

4. Pages ON, Aubert S, Combes A, Luyt CE, Pavie A, Leger P, et al. Paracorporeal pulsatile biventricular assist device versus extracorporeal membrane oxygenation-extracorporeal life support in adult fulminant myocarditis. *J Thorac Cardiovasc Surg.* 2009;137:194-7.
5. Rubino A, Costanzo D, Stanszus D, Valchanov K, Jenkins D, Sertic F, et al. Central veno-arterial extracorporeal membrane oxygenation (C-VA-ECMO) after cardiothoracic surgery: a single-center experience. *J Cardiothorac Vasc Anesth.* 2018;32:1169-74.
6. Chen Y-S, Lin J-W, Yu H-Y, Ko WJ, Jerng JS, Chang WT, et al. Cardiopulmonary resuscitation with assisted extracorporeal life-support versus conventional cardiopulmonary resuscitation in adults with in-hospital cardiac arrest: an observational study and propensity analysis. *Lancet.* 2008;372:554-61.
7. Pagani FD, Aaronson KD, Dyke DB, Wright S, Swaniker F, Bartlett RH. Assessment of an extracorporeal life support to LVAD bridge to heart transplant strategy. *Ann Thorac Surg.* 2000;70:1977-85.
8. Rousse N, Juthier F, Pinçon C, Hysi I, Banfi C, Robin E, et al. ECMO as a bridge to decision: recovery, VAD, or heart transplantation? *Int J Cardiol.* 2015;187:620-7.
9. Fukuhara S, Takeda K, Kurlansky PA, Naka Y, Takayama H. Extracorporeal membrane oxygenation as a direct bridge to heart transplantation in adults. *J Thorac Cardiovasc Surg.* 2018;155:1607-18.e6.
10. ECMO. Extra Corporal Life Support Registry Report. Ann Arbor, Michigan. Available at: <https://www.elseo.org/Portals/0/Files/Reports/2018/International%20Summary%20January%202018%20First%20Page.pdf>. Accessed December 14, 2018.
11. Cavarocchi NC, Pitcher HT, Yang Q, Karbowski P, Miessau J, Hastings HM, et al. Weaning of extracorporeal membrane oxygenation using continuous hemodynamic transesophageal echocardiography. *J Thorac Cardiovasc Surg.* 2013;146:1474-9.
12. Pappalardo F, Pieri M, Arnaez Corada B, Ajello S, Melisurgo G, De Bonis M, et al. Timing and strategy for weaning from venoarterial ECMO are complex issues. *J Cardiothorac Vasc Anesth.* 2015;29:906-11.
13. Platts DG, Sedgwick JF, Burstow DJ, Mullany DV, Fraser JF. The role of echocardiography in the management of patients supported by extracorporeal membrane oxygenation. *J Am Soc Echocardiogr.* 2012;25:131-41.
14. Santise G, Panarello G, Ruperto C, Turrisi M, Pilato G, Giunta A, et al. Extracorporeal membrane oxygenation for graft failure after heart transplantation: a multidisciplinary approach to maximize weaning rate. *Int J Artif Organs.* 2014;37:706-14.
15. Aissaoui N, Luyt C-E, Leprince P, Trouillet JL, Leger P, Pavie A, et al. Predictors of successful extracorporeal membrane oxygenation (ECMO) weaning after assistance for refractory cardiogenic shock. *Intensive Care Med.* 2011;37:1738-45.
16. Aissaoui N, El-Banayosy A, Combes A. How to wean a patient from veno-arterial extracorporeal membrane oxygenation. *Intensive Care Med.* 2015;41:902-5.
17. Chang W-W, Tsai F-C, Tsai T-Y, Chang CH, Jenq CC, Chang MY, et al. Predictors of mortality in patients successfully weaned from extracorporeal membrane oxygenation. *PLoS One.* 2012;7:e42687.
18. García-Gigorro R, Renes-Carreño E, Pérez-Vela JL, Marin-Mateos H, Gutierrez J, Corres-Peiretti MA, et al. Mechanical support with venoarterial extracorporeal membrane oxygenation (ECMO-VA): short-term and long-term prognosis after a successful weaning. *Med Intensiva.* 2017;41:513-22.
19. Criteria Committee, New York Heart Association, Inc. *Diseases of the Heart and Blood Vessels. Nomenclature and Criteria for Diagnosis.* 6th ed. Boston, MA: Little, Brown and Co; 1964. 114.
20. Vallabhajosyula P, Kramer M, Lazar S, McCarthy F, Rame E, Wald J, et al. Lower-extremity complications with femoral extracorporeal life support. *J Thorac Cardiovasc Surg.* 2016;151:1738-44.
21. Garan AR, Eckhardt C, Takeda K, Topkara VK, Clerkin K, Fried J, et al. Predictors of survival and ability to wean from short-term mechanical circulatory support device following acute myocardial infarction complicated by cardiogenic shock. *Eur Heart J.* 2018;7:755-65.
22. Schmidt M, Zogheib E, Rozé H, Repesse X, Lebreton G, Luyt CE, et al. The PRESERVE mortality risk score and analysis of long-term outcomes after extracorporeal membrane oxygenation for severe acute respiratory distress syndrome. *Intensive Care Med.* 2013;39:1704-13.
23. Li C-L, Wang H, Jia M, Ma N, Meng X, Hou X-T. The early dynamic behavior of lactate is linked to mortality in postcardiotomy patients with extracorporeal membrane oxygenation support: a retrospective observational study. *J Thorac Cardiovasc Surg.* 2015;149:1445-50.
24. Boulate D, Luyt C-E, Pozzi M, et al. Acute lung injury after mechanical circulatory support implantation in patients on extracorporeal life support: an unrecognized problem. *Eur J Cardiothorac Surg.* 2013;44:544-50.
25. Pappalardo F, Schulte C, Pieri M, Schrage B, Contri R, Soeffker G, et al. Concomitant implantation of Impella® on top of veno-arterial extracorporeal membrane oxygenation may improve survival of patients with cardiogenic shock. *Eur J Heart Fail.* 2017;19:404-12.
26. Scherer M, Moritz A, Martens S. The use of extracorporeal membrane oxygenation in patients with therapy refractory cardiogenic shock as a bridge to implantable left ventricular assist device and perioperative right heart support. *J Artif Organs.* 2009;12:160-5.
27. Marasco SF, Lo C, Murphy D, Summerhayes R, Quayle M, Zimmet A, et al. Extracorporeal life support bridge to ventricular assist device: the double bridge strategy. *Artif Organs.* 2016;40:100-6.
28. Unai S, Yamane K, Tanaka D, Cook G, Hirose H, Cavarocchi NC, et al. Quality of life and mid-term survival of patients bridged with extracorporeal membrane oxygenation to left ventricular assist device. *ASAIO J.* 2017;63:273-8.

Key Words: extracorporeal membrane oxygenation, cardiogenic shock, in-hospital mortality

Discussion



Dr Amit A. Pawale (New York, NY). You described the independent predictors of in-hospital mortality after weaning from VA-ECMO and their midterm survival. What proportion of patients who died within 24 hours were excluded as “terminally weaned” or in your article as a poor decision?



Dr Federico Sertic (Philadelphia, Pa). There were 28 patients who died within 24 hours after weaning.

Dr Pawale. You mentioned prolonged ECMO support as a cause of mortality. Was it a linear trend in mortality with duration of support or was there a day after which the mortality went up suddenly?

Dr Sertic. We identified a linear correlation with an inflection point at 13.5 days associated with 80% in-hospital mortality.

Dr Pawale. So, 13.5 days on support?

Dr Sertic. On support, yes.

Dr Pawale. In your 3-year follow-up of all the patients who were weaned from VA-ECMO, did any of these patients get an LVAD or a transplant during these 3 years?

Dr Sertic. None of the patients underwent LVAD or heart transplant during subsequent admissions at our institution. For some of the patients, referred from out of the region, this information was not available.

Dr Pawale. At the wean from the ECMO, in what proportion of patients did you use adjuncts like a balloon pump, leaving the Impella in or using VV-ECMO for your pulmonary dysfunction patients?

Dr Sertic. Approximately 25% of the patients had an intra-aortic balloon pump to assist weaning; 5 patients were transitioned from VA to VV-ECMO, and we supported 5 patients with the Impella along with ECMO. We usually removed

the ECMO leaving the Impella in, and then we assessed for myocardial recovery. If the heart did not recover within a few days (2-3), we moved to long-term mechanical support.



Dr Mark S. Slaughter (*Louisville, Ky*). You say ejection fraction (EF) at the time of weaning. It sounds as though it's a heterogeneous type of support, though. So if some are on a balloon pump and ECMO, some are on Impella and ECMO, some are on multiple inotropes and ECMO, was there any standardization or you just picked a day and that was the day of weaning as opposed to they are on 4 liters of ECMO, perhaps we can get the Impella out, they are down to 1 inotrope, now because they are EF, or you picked a day, because otherwise it seems arbitrary.

Dr Sertic. We chose the EF when a patient was deemed weanable after a successful weaning trial with transesophageal echocardiography assessment. The patient was then electively decannulated the following day in the operating room.

Dr Slaughter. If we are going to take ECMO out, we tend to wean it down over 5 days, and we get them down to about a liter and leave them at a liter for about 24 hours and then assess their ventricular function before we would ever take it out.



Dr Marc Ruel (*Ottawa, Ontario, Canada*). You have a component in your article of successful weaning from ECMO; I think there were 90 such patients or so. You also reported patients who were discharged from hospital, which was a smaller number. Therefore, what is your definition of successful weaning from ECMO?

Dr Sertic. That's the main reason why we decided to do this study. The discrepancy between weaned and discharged patients. We wanted studies in the literature that have considered weaning successful if a patient is alive for more than 30 days and other studies if a patient is alive for more than 48 hours after weaning, which may be arbitrary. Therefore, we wanted to go into more depth and understand which factors need to be considered to achieve a successful weaning to try and reduce the gap between weaned and discharged patients, and discern when to consider other heart replacement options.



Dr Christian Bermudez (*Pittsburgh, Pa*). I am Christian Bermudez, the principal investigator of this study. I want to make a few comments regarding the weaning process and why we did this study.

A number of reports have been done regarding outcomes of ECMO, but we

don't understand clearly what parameters should be used to have a safe and effective ECMO weaning. The effects of EF or valvular abnormalities at the time of weaning are poorly understood. Weaning could be done in a slow fashion as you do. We do it in a more rapid fashion. We do serial echos, we lower the flow for a few minutes, for 20 minutes, up to 1 liter, and when we see that we have stable hemodynamics with a relatively acceptable EF (~25%-30%), then we decide to take the patient back to the operating room to do the weaning, ideally without mechanical support. The cases that we have weaned with the Impella were because they already had the Impella in place. We don't add the Impella after weaning because that patient may require long-term support. We consider that a failed weaning.

So we looked at the EF. We were concerned about the minimum EF needed to safely wean. As you see, in some you have below 30%. It's a complex process. On top of that, if you have mitral regurgitation with severe tricuspid regurgitation, you already see a trend toward poorer outcomes.

We excluded patients who died within 24 hours, because we wanted to exclude the patients who were terminally weaned. Sometimes patients are not candidates for advanced therapies. In those cases, when advanced options are not possible, frequently you just take the ECMO out and pray. We wanted to exclude those patients from the study. We wanted to see who survived at least 24 hours even though the definition of success has been 30 days, which I consider arbitrary. We probably should consider patient success when a patient goes home.

So this is an area that requires further analysis. How do we do it better? What do we consider successful weaning? When is it time to go to long-term device instead of trying multiple short-term options including Impellas, TandemHeart, and balloons, which in our experience has been associated with modest outcomes. We have experienced that a combination of multiple short-term devices can be done, but in general is not a great option and has led to poor outcomes. We consider that if they are not weanable from ECMO, a rapid VAD evaluation should be performed, and the patient should be bridged to a long-term device as soon as possible. As you see, the outcomes reflect that.

Dr Slaughter. I may have misunderstood your analysis, but I got the impression that ECMO was a risk factor for death or was it duration of support?

Dr Sertic. A risk factor for mortality was the prolonged duration of ECMO support.

Dr Slaughter. So the idea is if they are not better in about 2 weeks, then the answer is they are not going to get myocardial recovery or nothing?

Dr Sertic. Yes, correct.