Out of ECMO center refractory cardiac arrest in children: a retrospective multicenter analysis of a regional care program

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Abstract

Purpose: Extracorporeal membrane oxygenation during cardiac arrest resuscitation is a life saving technology widely described for in hospital cardiac arrest in children with a cardiac underlying disease. However, only scarce data is available for out-of-hospital cardiac arrest in children.

Methods: We performed a multicenter retrospective analysis of all medical charts for out of ECMO center refractory cardiac arrests in children from January 2022 to June 2024. We analyzed medical chart from all refractory cardiac arrest in children between 0 days and 15 years old.

Results: Among 250 calls for cardiac arrest, 184 reached the definition of refractory arrest. Thirty-three were included in the regional program while the others did not reach the inclusion criteria. Seventeen arrived on time in the PICU and 13 were implanted on VA ECMO (4 ECMO implantation failure). Median age was 24.3 months (9.9 – 93.8). Length of low flow at first call was 25 minutes (18 – 40), length of cannulation was 30 minutes (20 – 42) and delay between the cardiac arrest and the ECMO running was 82 minutes (50 – 113). The survival rate was 6% (1/17). Four patients died from brain death without organ donation.

Conclusion: We described a large cohort of E-CPR for pediatric out of ECMO center refractory cardiac arrests. The results highlight a poor prognosis of out of ECMO center cardiac arrest despite solid regional organization. Considering these results, we decided to limit E-CPR indications to cardiac arrhythmia or accidental hypothermia.

Research in context

- *ECMO implantation is an expanding resuscitation strategy in refractory cardiac arrest, with only scare data in children.*
- *Extra hospital refractory cardiac arrest in children is a severe medical event in children with very poor prognosis.*
- *We review the efficacy of a regional organization for E-CPR in EOCA.*

What this study means

- *Despite a solid regional organization for extra hospital refractory cardiac arrest in children, E-CPR do not significantly improved prognosis.*
- *A carefully patient selection before deploying E-CPR for EHCA is essential.*
- *Patient presenting cardiac refractory cardiac arrest in a context of arrhythmia or accidental hypothermia have the best outcomes.*

Introduction

Cardiac arrest in children is a severe medical condition associated with a low survival rate and a poor neurological prognosis. In the pediatric literature, beyond 10 minutes of cardiopulmonary resuscitation (CPR), the probability of survival decreases with almost 70% of death. Beyond 60 minutes, whatever the studies, the mortality rate is close to 100% (1). However, according to studies, around 80% of the survivors have a neurological outcome considered favorable on global assessment scales such as the Pediatric Cerebral Performance Category Scale (PCPC) and Pediatric Overall Performance Category (POPC) (2) or on Health related quality of life (3). Beside survival, it is accepted that the duration of CPR is a major risk factor for neurological sequelae and that beyond 20 minutes the risk of irreversible neurological sequelae is very high (4). To quickly restore adequate organ perfusion, some teams perform extracorporeal membrane oxygenation (ECMO) implantation during cardiac arrest resuscitation (E-CPR). Several pediatric data on E-CPR exist for intra-hospital refractory cardiac arrest (IHCA) (4–7), especially for cardiac arrest around cardiac surgery. However, only few data are available for the out-of-hospital refractory cardiac arrest (OHCA) (8). E-CPR seems to be associated with higher survival rate that conventional cardiopulmonary resuscitation (CCPR) (9) but data are scarce and there is a discrepancy between the few published data.

Given the paucity of pediatric data on the prognosis and outcome of refractory cardiac arrest occurring outside an ECMO center, we decided to report the results of our Ile-de-France pediatric E-CPR program, which has started in 2021.

Material and Methods

Study design: We conducted a multicenter retrospective analysis of the two-referral center for ECMO in Paris, France: Armand-Trousseau hospital and Necker hospital. Inclusion criteria were refractory cardiac arrest in children between 0 days and 15 years old with zero no flow and the possibility of arriving at the nearest ECMO center within 60 minutes. Refractory cardiac arrest was defined by a non-return to spontaneous circulation after 10 minutes of resuscitation by a trained medical team.

Exclusion criteria were futility on medical condition, non-witnessed cardiac arrest, and call too late to arrive in time at ECMO center.

Data collection : the collected data were age (months), weight (kg), underlying disease, location of cardiac arrest (home/street, hospital without ECMO program), distance between cardiac arrest location and ECMO center (km), ECMO implantation out of an ECMO center by a mobile unit, time from collapse to PICU arrival (minutes), time from collapse to ECMO initiation (minutes), length of cannulation (minutes), site of cannulas insertion, proportion of successful cannulation, cardiac arrest etiology, POPC and PCPC scores (10), proportion of ECMO, weaning survival rate and rate of organ donation.

E-CPR program:

The E-CPR program was developed jointly by the two-referral pediatric ECMO centers and the pediatric emergency transport unit. It consisted of a standardized operating procedure, and a checklist of the

required equipment. A role chart was created specifying the position and the role of each person role when the patient arrived.

Before and during protocol implementation, training sessions were conducted, and a training plan based on in-situ clinical simulation was initiated. A complete cannulation team, comprising an intensivist with cannulation competency, a pediatric surgeon and a nurse with competency in ECMO initiation and management was available 24/7 on site or on call (at night).

The referring unit first contacted the call center of the pediatric emergency transport unit, who had a dedicated call sheet (supplemental data) with 3 questions to quickly screen obvious contra-indication to ECPR. Then, the eligible patient had to fulfill 3 criteria to be candidate for the E-CPR program: 1) to fulfill all the criteria for ECMO implantation, 2) to arrive in an ECMO PICU within 60 minutes of the cardiac arrest and 3) to achieve a full flow assistance within 90 minutes of the cardiac arrest.

If all criteria were met, the patients were addressed to the closest E-CPR center. All patients received manual or mechanical chest compressions using LUCAS® (Stryker Corporation, Michigan, USA) during the transport to the ECMO center.

ECMO implantation

The arterial cannula insertion was performed at bedside by a pediatric surgeon using the open Seldinger strategy. The venous cannulation could be carried out by the surgeon either with the open Seldinger strategy or by the pediatrician with the percutaneous strategy.

The ECMO devices used for this program were Cardiohelp™ system (Getinge ™ Stockholm, Sweden) with the oxygenator 5.0 or 7.0 (weight above 25 kg) and the Deltastream DP3™ system (Xenios AG, Heilbronn, Germany) with the oxygenators Medos Hilite 800LT or 2400 LT. We used the Euroset™ or Getinge™ cannulas.

Once the ECMO was initiated and a stable ECMO full flow was achieved, chest compressions were stopped. Post-resuscitation care included targeted temperature management between 35 and 36°C and multimodal assessment of neurological prognosis.

The methodology was consistent with ethical standards, and this report follows the guidelines of the Strengthening the Reporting of Observational studies in Epidemiology statement. Data management was performed in accordance with the French MR004 methodology, which waived parent consent. This study received ethical approval from the French Society of pediatrics (CERSFP_2025_206-2).

Statistics

Summary statistics were computed, namely median and interquartile range (IQR) for quantitative variables or percentages for qualitative variables. Baseline comparison of groups used the nonparametric Wilcoxon or Kruskal Wallis tests or the exact Fisher test, respectively.

All p-values below 0.05 were considered as significant.

Data analysis were performed using R + + Software™ (Bordeaux, France).

Results

Two hundred and fifty calls for pediatric cardiac arrest were received during the study period. Among them, 184 reached the definition of refractory arrest, and 33 were included in the regional program (Fig. 1). Reason for program exclusion were sustainable ROSC in 15 patients (10%), 39 calls too late to arrive on time at ECMO center (26%), 39 patients with no flow (26%), 58 patients with severe comorbidities futility (38%). Seventeen patients (included one neonate) (51%) arrived on time in the PICU, among them 13 (77%) were implanted on VA ECMO while ECMO implementation failed in the 4 others (23%). All ECMO implantation failures were due to arterial cannula insertion issue. Demographic data are reported in Table 1.

Table 1
Demographic characteristics

Demographic data	**Total cohort (n = 17)**
Median age (months)	24.3 (9.9–93.8)
Pediatric patient (N, %)	16 (94%)
Location of cardiac arrest	(9, 53%)
• At home (N, %)	(8, 47%)
• In hospital without ECMO (N, %)	
Circulatory failure before cardiac arrest (N, %)	(12, 70%)
Associated medical condition	(4, 24%)

Regarding etiology of the cardiac arrest, viral myocarditis was identified in 6 patients (34%), cardiac arrhythmias as initial pathology in 2 patients (12%), septic shock in 3 patients (18%), severe hypoxemia in 3 patients (18%), drowning in 1 patient (6%), anaphylactic shock in 1 patient (6%) and meconium aspiration syndrome in 1 patient (6%).

Median age was 24.3 months (9.9–93.8). Length of low flow at first call was 25 minutes (18–40) and time between the cardiac arrest and the ECMO running was 82 minutes (50–113). Most of the patients benefited from neck cannulation (87%) with a median time for cannula insertion of 30 minutes (20–35). Median time for canula insertion was shorter for femoro-femoral cannulation than jugular-carotid cannulation (15 min vs 31 min) A mobile ECMO unit was deployed for three patients (intra hospital cardiac arrest without ECMO supply) and the others benefit from a scoop and run to ECMO center strategy. Data on cannulation are reported in Table 2.

Table 2
resuscitation and ECMO datas

ECMO implantation data	Total cohort (n = 17)
Cardiac arrest onset at night (N, %)	10 (59%)
Distance from cardiac arrest onset an ECMO center (km)	17 (7–40)
Low flow duration at call (min)	25 (19–38)
Length of low flow at ECMO center arrival (min)	72 (50–88)
Cannulation duration (min)	30 (20–35)
Interval between cardiac arrest and ECMO start (min)	82 (60–98)
ECMO implantation success (N, %)	13 (76)
Site of cannulation	2 (13)
• Femoro-femoral cannulation (N, %)	11 (87)
• Jugular-carotid cannulation (N, %)	

Only one patient was weaned from ECMO and successfully discharged from hospital with a POCP score of 2 (mild motor sequelae). This patient had presented a cardiac arrest after drowning with a profound hypothermia (27°C). She presented signs of life all along resuscitation process and ECMO was implanted 180 min after cardiac arrest onset. Brain death was identified in 4 patients but organ donation was refused by the French national agency for organ donation, due to unknown reason for cardiac arrest at call. All other children suffered from multiple organ failure and ECMO retrieval was discontinued for ethical consideration (Table 3).

Table 3
Outcomes

Outcomes	Total cohort (n = 13)
Surviving patient (n = 1)	
• ECMO weaning (N, %)	1 (7)
• ICU survival (N, %)	1 (7)
Deceased patients	
• Brain death (N, %)	4 (33)
• Multiple organs failure (N, %)	8 (67)
• Organ donation (N, %)	0 (100)

Discussion

ECMO during cardiopulmonary resuscitation (ECPR) is a developing life support in case of refractory cardiac arrest (11). Most of the published studies in children report IHCA management, with a high rate of post cardiotomy cardiac arrest (6, 12, 13). The survival for these patients seems to slightly increase over time but remains around 30% (1, 4, 14). Data on OHCA remain scarce, especially for non-cardiac pediatric patients.

We report here the first French series on the management of refractory cardiac arrest in children outside an ECMO center. One of the strengths of this series is the regional organization of the care, enabling rapid referral of the child to the nearest ECMO center. Nearly all the patients were cannulated using a scoop and run strategy rather implantation by a mobile unit. This decision was taken in view of the lack of human resources, which made impossible to deploy a mobile unit at all times of the day and night. However, this did not lengthen the ECMO start-up time as much. Indeed, our median delay between collapse and ECMO start was 82 minutes, similar than Olson *et al.* study (8) but a little longer than in IHCA studies (5, 15, 16). However, our delay for cannulas insertion is lower or in accordance with all recent studies (5, 16, 17). These results highlight the need to shorten the delay between collapse and arrival to the ECMO team.

Despite this organization and early start of ECMO, the survival rate of our cohort remains very low. Nonetheless, these results are in line with the literature of E-CPR. Our study is one of the few to report the outcome of out-of-ECMO center refractory cardiac arrest in children. Recently, Olson *et al.* (8), published an analysis of the ELSO database for OHCA with survival higher than our series. Two mains explanations can be found to understand this difference.

Firstly, our patients were younger than Olson report's (respectively 2 vs 8 years old), which imply a higher rate of neck cannulation. However, cervical cannulations are obviously longer and involve more interruption of CPR in order to insert properly the arterial and venous cannula. It is well known that CPR interruptions are associated with worst outcomes (18, 19) as well as the duration of CPR (8, 16).

Secondly, we have not included patients with cardiac arrhythmia during the study period due to an unexplained low rate of call for these patients. But these patients are known to have a better prognosis when an ECPR is done (8, 12, 13). Refractory cardiac arrest occurring in a context of hemodynamic or respiratory failure is often indicative of prolonged visceral and brain hypoperfusion with hypoxemia and multiorgan failure. Cardiac arrest is the end stage of these clinical situations and is often associated with worst prognosis.

Thirdly, despite widespread and repeated communication about the need to refer a child to an ECMO center within 10 minutes of the onset of cardiac arrest, we faced a high rate of late calls (25 minutes of low flow at first call) and 39 patients were not included due to a too long low flow at first call.

Management of out-of-ECMO center refractory cardiac arrest in children remains a challenge for ECMO centers and will probably require adjustments in order to achieve higher survival rates. In adults, there is still a lack of evidence supporting E-CPR against C-CPR, except in specific clinical condition (20–22).

Indeed, rapid cannula insertion once the surgical team has reached the patient does not in itself guarantee a positive prognosis as neurological injury and multiorgan failure mainly depends on the length and the quality of pre-ECMO CPR (23). Whereas it is well known that an efficient CPR do not guarantee survival, conversely an inefficient CPR guarantee a poor prognosis.

To improve outcome of extra-ECMO center refractory cardiac arrest, we have identified several areas for improvement.

First, patients' selection needs to be improved. Some criteria are ready well known to be associated with a worst prognosis such as length of no flow, length of CPR, asystolia as initial rhythm, no signs of life during CPR. ELSO guidelines proposed clinical inclusion criteria for E-CPR (24) and a recent study from Redfors *et al*. (25) proposed a Pre-ECPR score with a AUC (area under the curve) of 87% for adult cardiac arrest. To our knowledge, no such score exists for the pediatric population. However, cardiac arrhythmia as initial rhythm, accidental hypothermia, and short low flow before ECMO start and zero no flow seem to be robust criteria for favorable outcomes in the pediatric population. On the other hand, septic shock and terminal hypoxemia seem to be associated with very poor prognosis in case of E-CPR cannulation.

Secondly, a major factor associated with good prognosis is the efficacy of pre-ECMO CPR. Moreover, it has been proven that treatment by a bystander trained in resuscitation is more effective than a non-trained bystander (26). Indeed, cardiac arrest is then recognized early and chests compressions are more efficient. It is also essential to deploy simulation program for emergency medicine providers to better resuscitate the patient during ECMO implantation (27–29). Elsewhere, we can assume that CPR during a scoop and run strategy is potentially not as effective as in a resuscitation room, given the movements of the truck and the risk of accident. Nevertheless, a recent study from Yates *et al.* (30) failed to identify a significant association between the early hemodynamic parameters obtained with high quality CPR and outcomes. Moreover, Raymond *et al.* recently demonstrate that adherence to American Heart Association guideline-complaint CPR was not significantly associated with outcomes (31).

Thirdly, the delay between collapse and ECMO implantation might be limited using mobile ECMO team. It is already used for adults in some countries and allows shortening this crucial delay between cardiac arrest and ECMO support. The PRECARE feasibility study (32) evaluated the feasibility of a dedicated E-CPR mobile unit for OHCA in adults and succeeded in decreasing median delay between CA and ECMO stars to 38 minutes with a survival rate of 33%. However, only 12 of the 123 cardiac arrests identified during the study period benefited from an E-CPR resuscitation. These results confirmed the previous study from Lamhaut *et al.* (33) who developed a dedicated mobile ECMO team for OHCA. This team was called out to all OHCA, enabling ECMO to be started within 20 min after the collapse. This strategy allowed to drastically reduce delay between CA and ECMO start to 20 minutes, notwithstanding requiring many resources, and generating high costs for a survival rate around 25%.

The last interesting finding of this study is the absence of organ donation from pediatric brain-dead patients. No organ donations were accepted by the French transplant agency. Half of the patients were

excluded because their multiple organ failure was too severe, or because the infectious agent had not yet been identified. In these times of organ shortage, it may be useful to re-consider the contraindications for organ removal, particularly in infectious contexts.

Conclusion

The results highlight a poor prognosis of out of ECMO center cardiac arrest in children despite regional organization. Considering these results, we decided to modify our pediatric E-CPR program for out-of-hospital cardiac arrests in our region and to limit indication to cardiac arrest due to cardiac arrhythmia or accidental hypothermia.

Abbreviations

CCPR
conventional cardiopulmonary resuscitation
CPR
cardiopulmonary resuscitation
ECMO
extracorporeal membrane oxygenation
IHCA
intra-hospital refractory cardiac arrest
OHCA
out-of-hospital refractory cardiac arrest
PCPC
Pediatric Cerebral Performance Category Scale
POPC
Pediatric Overall Performance Category
ROSC
recovery of spontaneous circulation

Declarations

Author Contribution

JS, JR, EH. wrote the main manuscript text.MG, ES and PLL collected the data and performed statistical analysis All authors reviewed the manuscript.

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All other authors have no conflict of interest to declare

All procedures were followed in accordance with the ethical standards of the responsible committee on human experimentation (institutional or regional) and with the Helsinki Declaration of 1975.

References

1. Lopez-Herce J, Del Castillo J, Carrillo A (2014) Cardiac arrest prognostic factors in children. Resuscitation 85:e35
2. Berg RA, Nadkarni VM, Clark AE et al (2016) Incidence and Outcomes of Cardiopulmonary Resuscitation in PICUs. Crit Care Med 44:798–808
3. van Zellem L, Utens EM, Legerstee JS et al (2015) Cardiac Arrest in Children: Long-Term Health Status and Health-Related Quality of Life. Pediatr Crit Care Med 16:693–702
4. Bembea MM, Ng DK, Rizkalla N et al (2019) Outcomes After Extracorporeal Cardiopulmonary Resuscitation of Pediatric In-Hospital Cardiac Arrest: A Report From the Get With the Guidelines-Resuscitation and the Extracorporeal Life Support Organization Registries. Crit Care Med 47:e278–e285
5. Marquez AM, Vargas-Gutierrez M, Todd M et al (2025) A single center experience and outcomes with central and peripheral cannulations for paediatric extracorporeal cardiopulmonary resuscitation. Resuscitation 214:110678
6. Alsoufi B, Al-Radi OO, Nazer RI et al (2007) Survival outcomes after rescue extracorporeal cardiopulmonary resuscitation in pediatric patients with refractory cardiac arrest. J Thorac Cardiovasc Surg 134:952–959e2
7. Morales-Demori R, Olson TL, Alali A et al (2025) Outcomes in Pediatric ECPR for In-Hospital Cardiac Arrest: An ELSO Registry Analysis. Resuscitation 110794
8. Olson TL, Kilcoyne HW, Morales-Demori R et al (2024) Extracorporeal cardiopulmonary resuscitation for pediatric out-of-hospital cardiac arrest: A review of the Extracorporeal Life Support Organization Registry. Resuscitation 203:110380
9. Coute RA, Nathanson BH, DeMasi S et al (2023) Disability-Adjusted Life Years Due to Pediatric Out-of-Hospital Cardiac Arrest in the United States: A CARES Surveillance Group Study. Circ Cardiovasc Qual Outcomes 16:e009786
10. Fiser DH (1992) Assessing the outcome of pediatric intensive care. J Pediatr 121:68–74
11. Sperotto F, Daverio M, Amigoni A et al (2024) Extracorporeal Cardiopulmonary Resuscitation Use Among Children With Cardiac Disease in the ICU: A Meta-Analysis and Meta-Regression of Data Through March 2024. Pediatr Crit Care Med 25:e410–e417
12. Lasa JJ, Rogers RS, Localio R et al (2016) Extracorporeal-Cardiopulmonary Resuscitation (E-CPR) During Pediatric In-Hospital Cardiopulmonary Arrest is Associated with Improved Survival to Discharge: A Report from the American Heart Association's Get With the Guidelines® - Resuscitation Registry (GWTG-R). Circulation 133:165–176

13. Kramer P, Mommsen A, Miera O et al (2020) Survival and Mid-Term Neurologic Outcome After Extracorporeal Cardiopulmonary Resuscitation in Children. Pediatr Crit Care Med 21:e316–e324
14. Martinez PA, Totapally BR (2016) The epidemiology and outcomes of pediatric in-hospital cardiopulmonary arrest in the United States during 1997 to 2012. Resuscitation 105:177–181
15. Loaec M, Himebauch AS, Reeder R et al (2024) Outcomes of Extracorporeal Cardiopulmonary Resuscitation for In-Hospital Cardiac Arrest Among Children With Noncardiac Illness Categories. Crit Care Med 52:551–562
16. Delmo Walter EM, Alexi-Meskishvili V, Huebler M et al (2011) Rescue extracorporeal membrane oxygenation in children with refractory cardiac arrest. Interact Cardiovasc Thorac Surg 12:929–934
17. Torres-Andres F, Fink EL, Bell MJ et al (2018) Survival and Long-Term Functional Outcomes for Children With Cardiac Arrest Treated With Extracorporeal Cardiopulmonary Resuscitation. Pediatr Crit Care Med 19:451–458
18. Järvenpää V, Mäki P, Huhtala H et al (2024) Compliance with CPR quality guidelines and survival after 30 days following out-of-hospital cardiac arrest. A retrospective study. Acta Anaesthesiol Scand 68:80–90
19. Yannopoulos D, Aufderheide TP, Abella BS et al (2015) Quality of CPR: An important effect modifier in cardiac arrest clinical outcomes and intervention effectiveness trials. Resuscitation 94:106–113
20. Supady A, Bělohlávek J, Combes A et al (2025) Extracorporeal cardiopulmonary resuscitation for refractory cardiac arrest. Lancet Respir Med S 2213-2600(25)00122–5
21. Wang J-Y, Chen Y, Dong R et al (2024) Extracorporeal vs. conventional CPR for out-of-hospital cardiac arrest: A systematic review and meta-analysis. Am J Emerg Med 80:185–193
22. Taccone FS, Minini A, Avalli L et al (2024) Impact of extracorporeal cardiopulmonary resuscitation on neurological prognosis and survival in adult patients after cardiac arrest: An individual pooled patient data meta-analysis. Resuscitation 202:110357
23. Riggs M, Franklin R, Saylany L (2019) Associations between cardiopulmonary resuscitation (CPR) knowledge, self-efficacy, training history and willingness to perform CPR and CPR psychomotor skills: A systematic review. Resuscitation 138:259–272
24. Richardson A, Sacha) C, Tonna JE, Nanjayya V et al (2021) Extracorporeal Cardiopulmonary Resuscitation in Adults. Interim Guideline Consensus Statement From the Extracorporeal Life Support Organization. ASAIO J 67:221
25. Redfors B, Byttner A, Bengtsson D et al (2024) The Pre-ECPR Score: Developing and Validating a Multivariable Prediction Model for Favorable Neurological Outcomes in Patients Undergoing Extracorporeal Cardiopulmonary Resuscitation. J Cardiothorac Vasc Anesth 38:3018–3028
26. Kaneto Y, Owada H, Kamikura T et al (2024) Advantages of bystander-performed conventional cardiopulmonary resuscitation in out-of-hospital cardiac arrest presumably caused by drowning in Japan: a propensity score-matching analysis using an extended nationwide database. BMJ Open 14:e080579

27. Whitmore SP, Gunnerson KJ, Haft JW et al (2019) Simulation training enables emergency medicine providers to rapidly and safely initiate extracorporeal cardiopulmonary resuscitation (ECPR) in a simulated cardiac arrest scenario. Resuscitation 138:68–73
28. Sawyer T, Burke C, McMullan DM et al (2019) Impacts of a Pediatric Extracorporeal Cardiopulmonary Resuscitation (ECPR) Simulation Training Program. Acad Pediatr 19:566–571
29. Ueda K, Yamane T, Aguru Y et al (2019) Establishing protocol and simulation-based learning to initiate ecpr in our institution. JACC 73:2145–2145
30. Yates AR, Naim MY, Reeder RW et al (2024) Early Cardiac Arrest Hemodynamics, End-Tidal C o2, and Outcome in Pediatric Extracorporeal Cardiopulmonary Resuscitation: Secondary Analysis of the ICU-RESUScitation Project Dataset (2016–2021). Pediatr Crit Care Med 25:312–322
31. Raymond TT, Yu P, Esangbedo I et al (2025) Outcomes after extracorporeal cardiopulmonary resuscitation in pediatric in-hospital cardiac arrest: does quality of. CPR matter? Resusc 211:110599
32. Kruit N, Burns B, Shearer N et al (2025) Pre-hospital ECPR for refractory cardiac arrest - The PRECARE pilot feasibility study. Resuscitation 212:110631
33. Lamhaut L, Hutin A, Puymirat E et al (2017) A Pre-Hospital Extracorporeal Cardio Pulmonary Resuscitation (ECPR) strategy for treatment of refractory out hospital cardiac arrest: An observational study and propensity analysis. Resuscitation 117:109–117

Figures

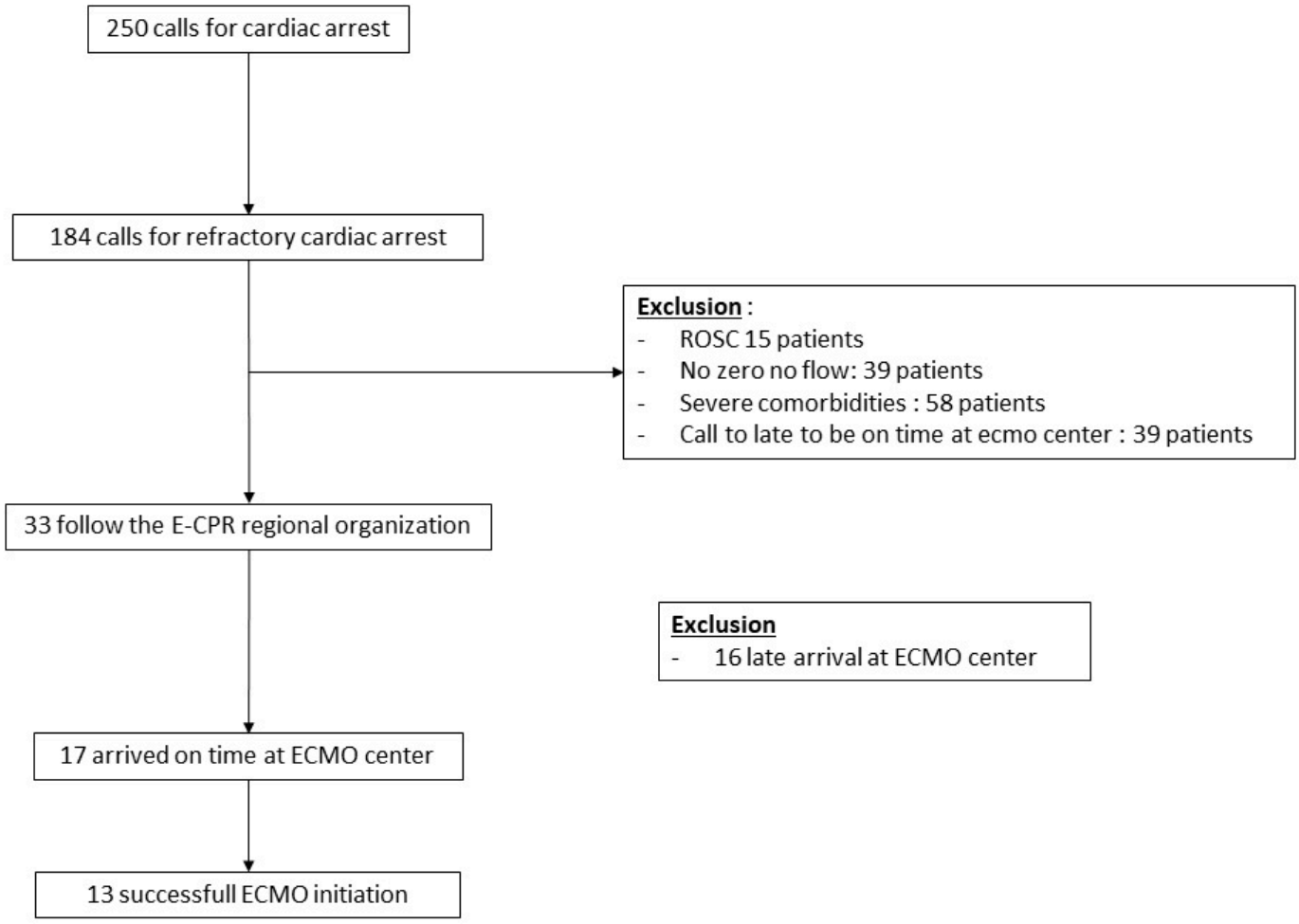

Figure 1

Flow chart