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CASE REPORT

Emergency Medical Services

Out-of-hospital extracorporeal membrane oxygenation cannulation for refractory ventricular fibrillation: A case report

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Abstract

Out-of-hospital cardiac arrest survival continues to be dismal with the only recent improvement being that of extracorporeal cardiopulmonary resuscitation (E-CPR) or cardiopulmonary resuscitation (CPR), augmented by extracorporeal membrane oxygenation (ECMO). Minimizing time until initiation of E-CPR is critical to improve neurologically intact survival. Bringing E-CPR to the patient rather than requiring transport to the emergency department may increase the number of patients eligible for E-CPR and the chances for a good outcome. We developed a out-of-hospital E-CPR (P-ECMO) program that includes the novel use of a hand-crank and emergency medical services (EMS) providers as first assistants. Here, we report the first P-ECMO procedure in North America for refractory ventricular fibrillation involving a 65-year-old male patient who was cannulated in the field within the recommended 60-minute low-flow window and transported to our institution where he underwent coronary stenting. Details of program design and the procedure used may allow other systems to consider implementation of a P-ECMO program.

KEYWORDS

cardiac arrest, extracorporeal membrane oxygenation, out-of-hospital

1 | INTRODUCTION

Almost 350,000 adults suffer an out-of-hospital cardiac arrest in the United States each year.[1] Many strategies have been used to improve outcomes, including early bystander cardiopulmonary resuscitation (CPR), wider societal access to defibrillators, and a stronger focus on high quality chest compressions.[2-4] Unfortunately, neurologically intact survival from out-of-hospital cardiac arrest remains dismal.[5-7] After 20 minutes of unsuccessful advanced cardiac life support, neurologically intact survival is <1%.[7] Over the last two decades, extracorporeal membrane oxygenation (ECMO) has become a viable option for refractory cardiac arrest patients.[8] ECMO used in this fashion is called extracorporeal cardiopulmonary resuscitation (E-CPR). E-CPR typically involves, while external chest compressions continue,

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ultrasound-guided placement of a large cannula in a femoral vein to drain a majority of the patient's blood volume, and a pump to force the blood through an oxygenator (that also removes CO_2 using concentration gradients) and then returns the blood via another large cannula placed in the femoral artery with enough pressure to perfuse the vital organs. Survival-to-discharge rates for E-CPR range from 29%[9] to 48%.[10] Although ECMO support for out-of-hospital cardiac arrest patients brought to the emergency department is becoming more common at major institutions, ECMO cannulation in the pre-hospital environment (P-ECMO) has not previously been reported in North America.

2 | CASE PRESENTATION

A 65-year-old male with past medical history of type 2 diabetes and tobacco use suffered a witnessed cardiac arrest with immediate bystander compression-only CPR. An engine company, paramedic rescue, and paramedic supervisor from Albuquerque Fire Rescue were dispatched along with a paramedic transport unit from Albuquerque Ambulance. Per a citywide protocol based on national guidelines, Albuquerque Fire Rescue dispatchers identified the patient as a possible ECMO candidate. Because the event occurred in an outlying area of the city, our P-ECMO team consisting of a University of New Mexico critical care cannulation physician and 2 Albuquerque Fire Rescue paramedics (Albuquerque Fire Rescue-PM) with locally provided cannulation assistant training, responded in a specialized ambulance, ECMO-1. A University of New Mexico Emergency Medical Services physician (EMS-MD) and a second cannulation physician arrived separately.

ECMO-1 has been outfitted specifically for P-ECMO with an expandable metal table, a Maquet Rotoflow hand-crank, and Quadrox oxygenator-mount. The vehicle is stocked with our uniquely designed University of New Mexico ECMO Medline pack and University of New Mexico Cannulation kit (Appendix 1). To facilitate cannulation, a small ultrasound is secured across from the bench seat. The ultrasound probe is hung from the ceiling of ECMO-1 via a bungee cord, allowing the probe to be pulled down into the sterile field only when needed.

ECMO-1 is housed at Albuquerque Fire Rescue Station 3, which is located on the main University of New Mexico campus, less than a mile from the hospital. When activated, ECMO-1 is driven to University of New Mexico Hospital to pick up the on-call cannulation physician who brings a pre-primed Rotoflow circuit.

On arrival of the first EMS unit to the scene, the patient was noted to be in ventricular fibrillation and shocked into a sinus rhythm, at which time the P-ECMO team was cancelled. However, the patient soon returned to ventricular fibrillation refractory to multiple attempts at defibrillation including vector change, 300 mg amiodarone, and a supraglottic airway. Compressions via a Lund University Cardiopulmonary Assist System device, ventilations via paraPAC ventilator, and standard advanced cardiac life support were continued while ECMO-1 was asked to reinitiate a response by the EMS-MD who arrived on scene.

FIGURE 1 University of New Mexico and Albuquerque Fire Rescue ECMO-1 with privacy tent

While en route to the scene inside ECMO-1, the cannulation physician attached the Rotoflow head to the hand-crank and the Quadrox to the oxygenator mount, and hung the circuit from the ceiling via a carabineer. A clamp was placed just after the oxygenator, which will be the final clamp removed. The Quadrox was attached to the oxygen regulator to provide 4 liters per minute of oxygen and sweep gas to coincide with a planned ECMO flow of 4 liters per minute to give a ventilation-to-perfusion ratio of one. The cannulation physician and Albuquerque Fire Rescue-PM then built the "Seven-Layer Bean Dip" of sterile cannulation supplies inside a 12-inch diameter bowl (Appendix 2) and donned sterile garb.

On arrival of ECMO-1, the patient was "reverse loaded" (ie, feet first) onto the ECMO-1 stretcher, was stripped from the waist down, had bilateral chlorhexidine femoral triangle preparation, and was loaded into the ambulance. Albuquerque Fire Rescue deployed an 8-foot tall privacy tent around the back of the ECMO-1 to limit onlookers (Figure 1). A femoral drape was placed on the patient and sterile gel was applied. Cannulation was performed in the following manner: micro-puncture kits were used to obtain femoral arterial access on the left and venous access on the right; bilateral Amplatz wires were inserted and small skin incisions were made; 15 and 25 French femoral arterial and venous cannulas were inserted over the Amplatz wires, respectively; the circuit was stripped of plastic wrap and sterile clamps were applied on both the venous and arterial sides of the circuit; and the circuit was cut and cannulas were connected using sterile saline, for airless connection, per standard procedure (Figure 2). The Albuquerque Fire Rescue-PM hand-cranked to 2000 rpm while the clamps on the circuit and cannulas were removed, with the exception of the final, post oxygenator fail-safe clamp. Once the cannulation physician was assured that no air or blood clots entered the circuit, the final clamp was removed. At this point, the Albuquerque Fire Rescue-PM increased the hand crank to 4000 rpm, and CPR was stopped (Figure 3). A right femoral arterial line was placed and connected to a Centurion Compass disposable vascular pressure monitor, used to provide a mean arterial pressure reading.[11] Flow of 4.5 liters per

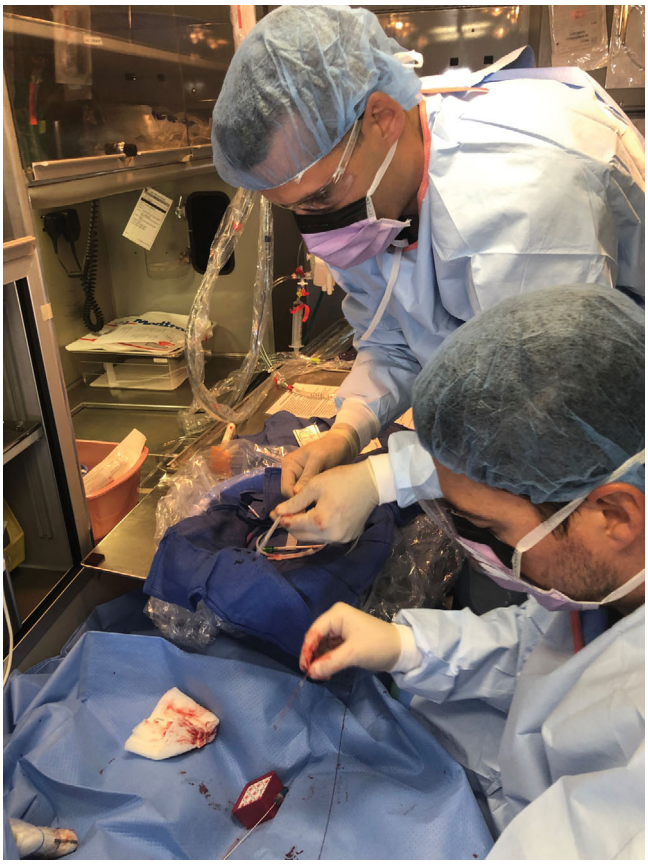

FIGURE 2 Field ECMO cannulation (from this case)

FIGURE 3 Actual hand cranking for out-of-hospital ECMO

minute was confirmed via digital flow probe; the circuit had good color change post oxygenator indicating the oxygenator was functioning, and the patient had a mean arterial pressure of 50–60 mm Hg.

While cannulation ensued, an Albuquerque Fire Rescue-PM supervisor and 3 EMS-MDs (2 faculty and 1 fellow) orchestrated the ongoing resuscitation from the patient's head at the rear door of ECMO-1. Efforts included endotracheal tube intubation; transesophageal echocardiography to assess cannula position, complications, and cardiac function; initiation of a 20 mcg/min epinephrine drip; infusion of 2 liters lactated ringers, administration of 5000 units heparin after Amplatz insertion; and placement of cerebral oximetry.

Despite continued ventricular fibrillation, the patient's skin color markedly improved, cerebral oxygenation increased to 60%, and spontaneous respirations commenced. Albuquerque Fire Rescue-PM continued hand-cranking until arrival at the hospital. While still inside ECMO-1, the Rotoflow head was switched from hand-crank to the Maquet Rotoflow device.

The patient was placed on ECMO 59 minutes after initial collapse, 40 minutes after secondary arrest, and 15 minutes after ECMO-1 arrived on scene. The total EMS scene time was 72 minutes, while total on-scene time for ECMO-1 was 37 minutes.

On entry to the hospital, the patient immediately underwent computed tomography (CT) imaging of the head and torso, which was unremarkable. The patient returned to sinus tachycardia, and the ECG revealed an ST-elevation myocardial infarction. The patient was taken to the catheterization laboratory. Stents were placed in an occluded left anterior descending artery within 2 hours of arrival. The patient was then admitted to the Cardiovascular ECMO ICU on a cooling protocol. After 24 hours, sedation and cooling were weaned. Unfortunately, the patient was noted to have fixed and dilated pupils. Repeat CT of the head demonstrated uncal herniation and complete loss of grey-white differentiation. Brain death testing by clinical criteria and apnea testing as per the Alfred hospital protocol was completed, and brain death was confirmed.[12] An attempt at organ donation was made, but the patient was deemed not a candidate. Life support was withdrawn, and the patient expired.

3 | DISCUSSION

To our knowledge, this is the first North American P-ECMO cannulation of an out-of-hospital ventricular fibrillation-induced cardiac arrest patient. Internationally, P-ECMO is also very rare outside of Paris, France, where they have achieved as high as a 38% survival-to-discharge rate.[13] Barriers to P-ECMO may include the following: a limited number of hospital-based eCPR programs; willingness and availability of ECMO cannulators to leave the hospital; acceptance of on-scene physicians by the EMS providers; dispatch logistics; and the cost of ECMO equipment and retrofitting an ambulance. Trust and a solid relationship between hospital-based providers and both EMS

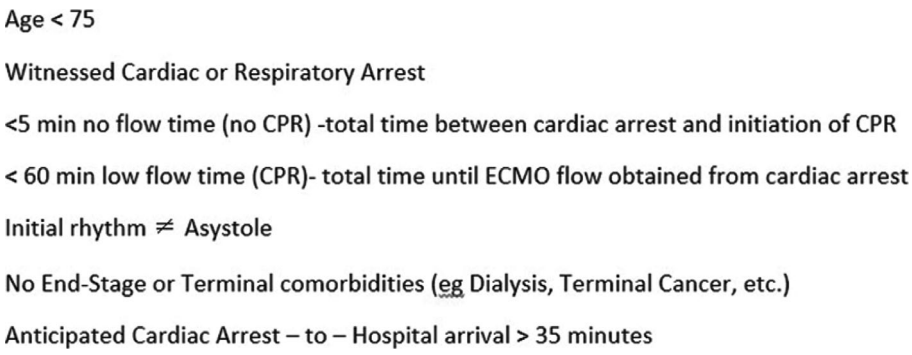

FIGURE 4 Screening criteria for out-of-hospital ECMO

medical and non-medical leadership are essential to developing a successful program. A barrier our P-ECMO team continues to struggle with is the limited availability of our cannulation physicians. Currently P-ECMO is only offered on weekdays from 8 am to 5 pm, but our team is currently exploring options to overcome this obstacle.

Our P-ECMO program began screening patients in July, 2019, and represents a unique collaboration between Albuquerque Fire Rescue, University of New Mexico Hospital, the Division of Pre-hospital Care within the University of New Mexico Department of Emergency Medicine, and the University of New Mexico Center for Adult Critical Care. University of New Mexico Hospital physicians have maintained an eCPR algorithm since 2017 for in-hospital and out-of-hospital cardiac arrest patients. Appropriately screened patients in refractory cardiac arrest are placed on veno-arterial ECMO either in the intensive care unit or the emergency department. Screening criteria for P-ECMO is the same as our in-hospital eCPR criteria and consistent with published standards (Figure 4).[14] In the case of P-ECMO, the notable addition is anticipated arrest-to-hospital arrival time of >35 minutes. Out-of-hospital cardiac arrest patients are typically brought to University of New Mexico Hospital by EMS with Lund University Cardiopulmonary Assist System compression if the anticipated arrest-to-hospital arrival time is <35 minutes. If >35-minute transport time is anticipated, cardiac arrest patients historically received advanced cardiac life support until either return of spontaneous circulation or termination of resuscitation on scene. With our P-ECMO protocol, if arrest-to-hospital arrival time is >35 minutes, ECMO-1 is dispatched to the scene. This time cut-off was chosen to achieve an arrest-to-cannulation time of <60 minutes, a duration typically associated with better odds of survival in the eCPR literature.[14] The development of a P-ECMO program addresses the discrepancy in care for patients who suffer cardiac arrest at long distances from University of New Mexico Hospital.

In addition to expanding the geographic footprint of ECMO, the P-ECMO team has drastically improved the ease and potential cost of ECMO in the out-of-hospital setting. In traditional ECMO, the magnetically coupled hand-crank is used as the backup method to provide flow to patients when power is unexpectedly lost to the ECMO device. Intentional use of a hand-crank to provide ECMO circuit flow has not been previously reported in the literature and is an innovation that has allowed P-ECMO to be implemented in our system. Use of the hand-crank obviates the need for an ECMO specialist, permits usage of the less expensive Rotoflow circuit that can function as the in-house circuit, and can be easily transferable to the full Rotoflow device at the hospital. Our in-hospital ECMO program also uses the manual hand-crank method to initiate ECMO support after hours when the ECMO specialist is not immediately available. The standard of care in the out-of-hospital arena mirrors our in-hospital standard of care.

ECMO support provides the greatest improvement in survival for refractory cardiac arrest since the automated external defibrillator.[8-10,13,14] Our P-ECMO program has greatly streamlined an historically complex and resource intensive process. Having critical care physicians who are willing to cannulate at the scene, the cost-limiting and innovative use of the hand-crank, and EMS providers acting within the New Mexico state EMS scope of practice who can function as first-assist for the cannulation physicians has enabled our P-ECMO program to exist in a resource-limited state. Our program serves as a model that could be replicated across the country. Despite our patient succumbing to brain death (that occurs in 52% to 71% of E-CPR patients), the cannulation occurred without complications in <60 minutes, which is the standard for in-hospital ECMO. Our novel, cost-limited approach to out-of-hospital ECMO has the potential to improve outcomes in patients who are remote from eCPR centers.

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APPENDIX: UNIVERSITY OF NEW MEXICO P-ECMO PROGRAM SUPPLIES

University of New Mexico Medline ECMO pack

2-sterile gloves size 7.5
2-sterile gloves size 8
2-bouffant head covers
2-surgical masks
2-sterile gowns
2-large chlorprep sticks
1-large sterile femoral drape
1-curved Kelly clamp
1-small suture scissors
1-needle driver
1-pop-off silk suture pack
2-small plastic bowls
4-large tubing clamps
1-bandage scissors
1-#11 blade scalpel
2-megaderms
2-smaller tegaderms
2–3/8 tubing connectors
1-used needle holder pad
2- 4 × 4 gauze packs

University of New Mexico Cannulation Kit

2-micro puncture kits
2–4 French Introducer Sheaths
2-Amplatz wires
1–12 French dilator
1-Maquet dilator pack #16,#20,#24

APPENDIX: UNIVERSITY OF NEW MEXICO "7-LAYER BEAN DIP" FOR P-ECMO

Developed to facilitate easy step-by-step cannulation in the prehospital environment. Each layer is set up in reverse order so that when cannulation occurs each layer will be a step in the cannulation working toward the bottom of the bowl.

Large Medline bowl

First layer: sterile C-arm plastic wrap over the bowl
Second layer: four ECMO clamps, scissors and a 60 cc Toomey syringe; then a sterile blue towel
Third layer: vascular dilators, a scalpel, and curved and straight hemostats; then a sterile blue towel
Fourth layer and fifth layers are duplicates: one Amplatz wire and one micro-puncture introducer kit
Sixth layer: is sterile ultrasound gel, gauze pads, sharps cushion, femoral groin drape, and chlorhexadine stick
Seventh layer: a final C-arm sterile drape plastic wrap to keep everything sterile.