


CASE REPORT OPEN ACCESS

# Pediatric ECPR as Bridge to Surgery: Successful Management of Refractory Cardiac Arrest in High-Risk ICD Lead Extraction

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## ABSTRACT

**Background:** Refractory cardiac arrest remains a major challenge in children, with poor survival despite advances in cardiopulmonary resuscitation (CPR). Extracorporeal cardiopulmonary resuscitation (ECPR), defined as rapid deployment of extracorporeal membrane oxygenation (ECMO) during ongoing CPR, provides circulatory and respiratory support and can serve as a bridge to definitive interventions. While increasingly reported in adults, pediatric use remains limited due to anatomical and physiological challenges, with evidence largely restricted to case reports and small series.

**Case Presentation:** A 14-year-old female with dilated cardiomyopathy, severe left ventricular dysfunction (LVEF 12.5%), and prior implantable cardioverter-defibrillator placement underwent elective lead extraction and generator replacement. During the procedure, pericardial effusion with hemodynamic collapse occurred, requiring emergent pericardiocentesis. Despite transient return of spontaneous circulation, refractory cardiac arrest developed after 24 min of CPR. ECPR was initiated via percutaneous femoral veno-arterial ECMO, restoring systemic perfusion. Transesophageal echocardiography revealed right atrial perforation, which was surgically repaired. Hemodynamic stability was achieved with combined ECMO and intra-aortic balloon pump support. The patient was successfully decannulated on postoperative Day 1, extubated on Day 4 without neurological deficits, and discharged to a heart transplant program.

**Conclusion:** This case highlights the pivotal role of ECPR as a bridge to definitive repair in pediatric patients experiencing refractory arrest during high-risk interventions. Early initiation, skilled cannulation, and multidisciplinary coordination were critical for survival. Pediatric experiences such as these are essential to refine selection criteria, inform procedural planning, and expand the limited evidence supporting ECPR as a transformative strategy in resuscitation for this vulnerable population.

## 1 | Introduction

Refractory cardiac arrest remains a significant challenge in both adult and pediatric populations, with persistent low survival despite advances in conventional cardiopulmonary resuscitation (CPR). Extracorporeal cardiopulmonary resuscitation (ECPR)

has emerged as an innovative strategy for selected patients in whom conventional CPR fails to achieve sustained return of spontaneous circulation (ROSC). ECPR involves rapid initiation of extracorporeal membrane oxygenation (ECMO), providing circulatory and respiratory support, and can serve as a bridge to therapies aimed at restoring native cardiac function.

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While ECPR has gained recognition in adults, its use in pediatric patients remains limited and largely supported by case reports and small series. Pediatric patients present unique physiological and anatomical challenges, including smaller vessels, variable hemodynamic responses, and a higher risk of complications during cannulation and extracorporeal support. Consequently, pediatric ECPR requires specialized expertise and institutional readiness, limiting widespread adoption.

Furthermore, ECPR as a bridge to high-risk interventional procedures—such as complex cardiac catheterizations, electrophysiological interventions, or surgical repairs—has been scarcely reported in children. Evidence guiding timing, patient selection, and procedural planning in this context is minimal, highlighting a knowledge gap. Early experiences suggest that when conventional CPR fails in critically ill pediatric patients undergoing high-risk interventions, ECPR may not only sustain life but also provide a critical window to complete potential life-saving procedures [1].

This case report contributes to the limited pediatric literature on ECPR by describing its application during a high-risk interventional procedure, emphasizing technical considerations and clinical outcomes. Such experiences are essential to inform practice, refine selection criteria, and ultimately improve survival in this vulnerable population.

## 2 | Case Presentation

A 14-year-old female with dilated cardiomyopathy and severely reduced left ventricular ejection fraction (12.5%) (Video S1), associated with pathogenic variants in SCN5A and RyR2 genes, was diagnosed with sinus node dysfunction in 2017 and received a dual-chamber pacemaker. In 2019, she developed recurrent ventricular tachycardia, prompting upgrade to an implantable cardioverter-defibrillator (ICD).

The patient was admitted to the emergency department following an ICD alarm for lead extraction and generator replacement. A comprehensive pre-procedural risk assessment was conducted prior to transvenous lead extraction (TLE). The lead dwell time was 8 years, as the lead had been implanted in 2017 and abandoned in 2018. Relevant risk factors included female sex, low body mass, and the extraction of two leads. The patient had no history of prior sternotomy and no congenital anatomical considerations. Risk stratification demonstrated an intermediate anatomical risk, with a SafeTY TLE score of 7.62 and an EROS score of 2 [2, 3]. Nevertheless, despite the intermediate anatomical profile, the overall procedural risk was deemed high due to the patient's severe preexisting left ventricular dysfunction and limited physiological reserve, which significantly increased the potential impact of any periprocedural complication.

A temporary pacemaker was inserted via right venous access, and a subclavian incision was made for generator removal. Right ventricular and ICD leads were extracted using the Liberty Cook system, followed by the removal of the right atrial lead with the same technique. Shortly afterward, transesophageal echocardiography (TEE) revealed pericardial effusion (Figure 1A).

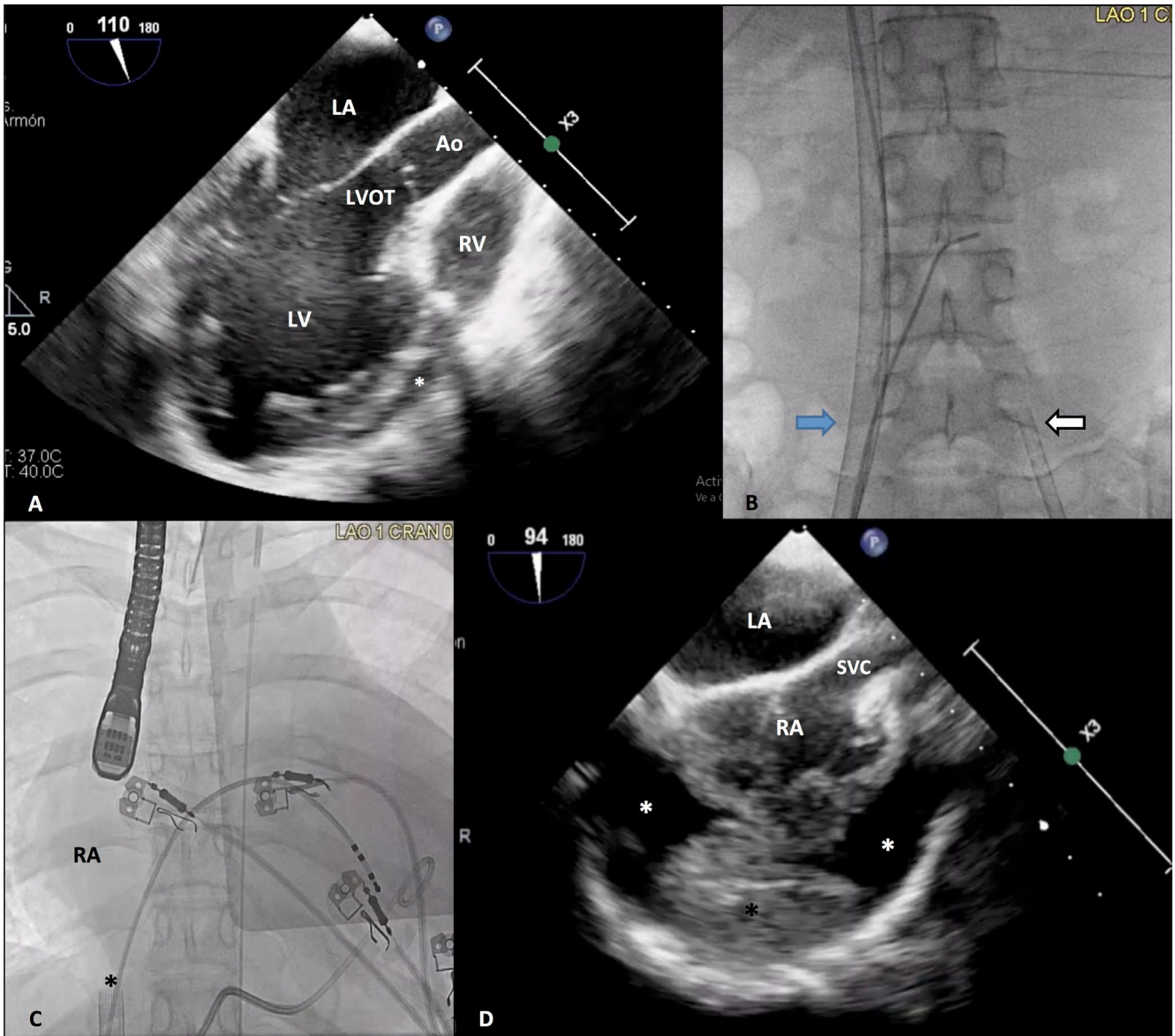
She developed hemodynamic instability, prompting emergent pericardiocentesis with drainage of 450 mL of blood. During the procedure, she suffered cardiac arrest, requiring 10 min of conventional CPR. Following an initial arrest with ROSC, the patient developed a second arrest that progressed to pulseless electrical activity (PEA), requiring approximately 14 additional minutes of high-quality CPR. During this period, the patient exhibited persistent hemodynamic collapse, absence of effective mechanical cardiac activity, and TEE findings demonstrating severe pericardial effusion with no ventricular output; spontaneous contrast was also observed within the cardiac chambers (Video S2). Despite pericardial drainage, the arrest remained refractory, fulfilling our institutional criteria for refractory cardiac arrest and prompting initiation of ECPR. The arterial blood gas obtained during cardiac arrest (pre-ECMO) showed: pH 7.32, PaO<sub>2</sub> 236 mmHg, PaCO<sub>2</sub> 34 mmHg, and lactate 11.5 mmol/L. The patient's baseline serum creatinine was 0.709 mg/dL.

### 2.1 | Cannulation and ECMO Support

In addition to the availability of a preassembled ECMO system, activation of the ECMO code enabled the cannulation and perfusion teams to respond immediately via radio communication, facilitating rapid initiation of the ECPR pathway. Percutaneous veno-arterial (V-A) ECMO cannulation was performed under real-time ultrasound guidance using the Seldinger technique, while advanced cardiovascular life support continued. The right common femoral vein and left common femoral artery were cannulated successfully. Venous drainage was achieved with a 23 French multifenestrated Bio-Medicus cannula (Medtronic, Minneapolis, MN, USA), advanced via the right femoral vein with the tip positioned at the cavoatrial junction, confirmed by TEE (Figure 1B). Arterial return was provided through a 15 French Bio-Medicus cannula (Medtronic) inserted percutaneously in the left femoral artery, with positioning verified by fluoroscopy (Figure 1C). Cannulation was achieved within 17 min, with prompt establishment of full ECMO flow thereafter. Initiation of V-A ECMO achieved 4 L/min flow, normalized arterial pressure, and restored circulation. TEE demonstrated low pulsatility index and persistent aortic valve closure, prompting insertion of a 30-cc intra-aortic balloon pump (IABP) in the right femoral artery for left ventricular unloading.

### 2.2 | Surgical Intervention and Recovery

Following hemodynamic stabilization, TEE revealed contained bleeding in the pericardium adjacent to the right atrium (Figure 1D). The patient was transferred to the operating room, where a 5-mm right atrial perforation with 400 mL of hemopericardium was identified and repaired. A distal perfusion cannula was also placed in the left femoral artery. She was admitted to the cardiovascular critical care unit. ECMO decannulation occurred on postoperative Day 1, and she was extubated on Day 4. Neurological outcome was assessed using the Cerebral Performance Category (CPC) score, with the patient achieving a CPC score of one at discharge, indicating normal cerebral function without deficits. A comprehensive neurological evaluation was performed, including a detailed clinical examination. Neuroimaging showed no evidence of acute ischemic or



**FIGURE 1** | (A) Transesophageal echocardiography. Mid-esophageal long-axis view showing a spherical, globular, and dilated LV. A pericardial effusion is noted along the anterolateral wall (asterisk). (B) Venous drainage cannula inserted via the right common femoral vein, advancing through the IVC into the RA (blue arrow). An arterial return cannula is inserted through the left common femoral artery and directed toward the left iliac artery (white arrow). (C) Tip of the venous return cannula in its final position at the cavoatrial junction (asterisk). (D) Superior esophageal bicaval view demonstrates pericardial effusion (asterisks) and a pericardial hematoma compressing the RA. LA, left atrium; LV, left ventricle; LVOT, left ventricular outflow tract; Ao, aorta; RV, right ventricle; RA, right atrium; SVC, superior vena cava; IVC, inferior vena cava.

hemorrhagic brain injury. The patient was subsequently transferred to the general ward for continued recovery and is currently listed for heart transplantation.

### 3 | Discussion

The use of ECPR is a life-saving option that has shown an increasing trend, currently accounting for 18% of pediatric ECMO cases, compared with only 5% in 2004. Survival rates in the ELSO registry range from 31% to 64% in pediatric patients and 15%–50% in adults. This modality may serve as a bridge to life-saving intervention, as in our case, where the patient experienced refractory cardiac arrest due to right atrial perforation [4].

In patients with severely reduced stroke volume, chest compressions are often insufficient to maintain adequate cerebral and systemic perfusion, warranting earlier ECPR consideration. In our patient, the markedly low ejection fraction further limited the likelihood of successful conventional CPR. Although the immediate cause of arrest (pericardial tamponade) was temporarily corrected, the underlying structural disease ultimately required surgical repair and hemodynamic stabilization.

Reported benefits of ECPR in structural heart disease include decreased myocardial workload, reduced vasopressor and inotropic requirements, improved myocardial oxygen delivery, enhanced end-organ perfusion, targeted temperature management, and correction of acidosis [4].

Despite these benefits, ECPR carries significant risks such as bleeding, vascular injury, cannula malposition, thrombotic events, and hemolysis. The risk profile varies with the cannulation site. Cannulation must be performed rapidly, through peripheral or central access. Central access is generally reserved for patients with recent sternotomy. Peripheral cannulation may be surgical or percutaneous [4, 5]. Femoral VA access was selected due to the patient's size (154 cm, 43 kg) and the need for rapid peripheral percutaneous cannulation during ECPR. In neonates and children under 15 kg, the right internal jugular vein is generally preferred for drainage; however, in larger children and adolescents, femoral venous access is typically appropriate, with optional supplemental jugular access if required. In this setting, femoral cannulation offered the fastest and least disruptive approach, as it can be performed percutaneously under ultrasound guidance without interfering with ongoing CPR and is well suited for the catheterization laboratory environment. Central cannulation was not feasible because it would have required interrupting resuscitative efforts and a longer procedural time, which is suboptimal in ECPR. Similarly, carotid access—reserved for smaller children, infants, and neonates—was not appropriate for this patient [5].

Therefore, ECPR should be reserved for carefully selected scenarios, and prolonged support avoided, as it increases severe complications [6]. In our patient, arrest was due to right atrial perforation, necessitating surgical repair, allowing timely ECMO decannulation and minimizing ECPR-related adverse events.

Patient-specific characteristics, including age, sex, underlying comorbidities, and the presence of single ventricle physiology, together with the precipitating event and context of cardiac arrest, are critical determinants of prognosis in pediatric ECPR. Pre-ECMO hemodynamic and laboratory parameters—such as blood gas values (pH, PaO<sub>2</sub>, PaCO<sub>2</sub>, lactate), renal function (creatinine), and other relevant markers—provide essential insight into the severity of metabolic derangements and end-organ perfusion. Details of the arrest, including whether it was witnessed, the initial cardiac rhythm, bystander CPR, CPR quality, and the duration of conventional resuscitation prior to ECMO, have been consistently associated with survival outcomes and neurological recovery [6, 7]. Furthermore, a review of the Extracorporeal Life Support Organization (ELSO) registry identified factors associated with survival to discharge, including an initial shockable rhythm, signs of life prior to ECMO initiation, and early postarrest lactate levels [8]. In our case, the scheduled nature of the procedure likely favored a positive outcome, and the initial rhythm was ventricular fibrillation.

Long-term outcomes depend on the underlying etiology and indication for ECMO. A study of pediatric patients aged 5 years requiring ECMO reported a 6% incidence of neuromotor and cognitive impairments [9]. In another study of 25 pediatric patients undergoing ECPR after refractory arrest post-cardiac surgery, frequent complications were renal dysfunction (88%), bleeding (20%), ventricular dysfunction (20%), sepsis with multiorgan failure (16%), and severe neurologic impairment (8%) [10].

## 4 | Conclusion

This case highlights the pivotal role of ECPR as a bridge to definitive surgical repair in pediatric patients with refractory cardiac arrest during high-risk interventions. When applied in carefully selected scenarios with prompt cannulation and multidisciplinary coordination, ECPR can transform an otherwise fatal event into a survivable condition, underscoring its potential to expand the boundaries of pediatric resuscitation.

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The authors have nothing to report.

### Ethics Statement

The local research and institutional ethics committees waived approval for this study.

### Consent

Written informed consent was obtained for the publication of patient information and images, from a legally authorized representative.

### Conflicts of Interest

The authors declare no conflicts of interest.

### Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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### Supporting Information

Additional supporting information can be found online in the Supporting Information section. **Video S1:** Transthoracic echocardiography. Baseline echocardiographic assessment demonstrates a severely dilated and dysfunctional left ventricle with markedly reduced ejection fraction. The findings are illustrated in the apical four-chamber and mid-ventricular short-axis views. **Video S2:** Transesophageal echocardiography. A mid-esophageal four-chamber view demonstrates the patient in cardiac arrest, with spontaneous contrast formation observed in both left heart chambers. Thrombus formation is noted around the implantable cardioverter-defibrillator lead in the right-sided chambers.