

Supplemental Content

This document contains important additional literature that support the statements and recommendations, but which have to be listed separate due to formatting restrictions.

Guideline for Extracorporeal Cardiopulmonary Resuscitation (ECPR) in Adults. A Statement from the Extracorporeal Life Support Organization (ELSO)

Alexander (Sacha) C Richardson
Joseph E Tonna
Vinodh Nanjajya
Paul Nixon
Anne-Marie Guerguerian
Darry Abrams
Lakshmi Raman
Stephen Bernard
Simon Finney
Brian Grunau
Scott T. Youngquist
Stephen H. McKellar
Zachary Shinar
Jason Bartos
Lance Becker
Demetris Yannopoulos
Jan Belohlavek
Lionel Lamhaut
Vincent Pellegrino

CORRESPONDING AUTHOR:

Alexander (Sacha) C Richardson MBCh MA MRCP FCICM
The Alfred Hospital,
Prahran, VIC 3004, Australia
Sacha.Richardson@alfred.org.au

Index:

Indications for ECPR
Prognostic Factors for ECPR
Mechanical CPR
Operators
Cannulation
Distal Perfusion Cannula
Cannula Size
End Tidal CO₂

Indications for ECPR

1. Grunau B, Scheuermeyer FX, Stub D, et al: Potential Candidates for a Structured Canadian ECPR Program for Out-of-Hospital Cardiac Arrest. *CJEM : Canadian journal of emergency medical care = JCMU : journal canadien de soins médicaux d'urgence*: 1-8, 2016 doi: 10.1017/cem.2016.8.
2. Panchal AR, Berg KM, Hirsch KG, et al: 2019 American Heart Association Focused Update on Advanced Cardiovascular Life Support: Use of Advanced Airways, Vasopressors, and Extracorporeal Cardiopulmonary Resuscitation During Cardiac Arrest: An Update to the American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation*: CIR0000000000000732, 2019 doi: 10.1161/CIR.0000000000000732.
3. Guidelines for ECPR Cases, Version 1.3, in (ELSO) ELSO (ed), Extracorporeal Life Support Organization (ELSO), 2013.

Prognostic Factors for ECPR

4. Otani T, Sawano H, Natsukawa T, et al: Low-flow time is associated with a favorable neurological outcome in out-of-hospital cardiac arrest patients resuscitated with extracorporeal cardiopulmonary resuscitation. *Journal of Critical Care* 48: 15-20, 2018 doi: 10.1016/j.jcrc.2018.08.006.
5. Forti A, Brugnaro P, Rauch S, et al: Hypothermic Cardiac Arrest With Full Neurologic Recovery After Approximately Nine Hours of Cardiopulmonary Resuscitation: Management and Possible Complications. *Annals of Emergency Medicine* 73 (1): 52-57, 2019 doi: 10.1016/j.annemergmed.2018.09.018.
6. Zakhary B, Nanjayya VB, Sheldrake J, Collins K, Ihle JF, Pellegrino V: Predictors of mortality after extracorporeal cardiopulmonary resuscitation. *Crit Care Resusc* 20 (3): 223-230, 2018.

Mechanical CPR

7. Lyon RM, Crawford A, Crookston C, Short S, Clegg GR: The combined use of mechanical CPR and a carry sheet to maintain quality resuscitation in out-of-hospital cardiac arrest patients during extrication and transport. *Resuscitation* 93: 102-6, 2015 doi: 10.1016/j.resuscitation.2015.05.030.
8. Wang PL, Brooks SC: Mechanical versus manual chest compressions for cardiac arrest. *Cochrane Database of Systematic Reviews*, 2018 doi: 10.1002/14651858.CD007260.pub4.
9. Zhu N, Chen Q, Jiang Z, et al: A meta-analysis of the resuscitative effects of mechanical and manual chest compression in out-of-hospital cardiac arrest patients. *Critical Care* 23 (1), 2019 doi: 10.1186/s13054-019-2389-6.

Operators

10. Mooney MR, Arom KV, Joyce LD, et al: Emergency cardiopulmonary bypass support in patients with cardiac arrest. *J Thorac Cardiovasc Surg* 101 (3): 450-4, 1991.

Cannulation

11. Grasselli G, Pesenti A, Marcolin R, et al: Percutaneous vascular cannulation for extracorporeal life support (ECLS): a modified technique. *The International journal of artificial organs* 33 (8): 553-7, 2010.
12. Rupperecht L, Lunz D, Philipp A, Lubnow M, Schmid C: Pitfalls in percutaneous ECMO cannulation. *Heart, lung and vessels* 7 (4): 320-326, 2015.

Echocardiography

13. Fair J, Mallin M, Mallemat H, *et al*: Transesophageal Echocardiography: Guidelines for Point-of-Care Applications in Cardiac Arrest Resuscitation. *Annals of Emergency Medicine* 71 (2): 201-207, 2018 doi: 10.1016/j.annemergmed.2017.09.003.

Distal Perfusion Cannulation

14. Kaufeld T, Beckmann E, Ius F, *et al*: Risk factors for critical limb ischemia in patients undergoing femoral cannulation for venoarterial extracorporeal membrane oxygenation: Is distal limb perfusion a mandatory approach? *Perfusion*: 267659119827231, 2019 doi: 10.1177/0267659119827231.

Cannula Size

15. Foley PJ, Morris RJ, Woo EY, *et al*: Limb ischemia during femoral cannulation for cardiopulmonary support. *Journal of Vascular Surgery* 52 (4): 850-853, 2010 doi: 10.1016/j.jvs.2010.05.012.
16. Dennis M, McCanny P, D'Souza M, *et al*: Extracorporeal cardiopulmonary resuscitation for refractory cardiac arrest: A multicentre experience. *International Journal of Cardiology* 231: 131-136, 2017 doi: 10.1016/j.ijcard.2016.12.003.

End Tidal CO₂

17. Ahn A, Nasir A, Malik H, D'Orazi F, Parnia S: A pilot study examining the role of regional cerebral oxygen saturation monitoring as a marker of return of spontaneous circulation in shockable (VF/VT) and non-shockable (PEA/Asystole) causes of cardiac arrest. *Resuscitation* 84 (12): 1713-6, 2013 doi: 10.1016/j.resuscitation.2013.07.026.
18. Sutton RM, French B, Meaney PA, *et al*: Physiologic monitoring of CPR quality during adult cardiac arrest: A propensity-matched cohort study. *Resuscitation* 106: 76-82, 2016 doi: 10.1016/j.resuscitation.2016.06.018.

Hyperoxia

19. Wang HE, Prince DK, Drennan IR, *et al*: Post-resuscitation arterial oxygen and carbon dioxide and outcomes after out-of-hospital cardiac arrest. *Resuscitation* 120: 113-118, 2017 doi: 10.1016/j.resuscitation.2017.08.244.
20. Youn CS, Park KN, Kim SH, *et al*: The Cumulative Partial Pressure of Arterial Oxygen Is Associated With Neurological Outcomes After Cardiac Arrest Treated With Targeted Temperature Management. *Crit Care Med*, 2017 doi: 10.1097/CCM.0000000000002935.
21. Damiani E, Adrario E, Girardis M, *et al*: Arterial hyperoxia and mortality in critically ill patients: a systematic review and meta-analysis. *Crit Care* 18 (6): 711, 2014 doi: 10.1186/s13054-014-0711-x.

Hypocarbica

22. Lee BK, Jeung KW, Lee HY, *et al*: Association between mean arterial blood gas tension and outcome in cardiac arrest patients treated with therapeutic hypothermia. *The American Journal of Emergency Medicine* 32 (1): 55-60, 2014 doi: 10.1016/j.ajem.2013.09.044.
23. Tolins ML, Henning DJ, Gaieski DF, Grossestreuer AV, Jaworski A, Johnson NJ: Initial arterial carbon dioxide tension is associated with neurological outcome after resuscitation from cardiac arrest. *Resuscitation* 114: 53-58, 2017 doi: 10.1016/j.resuscitation.2017.03.006.

24. Wang C-H, Huang C-H, Chang W-T, et al: Association between early arterial blood gas tensions and neurological outcome in adult patients following in-hospital cardiac arrest. *Resuscitation* 89: 1-7, 2015 doi: 10.1016/j.resuscitation.2015.01.003.

Temperature Management

25. Rolfes C, Muellenbach RM, Lepper PM, et al: Targeted temperature management in patients undergoing extracorporeal life support after out-of-hospital cardiac arrest: an EURO-ELSO 2018 annual conference survey. *Perfusion*: 267659119847033, 2019 doi: 10.1177/0267659119847033.
26. Bartos JA, Carlson K, Carlson C, et al: Surviving refractory out-of-hospital ventricular fibrillation cardiac arrest: Critical care and extracorporeal membrane oxygenation management. *Resuscitation* 132: 47-55, 2018 doi: 10.1016/j.resuscitation.2018.08.030.
27. Yannopoulos D, Bartos JA, Martin C, et al: Minnesota Resuscitation Consortium's Advanced Perfusion and Reperfusion Cardiac Life Support Strategy for Out-of-Hospital Refractory Ventricular Fibrillation. *J Am Heart Assoc* 5 (6), 2016 doi: 10.1161/JAHA.116.003732.

Percutaneous Coronary Interventions¹⁻³

28. Spaulding CM, Joly LM, Rosenberg A, et al: Immediate coronary angiography in survivors of out-of-hospital cardiac arrest. *N Engl J Med* 336 (23): 1629-33, 1997 doi: 10.1056/NEJM199706053362302.
29. Dumas F, Cariou A, Manzo-Silberman S, et al: Immediate Percutaneous Coronary Intervention Is Associated With Better Survival After Out-of-Hospital Cardiac Arrest: Insights From the PROCAT (Parisian Region Out of Hospital Cardiac Arrest) Registry. *Circulation: Cardiovascular Interventions* 3 (3): 200-207, 2010 doi: 10.1161/CIRCINTERVENTIONS.109.913665.
30. Reynolds JC, Callaway CW, El Khoudary SR, Moore CG, Alvarez RJ, Rittenberger JC: Coronary angiography predicts improved outcome following cardiac arrest: propensity-adjusted analysis. *J Intensive Care Med* 24 (3): 179-86, 2009 doi: 10.1177/0885066609332725.

Afterload and left ventricular decompression

31. Abrams D, Combes A, Brodie D: Extracorporeal membrane oxygenation in cardiopulmonary disease in adults. *J Am Coll Cardiol* 63 (25 Pt A): 2769-78, 2014 doi: 10.1016/j.jacc.2014.03.046.
32. Broome M, Donker DW: Individualized real-time clinical decision support to monitor cardiac loading during venoarterial ECMO. *J Transl Med* 14: 4, 2016 doi: 10.1186/s12967-015-0760-1.
33. Burkhoff D, Sayer G, Doshi D, Uriel N: Hemodynamics of Mechanical Circulatory Support. *J Am Coll Cardiol* 66 (23): 2663-2674, 2015 doi: 10.1016/j.jacc.2015.10.017.
34. Donker DW, Brodie D, Henriques JPS, Broome M: Left ventricular unloading during veno-arterial ECMO: a review of percutaneous and surgical unloading interventions. *Perfusion*: 267659118794112, 2018 doi: 10.1177/0267659118794112.
35. Rupprecht L, Florchinger B, Schopka S, et al: Cardiac decompression on extracorporeal life support: a review and discussion of the literature. *ASAIO J* 59 (6): 547-53, 2013 doi: 10.1097/MAT.0b013e3182a4b2f6.
36. Soleimani B, Pae WE: Management of left ventricular distension during peripheral extracorporeal membrane oxygenation for cardiogenic shock. *Perfusion* 27 (4): 326-31, 2012 doi: 10.1177/0267659112443722.

37. Chaparro SV, Badheka A, Marzouka GR, et al: Combined use of Impella left ventricular assist device and extracorporeal membrane oxygenation as a bridge to recovery in fulminant myocarditis. *ASAIO J* 58 (3): 285-7, 2012 doi: 10.1097/MAT.0b013e31824b1f70.
38. Cheng A, Swartz MF, Massey HT: Impella to unload the left ventricle during peripheral extracorporeal membrane oxygenation. *ASAIO J* 59 (5): 533-6, 2013 doi: 10.1097/MAT.0b013e31829f0e52.

Brain Death and Organ Donation

39. Casadio MC, Coppo A, Vargiolu A, et al: Organ donation in cardiac arrest patients treated with extracorporeal CPR: A single centre observational study. *Resuscitation* 118: 133-139, 2017 doi: 10.1016/j.resuscitation.2017.06.001.
40. Sandroni C, D'Arrigo S, Callaway CW, et al: The rate of brain death and organ donation in patients resuscitated from cardiac arrest: a systematic review and meta-analysis. *Intensive Care Med* 42 (11): 1661-1671, 2016 doi: 10.1007/s00134-016-4549-3.
41. West S, Soar J, Callaway CW: The viability of transplanting organs from donors who underwent cardiopulmonary resuscitation: A systematic review. *Resuscitation* 108: 27-33, 2016 doi: 10.1016/j.resuscitation.2016.07.229.