with RV dilation. A VV-ECMO was successfully implemented, leading to a rapid improvement in both oxygenation and RV function. ECMO can provide lifesaving hemodynamic and respiratory support in critically ill patients with a MAPE who are too unstable to tolerate other interventions or have failed other therapies. An important determinant of success in the use of ECMO for MAPE is the return of adequate RV function, which allows physicians to appropriately identify which type of ECMO to implant.

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1 Introduction

A pulmonary embolism (PE) is a common illness that can cause death [1]. Massive acute PE (MAPE) results in cardiac arrest in 41 % of cases and is associated with a high mortality rate [2]. The potential for sudden and fatal deterioration highlights the need for a prompt diagnosis and appropriate intervention. A MAPE is defined by sustained hypotension and is associated with a high risk for mortality. The hemodynamic response to a PE depends on the thrombus size, cardiopulmonary reserve, and neurohumoral effects. In patients with a MAPE, obstruction of blood flow increases the RV afterload, leading to RV dilation, interventricular septal deviation, RV failure, and septal deviation that impairs the left ventricular filling and end-diastolic volume, which may then cause reduced cardiac output, cardiogenic shock, and cardiac arrest. In these cases, patients require aggressive therapeutic measures, such as systemic thrombolysis, pharmaco-mechanical catheter-directed therapy, or surgical pulmonary embolectomy. For patients with cardiac arrest and a strongly suspected or proven PE, the use of fibrinolytics during cardiopulmonary resuscitation (CPR) may improve survival [3]. Clinical practice guidelines recommend fibrinolytic therapy for patients with MAPE and cardiac arrest, although few data are available to guide decisions about the agent, dose, rate, and frequency of administration [3, 4]. In several cases, there are absolute contraindications for this therapy. Catheter-based intervention is recommended for patients with circulatory collapse due to a MAPE and is equivalent to surgical embolectomy [5]. Extracorporeal membrane oxygenation (ECMO) is a treatment that uses a pump to circulate blood through an artificial lung back into the bloodstream of a

critically ill patient. This system provides heart–lung bypass support outside of the patient's body and thus supports a patient presenting heart and/or lung insufficiency.

Emergent veno arterial extra corporeal membrane oxygenation (VA-ECMO) provides an opportunity for improving the prognosis of an otherwise near-fatal condition and should be considered in the algorithm for managing a massive pulmonary embolism in an unstable patient [6]. Veno Venous ECMO (VV-ECMO) is rarely used in such unstable patients. Using two cases reports, we describe two modes of successful ECMO implantation (VA-ECMO vs. VV-ECMO) in case of a MAPE that resulted in cardiac arrest.

Written informed consent for data analysis and publication of these case reports series was not required by our local IRB as this observational study did not modify existing diagnostic or therapeutic strategies.

2 Case report no. 1

A 27-year-old male patient with active alcohol consumption and mild obesity (BMI, 27) was in a car accident. The patient was found outside of the vehicle with a Glasgow coma scale 7. The assessment of the lesions showed facial trauma (Lefort type 3) with bilateral temporo-basal hemorrhagic brain contusions, a non-displaced manubrium fracture and bilateral pulmonary contusions. The patient was transferred to intensive care and then intubated and sedated. At day 2, despite antithrombotic prophylaxis, the patient developed severe hypoxemia and then cardiac arrest. The first rhythm was a pulseless electrical activity. An external cardiac manual massage was started and 1 mg of epinephrine was administered; after 2–3 min, a sinus rhythm was restored with return of spontaneous circulation (ROSC). Transesophageal echocardiography (TEE) showed a massive dilatation of the right ventricle, which strongly suggested that the patient had a MAPE. In the present context of recent trauma with an absolute contraindication of systemic thrombolysis, persistent hemodynamic instability and severe hypoxemia, a peripheral femoro-femoral VA-ECMO with an anterograde reperfusion catheter for distal limb was surgically implanted followed by therapeutic anticoagulation with non-fractioned heparin. At day 5, ECMO was removed without any complications and the patient was treated with heparin. The patient woke up without significant neurological sequel and could be extubated at day 20.

3 Case report no. 2

A 56-year-old man without a significant previous disease presented with cardiac arrest during a football game. He immediately underwent external cardiopulmonary resuscitation (CPR), which one of his ambulance teammates performed without no-flow. An automatic defibrillator delivered two external shocks, and ROSC occurred after 10 min of external cardiac massage. A percutaneous coronary intervention showed non-significant lesions. At day 2, the patient was awakened, extubated and there was no significant neurological deficit. At day 5, although a prophylactic anticoagulation was started at admission, the patient lost consciousness and presented with ventricular fibrillation, which resulted in cardiac arrest. The patient underwent immediate external cardiac massage and an external electrical shock, which resulted in ROSC. TEE, performed under cardiac massage, showed severe right ventricular (RV) dilation and systolic dysfunction. These echocardiographic findings, the severe hypoxemia, the high $EtCO_2$–$PaCO_2$ gradient and the hemodynamic instability were strongly indicative of the presence of a MAPE. The patient was treated with intravenous thrombolysis (10 mg alteplase bolus and 90 mg over 60 min). A Doppler ultrasound realized during the thrombolysis revealed an endoluminal echo in the common femoral vein evoking a deep venous thrombosis. Rapidly, the patient remained hemodynamically stable with small doses of norepinephrine (0.2 microgram/kg/min). Following the systemic thrombolysis, the patient's hemodynamic status improved allowing stopping the vasoactive drugs but RV systolic dysfunction and severe hypoxemia-hypercapnia persisted. Two hours after the end of the thrombolytic therapy RV function improved while oxygenation doesn't. Then, we decided to perform a percutaneous echo-guided femoro-jugular VV-ECMO, followed by therapeutic anticoagulation with non-fractioned heparin. No bleeding complications were observed after the implantation of the cannulas. Subsequently, the patient's RV systolic function improved [the velocity time integral (VTI) and tricuspid annular plane systolic excursion (TAPSE) measured by TEE increased from 14.3 to 19.6 cm and from 1.2 to 1.6 cm, respectively]. At day 4, ECMO was removed without any complications. Therapeutic anticoagulation was continued. The patient woke up without significant neurological sequel and could be weaned off the ventilator at day eight.

4 Discussion

These two case reports demonstrate that first, ECMO may be an important therapeutic strategy in the event of a massive PE and second, there may be two different therapeutic strategies to treat the same disease. In one strategy, thrombolysis was performed with a partial response, and because the patient was still highly hypoxemic, a VV-ECMO was necessary. In the other strategy, thrombolysis was formally contraindicated and VA-ECMO was needed to attend to the patient's heart and lungs.

A massive acute pulmonary embolism (MAPE) is defined as an embolus causing sufficient obstruction to the

pulmonary flow, resulting in hemodynamic instability, right ventricular failure, and hypoxemia. It frequently portends a fatal outcome and has a mortality rate as high as 65 % in those patients requiring cardiopulmonary resuscitation [7, 8].

The standard therapy for PE in most patients is therapeutic anticoagulation, which prevents thrombus propagation and recurrent thromboembolism. Other treatment modalities can be attempted in instances of massive and submassive PE. The American Heart Association has recommended that thrombolytic therapy can be reasonably administered for MAPE (class IIa) and may be considered for submassive PE with worsening respiratory failure or severe RV dysfunction (class IIb) [5]. Catheter-based or surgical embolectomy is reasonable for MAPE in patients with contraindications to or continued instability after fibrinolysis (class IIa) and may be considered for submassive PE with worsening respiratory failure or severe RV dysfunction (class IIb) [9]. However, this form of embolectomy is rarely successful for patients in cardiogenic shock [10] and no reports have demonstrated yet that it decreases mortality in large randomized controlled trials [11, 12].

The choice of therapy for a MAPE often depends on the expertise available at each center. In hemodynamically unstable patients, particularly patients requiring cardiopulmonary resuscitation, the diagnostic and therapeutic options may be limited. VA-ECMO is commonly used in patients with MAPE despite the absence of randomized controlled trials demonstrating its effectiveness [13]. VA-ECMO provides inherent advantages in the treatment of a MAPE in patients who are often too unstable to successfully undergo surgical embolectomy or in whom thrombolysis is contraindicated [14]. VA-ECMO allows for decompression of the acutely overloaded right atrium and ventricle, stabilizing the hemodynamic status of the patient with adequate organ oxygenation and therapeutic anticoagulation until clot dissolution [15].

More interesting, as shown in the second case report, is that VV-ECMO can be used with a thrombolytic therapy in case of partial improvement with hemodynamic restoration and a persisting severe hypoxemia. Indeed, restoration of blood circulation without recovery of gas exchange (hypoxemia, hypercapnia, and acidosis) leads to the maintenance of a high RV afterload in a convalescent RV. Indeed, because abnormalities of the pulmonary blood flow and injury to the microcirculation are characteristic features of pulmonary embolism, even after intravenous thrombolysis, the expected consequence would be an increase in the dead space and impairment in carbon dioxide excretion and, thus, an increase in the pulmonary artery resistance with right ventricular failure. These factors are well described in acute respiratory distress syndrome (ARDS).

Pulmonary artery obstruction and circulating neurohumoral substances decrease the pulmonary vascular bed and cause an increase in the RV afterload. This phenomenon is exacerbated by pulmonary hypoxic vasoconstriction, which

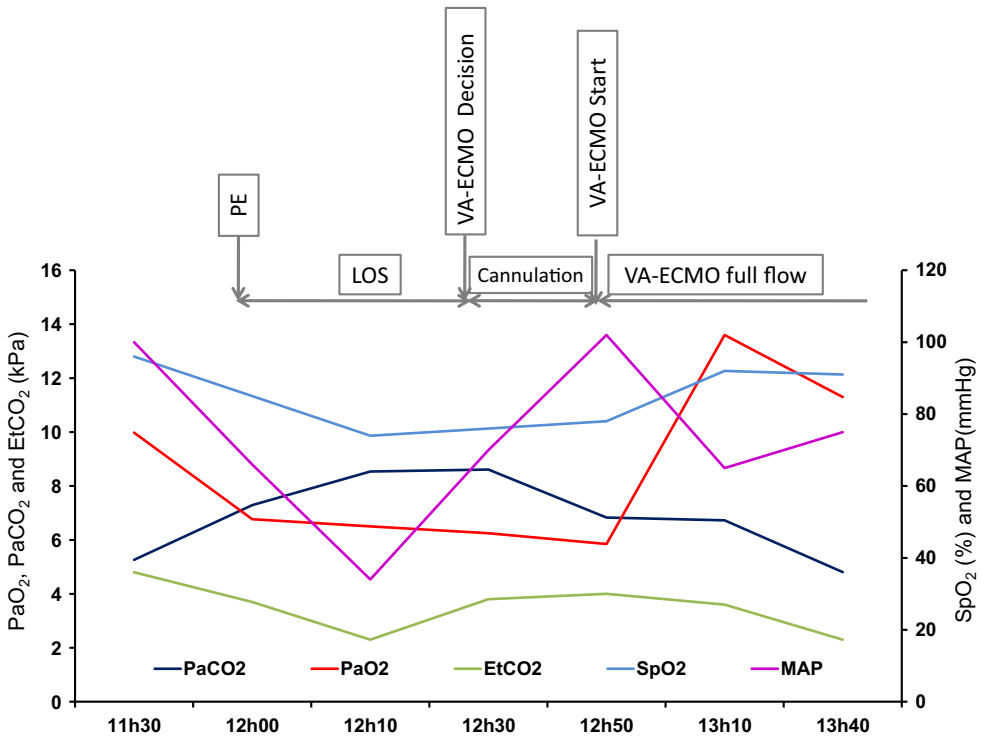

Fig. 1 Graph showing the $EtCO_2$ (kPa), $PaCO_2$ (kPa), PaO_2 (kPa), SpO_2 (%) and MAP (mmHg) variations for the massive pulmonary embolism and VA-ECMO implantation as well as the different sequences that were performed

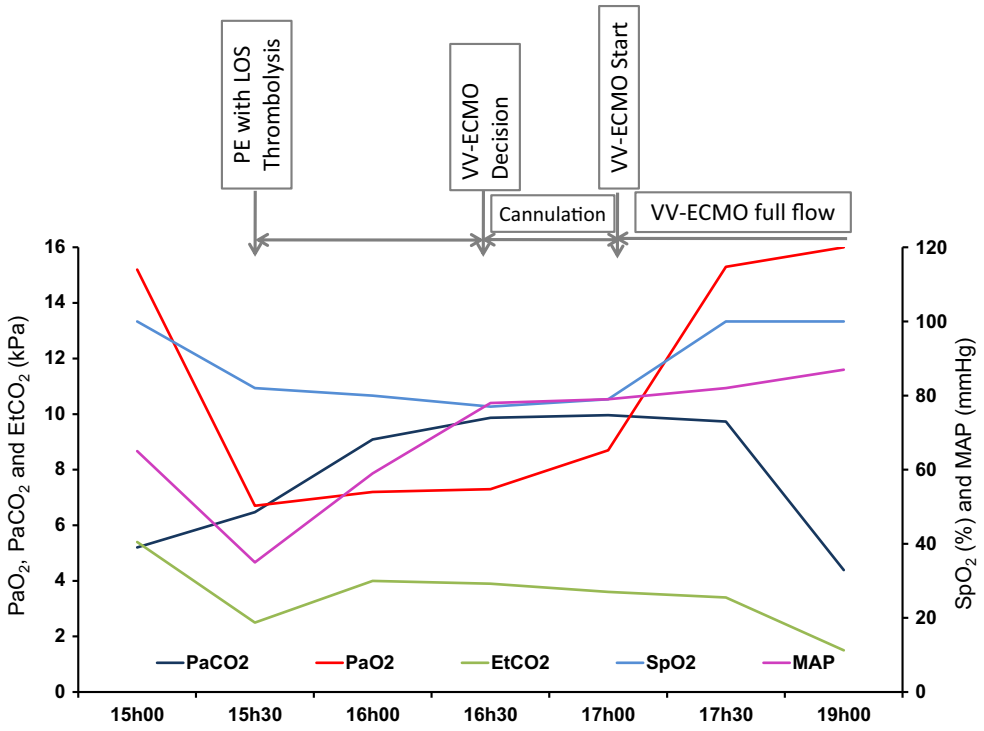

Fig. 2 Graph showing the $EtCO_2$ (kPa), $PaCO_2$ (kPa), PaO_2 (kPa), SpO_2 (%) and MAP (mmHg) variations for the massive pulmonary embolism, thrombolysis response and VV-ECMO implantation as well as the different sequences that were performed

increases the pulmonary artery vascular resistance. Moreover, an acute increase in the $PaCO_2$ has a major deleterious effect on the RV function in severe ARDS patients [16] as it induces a vasoconstriction of the pulmonary circulation [17]. Therefore, improved RV dysfunction and cardiac output in a patient who undergoes VV-ECMO following thrombolysis could be explained by the improvement in both the oxygenation and CO_2 clearance that then allowed for a decrease in the pulmonary artery vascular resistances.

Some case reports have demonstrated a beneficial effect of VA-ECMO support in hemodynamically unstable patients who experience a MAPE [6, 18]. Likewise, this set of case reports confirms the beneficial effect of ECMO in patients undergoing a MAPE, in both the VV (only with gas exchanger dysfunction) and VA configuration (when the hemodynamic status is also compromised). Despite these findings, the current guidelines for the management of MAPE do not yet consider ECMO as a first-line therapy for this catastrophic disease.

5 Conclusion

ECMO can provide lifesaving hemodynamic and respiratory support in critically ill patients with massive acute PE and absolute contraindications to thrombolysis who are too unstable to tolerate other interventions or have not responded well to other therapies. ECMO can be performed rapidly and at the bedside. An important determinant of success in ECMO for PE is the return of adequate RV function, which helps physicians choose an appropriate type of ECMO to implant (Figs. 1, 2).

Compliance with ethical standards

Conflict of interest The authors declare that no potential conflicts of interest exist with any companies/organizations whose products or services may be discussed in this article.

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