EDITORIAL

Electrocardiometry Fluid Responsiveness in Pediatric Septic Shock

Dhiren Gupta[1], Sandeep Dhingra[2]

Abstract

Hemodynamic monitoring and categorization of patients based on fluid responsiveness is the key to decisions prompting the use of fluids and vasoactive agents in septic shock. Distinguishing patients who are going to benefit from fluids from those who will not is of paramount importance as large amounts of fluids used conventionally based on surviving sepsis guidelines may be detrimental. Noninvasive monitoring techniques for the assessment of various cardiovascular parameters are increasingly accepted as the current medical practice. Electrical cardiometry (EC) is one such method for the determination of stroke volume, cardiac output (CO), and other hemodynamic parameters and is based on changes in electrical conductivity within the thorax. It has been validated against gold standard methods such as thermodilution [Malik V, Subramanian A, Chauhan S, et al. World J 2014;4(7):101–108] and is being used more often as a point-of-care noninvasive technique for hemodynamic monitoring. EC is Food and Drug Administration approved and validated for use in neonates, children, and adults. A meta-analysis in 2016, including 20 studies and 624 patients comparing the accuracy of CO measurement by using EC with other noninvasive technologies, demonstrated that EC was the device that offered the most correct measurements. The article in the current issue of *IJCCM* by Rao et al. (2020) has extended the use of EC to categorize pediatric patients with septic shock into vasodilated and vasoconstricted states based on systemic vascular resistance and correlate the categorization clinically. The authors also studied the changes in hemodynamic parameters after an isotonic fluid bolus of 20 mL/kg was administered. This is a pilot prospective observational study of 30 patients, which has given an insight into physiological rearrangements following fluid administration in patients with septic shock.

Keywords: Electrocardiometry, Fluid responsiveness, Functional echocardiography, Septic shock.

Indian Journal of Critical Care Medicine (2021): 10.5005/jp-journals-10071-23745

Hemodynamic monitoring and categorization of patients based on fluid responsiveness is the key to decisions prompting the use of fluids and vasoactive agents in septic shock. Distinguishing patients who are going to benefit from fluids from those who will not is of paramount importance as large amounts of fluids used conventionally based on surviving sepsis guidelines[1] may be detrimental. Noninvasive monitoring techniques for the assessment of various cardiovascular parameters are increasingly accepted as the current medical practice. Electrical cardiometry (EC) is one such method for the determination of stroke volume (SV), cardiac output (CO), and other hemodynamic parameters and is based on changes in electrical conductivity within the thorax.[2] It has been validated against gold standard methods such as thermodilution[3] and is being used more often as a point-of-care noninvasive technique for hemodynamic monitoring.

The EC monitor measures the change in electrical conductivity as a small current is passed through the electrodes placed on the neck and thorax. The change in electrical conductivity is brought about by the alignment of red blood cells from random to streamlined state before and after the opening of aortic valve, respectively. Using patented algorithms, the EC monitor derives peak aortic acceleration, left ventricle ejection time, SV, and cardiac index (CI). EC has proven useful for measuring CO in a wide spectrum of patient conditions and populations including neonates and children; however, its accuracy in measuring absolute values of SV has been inconsistent in published research.[4,5]

Fluid responsiveness in septic shock remains a challenge with no one method giving reliable and reproducible results. Semiquantitative and quantitative assessments of the preload, contractility, and afterload using noninvasive tools have been suggested, in conjunction with clinical and laboratory assessments, to direct shock management and select between vasopressors, vasodilators, and inotropes or a combination of these drugs. In a review by Fathi et al.,[6] echocardiography, transthoracic/transesophageal Doppler, and EC were compared. EC had the advantage of user independence with the ability for continuous monitoring of multiple parameters used for hemodynamic monitoring and decision-making.

Septic shock has various hemodynamic profiles, with children presenting with different combinations of changes in CO and systemic vascular resistance (SVR) that rapidly change over time.[7] Moreover, it has been found that as much as 50% of patients presenting with septic shock will not be fluid responsive from early on due to sepsis-induced myocardial depression (SMD) and changed sensitivity to adrenergic hormones.[8] Mortality can be

[1]Division of Pediatric Emergency and Critical Care, Department of Pediatrics, Institute of Child Health, Sir Ganga Ram Hospital, New Delhi, India

[2]Department of Pediatrics, Command Hospital, Panchkula, Haryana, India

Corresponding Author: Sandeep Dhingra, Department of Pediatrics, Command Hospital, Panchkula, Haryana, India, Phone: +91 7030495955, e-mail: dhingrasandeep@yahoo.co.in

How to cite this article: Gupta D, Dhingra. Electrocardiometry Fluid Responsiveness in Pediatric Septic Shock. Indian J Crit Care Med 2021;25(2):123–125.

Source of support: Nil

Conflict of interest: None

high in patients with septic shock with persisting low CO after fluid resuscitation. Fluid bolus therapy is essential for improving SV and hence CO until a certain limit according to the Frank–Starling curve. Extra fluids become hazardous, as they accumulate in various body tissues including the lungs and the liver manifesting clinically with deterioration in condition. Because of all these factors, there is a definite need for bedside noninvasive tools to assess fluid responsiveness and prevent its overload.

Among the noninvasive methods, the best studied are the 'inferior vena cava (IVC) distensibility index for the evaluation of preload volume status and fluid responsiveness, measured by ultrasound. In septic shock patients, IVC distensibility index values of >18% indicate fluid responsiveness with 90% sensitivity and 90% specificity.[9] However, there are many prerequisites that must be met to guarantee precise values. It is operator dependent and serial measurements are needed. Functional echocardiography and Doppler are other tools for noninvasive serial measurements of CO and SV and to decide resuscitative fluid bolus therapy and assessment of its response. An increase in SV by 10–15% indicates fluid responsiveness in septic shock.[10] Accurate measurements of the SV by these methods are time-consuming, operator dependent, and require manual calculations. Thermodilution, through a pulmonary artery catheter (PAC), is the gold standard method for measurement of CO, but it is invasive, time-consuming, and impractical in infants and small-sized children. Validation of transthoracic Doppler in children against the gold standard PAC thermodilution method has shown conflicting results.[11]

EC is Food and Drug Administration approved and validated for use in neonates, children, and adults. A meta-analysis in 2016, including 20 studies and 624 patients comparing the accuracy of CO measurement by using EC with other noninvasive technologies, demonstrated that EC was the device that offered the most correct measurements.[12] However, there was a high heterogeneity among the individual studies. Furthermore, the accuracy of cardiometry may be affected by severe tachycardia or bradycardia, aortic regurgitation, chest wall edema, and high-frequency ventilation.

CO-guided fluid therapy has recently been used using transpulmonary thermodilution method in young children with kidney transplant.[13] An algorithm based on CO was used to guide the administration of fluids, norepinephrine, and dobutamine, which led to favorable renal results and a trend toward less fluids in favor of norepinephrine.

The article in the current issue of *IJCCM* by Rao et al.[14] has extended the use of EC to categorize pediatric patients with septic shock into vasodilated and vasoconstricted states based on SVR and correlate the categorization clinically. The authors also studied the changes in hemodynamic parameters after an isotonic fluid bolus of 20 mL/kg was administered. This is a pilot prospective observational study of 30 patients, which has given an insight into physiological rearrangements following fluid administration in patients with septic shock.

Clinical examination of their cohort revealed that 19 (63.3%) children were having cold shock, out of which 5 (16.6%) required reclassification as a warm shock based on CI and SVR readings on EC monitor. This discrepancy between cold vs warm shock based on clinical examination and objective parameters was also reported by Ranjith et al.[15] In their study 'on multimodal hemodynamic monitoring of children in septic shock', 41 of 48 patients (85.5%) had vasodilatory shock on invasive blood pressure monitoring with pulse pressure of >40 mm Hg even though 14 (29%) had initially been classified clinically as cold shock. Clinical classification has been found to be unreliable due to the presence of SMD, vasoplegia, and sometimes uncorrected hypovolemia, which can lead to peripheral vasoconstriction in a centrally vasodilated state.

Rao et al.[14] have made similar observations by taking into consideration SVR values of 1000–1600 dyn sec/cm^5/m^2 as normal, and values below and above these limits as vasodilated and vasoconstricted states, respectively. They also observed that 5 (16.6%) patients had a pulse pressure of <40 mm Hg on IBP monitoring, though were in a vasodilated state based on SVR measurements, implying that a pulse pressure of >40 mm Hg may not appropriately classify patients into vasodilated state if compared with SVR. This finding needs validation in larger studies. Fluid responsiveness was also studied based on variation in CI in response to volume loading (20 mL/kg normal saline) and an increase of 10% was taken as responsive. It was seen in 10 of 14 (71.4%) patients with vasoconstricted shock while in only 6 of 16 (37.5%) in the vasodilated group. The clinical parameters of heart rate and mean arterial pressure postbolus did not show any significant difference in fluid responders as compared to nonresponders exposing their limitation in bedside monitoring of shock. Fluid responders had better outcomes, higher lactate clearance, and lower VIS scores with higher percentage of clinical resolution of shock than in nonresponders.

Patients in vasoconstricted state but unresponsive to fluid signified that there are other factors which can affect CI. Sepsis-induced myocardial dysfunction was noted in these children, underscoring the utility of bedside echocardiography. Even in the study by Ranjith et al.[15] echo analysis led to better judgment of intravascular volume and myocardial function in patients with fluid refractory septic shock, which ultimately led to improved outcomes.

This study endorses the need for continuous preferably noninvasive hemodynamic monitoring for initial classification of vasodilated vs. vasoconstricted states with IBP-derived pulse pressure or SVR as the additional parameters to clinical monitoring. Utility of functional echocardiography in identifying patients with SMD who may not benefit from further fluid therapy is also highlighted. Though EC has not been used for guiding interventions, it provides an insight into the physiological aspects of hemodynamic monitoring of children with septic shock.

Since there is no ideal diagnostic test for hypovolemia, a combination of clinical signs, IVC findings, central venous pressure (CVP) trends, echocardiographic estimation, EC, and other noninvasive bedside assessment methods of preload, contractility, and afterload provide a rational guide to fluid therapy and selection of appropriate cardiovascular medications. Following the trend of hemodynamic parameters instead of individual readings allows for personalized management and proper titration of therapy over time. With paucity of data analyzing the effect of noninvasive bedside hemodynamic monitoring on mortality in children with septic shock, adequately powered outcome studies are urgently needed.

Orcid

Dhiren Gupta https://orcid.org/0000-0002-8244-0768
Sandeep Dhingra https://orcid.org/0000-0002-2993-5112

References

1. Rhodes A, Evans LE, Alhazzani W, Levy MM, Massimo A, Ricard F, et al. Surviving sepsis campaign: international guidelines for management of sepsis and septic shock: 2016. Crit Care Med 2017;45(3):486–552. DOI: 10.1007/s00134-017-4683-6.
2. Osypka M. An introduction to electrical cardiometry™. Berlin, Germany; 2009, pp. 1–10. Available from: http://www.cardiotronic.net (accessed 30 December 2020).
3. Malik V, Subramanian A, Chauhan S, Hote M. Correlation of electric cardiometry and continuous thermodilution cardiac output monitoring systems. World J Cardiovasc Surg 2014;4(7):101–108. DOI: 10.4236/wjcs.2014.47016.
4. Narula J, Chauhan S, Ramakrishnan S, Gupta SK. Electrical cardiometry: a reliable solution to cardiac output estimation in children with structural heart disease. J Cardiothorac Vasc Anesth 2017;31(3):912–917. DOI: 10.1053/j.jvca.2016.12.009.
5. Taylor K, Rotta GL, McCrindle BW, Manlhiot C, Redington A, Holtby H. A comparison of cardiac output by thoracic impedance and direct fick in children with congenital heart disease undergoing diagnostic cardiac catheterization. J Cardiothorac Vasc Anesth 2011;25(5):776–779. DOI: 10.1053/j.jvca.2011.05.002.
6. Fathi EM, Narchi H, Chedid F. Non-invasive hemodynamic monitoring of septic shock in children. World J Methodol 2018;8(1):1–8. DOI: 10.5662/wjm.v8.i1.1.
7. Wong HR, Dalton HJ. The PICU perspective on monitoring hemodynamics and oxygen transport. Pediatr Crit Care Med 2011; 12(4 Suppl.):S66–S68. DOI: 10.1097/PCC.0b013e3182211c60.
8. Cariou A, Pinsky MR, Monchi M, Laurent I, Vinsonneau C, Chiche JD, et al. Is myocardial adrenergic responsiveness depressed in human septic shock? Intensive Care Med 2008;34(5):917–922. DOI: 10.1007/s00134-008-1022-y.
9. Barbier C, Loubières Y, Schmit C, Hayon J, Ricôme JL, Jardin F, et al. Respiratory changes in inferior vena cava diameter are helpful in predicting fluid responsiveness in ventilated septic patients. Intensive Care Med 2004;30(9):1740–1746. DOI: 10.1007/s00134-004-2259-8.
10. Lemson J, Nusmeier A, van der Hoeven JG. Advanced hemodynamic monitoring in critically ill children. Pediatrics 2011;128(3):560–571. DOI: 10.1542/peds.2010-2920.
11. Beltramo F, Menteer J, Razavi A, Khemani RG, Szmuszkovicz J, Newth CJ, et al. Validation of an ultrasound cardiac output monitor as a bedside tool for pediatric patients. Pediatr Cardiol 2016;37(1):177–183. DOI: 10.1007/s00246-015-1261-y.
12. Suehiro K, Joosten A, Murphy LS, Desebbe O, Alexander B, Kim SH, et al. Accuracy and precision of minimally-invasive cardiac output monitoring in children: a systematic review and meta-analysis. J Clin Monit Comput 2016;30(5):603–620. DOI: 10.1007/s10877-015-9757-9.
13. Voet M, Nusmeier A, Lerou J, Luijten J, Cornelissen M, Lemson J. Cardiac output-guided hemodynamic therapy for adult living donor kidney transplantation in children under 20 kg: a pilot study. Paediatr Anaesth 2019 Sep;29(9):950–958. DOI: 10.1111/pan.13705.
14. Rao SS, Reddy M, Lalitha AV, Ghosh S. Electrocardiometry for hemodynamic categorisation and assessment of fluid responsiveness in pediatric septic shock: a pilot observational study. Indian J Crit Care Med 2021;25(2):185–192.
15. Ranjit S, Aram G, Kissoon N, Ali MK, Natraj R, Shresti S, et al. Multimodal monitoring for hemodynamic categorization and management of pediatric septic shock: a pilot observational study. Pediatr Crit Care Med 2014 Jan;15(1):e17–e26. DOI: 10.1097/PCC.0b013e3182a5589c.