

COMMENTARY

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Passive leg raising test with minimally invasive monitoring: the way forward for guiding septic shock resuscitation?

Patrick M. Honore* and Herbert D. Spapen

Abstract

Background: Swift and adequate fluid loading is a cornerstone of septic shock therapy. Yet, careful assessment of volume responsiveness and volume amount during the resuscitation process is a prerequisite. Both overzealous initial fluid administration and late fluid overload are harmful and may be associated with increased mortality.

Main body: Static (i.e., central venous or pulmonary artery occlusion) pressure readings are erroneous for monitoring fluid resuscitation and should be abandoned. Dynamic measurements (i.e., stroke volume and pulse pressure variation) better predict fluid responsiveness than static filling pressures but the conditions necessary for these parameters to correctly evaluate preload dependency are frequently not met. The passive leg raising maneuver as a means to alter biventricular preload in combination with real-time measurement of cardiac output changes is an easy-to-use, fast, relatively unbiased, and accurate bedside test to guide fluid management and to avoid fluid overload during early septic shock treatment. Moreover, PLR may also be particularly useful to assist various treatments that trigger fluid removal during the “de-resuscitation” phase of septic shock.

Conclusions: The passive leg raising maneuver in combination with real-time measurement of cardiac output changes is an easy-to-use, fast, relatively unbiased, and accurate bedside test to guide fluid management during septic shock.

Keywords: Passive leg raising test, Minimally invasive monitoring, Fluid challenge, Volume loading, Fluid removal, Septic shock, Continuous renal replacement therapy

Main text

The recently published Surviving Sepsis Campaign guidelines strongly recommend ample volume resuscitation during the first day of septic shock treatment [1]. Such aggressive fluid challenge is intended to rapidly improve tissue perfusion by increasing stroke volume and thus cardiac output (CO). However, only half of the patients respond to a fluid load, its hemodynamic benefit is short-lived, and overzealous fluid administration during the first 24 h after admission was recently found to significantly increase mortality [2, 3]. The presence of hypotension and shock requires correct assessment of volume status (cardiac preload) and accurate evaluation of the response to a fluid challenge (volume responsiveness). Traditionally, the central venous and pulmonary artery occlusion pressure

have been used as surrogate estimates of respectively right and left ventricular preload. Yet, a large amount of studies have demonstrated that these static “filling” pressures poorly predict fluid responsiveness and are unable to guide fluid resuscitation [4]. Pursuing higher filling pressures may even have deleterious effects on kidney function by enhancing venous congestion and blocking venous outflow [5].

At the beginning of this millennium, several authors proposed to use physiologic heart-lung interactions during positive pressure ventilation as more reliable predictors of fluid responsiveness in septic shock [6]. Variations in both pulse pressure (PPV) and stroke volume (SVV) were found to be better tools to assess volume responsiveness than static pressure monitoring [7]. However, enthusiasm became curbed when monitoring of these dynamic variables failed to obtain optimal volume loading in both anesthetized [8] and critically ill patients [9]. Moreover, PPV and SVV measurements are reliable only under strict conditions and become significantly biased or impossible

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to interpret in spontaneously breathing patients, low tidal volume ventilation, and the presence of cardiac arrhythmias [10]. By far, the most simple and performant method to determine fluid responsiveness at the bedside is the passive leg raising (PLR) test. Lifting the patient's legs from zero to about 45° produces a rapid, temporary, and reversible increase in ventricular preload by increasing venous return from the lower extremities. PLR thus perfectly mimics fluid administration without having to give exogenous fluids and is most effective when performed in association with minimally invasive monitoring for real-time tracking of changes in CO [11]. In a recent issue of the *Journal of Intensive Care*, Krige et al. prospectively investigated the use of a novel generation Vigileo FloTrac™ system during a PLR maneuver in medico-surgical patients with vasopressor-dependent circulatory shock [12]. The study population almost entirely consisted of patients with septic shock or severe systemic inflammation (pancreatitis, intestinal ischemia). These investigators found that the recorded changes in CO, using a $\geq 9\%$ increase as cut point, predicted preload dependency with good sensitivity and specificity. This study definitely contributes to the growing literature on easy-to-use bedside monitoring of early volume resuscitation. However, evident limitations must be noticed. The sample size is small, all patients were mechanically ventilated from which only 20% were on spontaneous breathing, and the choice of bolus dose and cut-off value to define fluid responders remains arbitrary.

Through the years, awareness has risen that after initial aggressive fluid resuscitation the focus should shift towards obtaining a net and even negative fluid balance [13]. Late liberal fluid administration indeed is associated with increased morbidity and mortality [14]. This is even more relevant in septic shock where excessive volume expansion in association with release of pro-inflammatory and vasoactive peptides provokes significant damage to the endothelial glycocalyx [15]. As a result, intravascular fluid (including most of the resuscitation liquid!) will pass into the interstitial space and cause deleterious tissue edema. Eliminating excess fluid was associated with better survival in patients with acute respiratory distress syndrome [16] and septic shock [17]. However, methods to achieve this goal (e.g., intermittent hemodialysis, continuous renal replacement therapy, high-dose diuretics, and osmotic “tricks” such as rapid infusion of highly concentrated albumin or hypertonic saline, either alone or in combination) [18–20] have not been standardized. Moreover, too much fluid removal could impair CO, cause unwarranted bouts of hypotension, or impair renal function [21, 22]. Assuring the delicate volume equilibrium during the post-resuscitation phase necessitates accurate and reproducible monitoring. Dynamic measurements may not be appropriate in this setting. Patients either will be

rapidly freed from sedation and started on spontaneous (supported) breathing or develop organ failure necessitating specific ventilator or extracorporeal support. In addition, volume shifting is a possible trigger among others for cardiac dysrhythmias [23]. PLR testing may be particularly useful in this situation. Monnet et al. recently observed in a predominantly septic shock population that preload dependence as assessed by a positive PLR test (i.e., a $>9\%$ increase in baseline cardiac index) predicted hemodynamic intolerance of dialysis-induced fluid removal [24]. Taken together, the studies of Krige et al. [12] and Monnet et al. [24] definitely set the pace for a more efficient fluid management in patients with septic shock. Any approach to volume handling in septic shock, however, remains an intricate endeavor and should be individualized. During resuscitation, CO is not only influenced by fluid administration but also by changes in myocardial contractility and compliance. Comorbid conditions such as pre-existing kidney injury and severely impaired lung function may determine both volume and speed of fluid resuscitation. Finally, the impact of ongoing inflammation and concomitant endothelial damage on fluid shifts remains largely unforeseeable.

Conclusions

In conclusion, PLR testing in combination with more sophisticated real-time hemodynamic monitoring actually seems to be the most appropriate method to guide a bedside “do not harm” volume resuscitation strategy in septic shock. Future studies should assess the PLR maneuver using calibrated intermittent (e.g., echocardiography) or continuous (e.g., Pulse Contour Cardiac Output) monitoring and evaluate whether this test could become pivotal in managing fluid removal during the “de-resuscitation” phase of septic shock.

Abbreviations

CO: Cardiac output; PLR: Passive leg raising; PWV: Pulse pressure variation; SVV: Stroke volume variation

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References

- Rhodes A, Evans LE, Alhazzani W, Levy MM, Antonelli M, Ferrer R, et al. Surviving Sepsis Campaign: International Guidelines for Management of Sepsis and Septic Shock: 2016. *Intensive Care Med.* 2017;43:304–77.
- Marik PE, Lemson J. Fluid responsiveness: an evolution of our understanding. *Br J Anaesth.* 2014;112:617–20.
- Marik PE, Linde-Zwirble WT, Bittner EA, Sahatjian J, Hansell D. Fluid administration in severe sepsis and septic shock, patterns and outcomes: an analysis of a large national database. *Intensive Care Med.* 2017;43:625–32.
- Cecconi M, De Backer D, Antonelli M, Beale R, Bakker J, Hofer C, et al. Consensus on circulatory shock and hemodynamic monitoring. Task force of the European Society of Intensive Care Medicine. *Intensive Care Med.* 2014;40:1795–815.
- Legrand M, Dupuis C, Simon C, Gayat E, Mateo J, Lukaszewicz AC, Payen D. Association between systemic hemodynamics and septic acute kidney injury in critically ill patients: a retrospective observational study. *Crit Care.* 2013;17:R278.
- Reuter DA, Bayerlein J, Goepfert MS, Weis FC, Kilger E, Lamm P, et al. Influence of tidal volume on left ventricular stroke volume variation measured by pulse contour analysis in mechanically ventilated patients. *Intensive Care Med.* 2003;29:476–80.
- Marik PE, Cavallazzi R, Vasu T, Hirani A. Dynamic changes in arterial waveform derived variables and fluid responsiveness in mechanically ventilated patients: a systematic review of the literature. *Crit Care Med.* 2009;37:2642–7.
- Cannesson M, Le Manach Y, Hofer CK, Goarin JP, Lehot JJ, Vallet B, et al. Assessing the diagnostic accuracy of pulse pressure variations for the prediction of fluid responsiveness: a “gray zone” approach. *Anesthesiology.* 2011;115:231–41.
- Mahjoub Y, Lejeune V, Muller L, Perbet S, Zieleskiewicz L, Bart F, et al. Evaluation of pulse pressure variation validity criteria in critically ill patients: a prospective observational multicentre point-prevalence study. *Br J Anaesth.* 2014;112:681–5.
- Monnet X, Marik PE, Teboul JL. Prediction of fluid responsiveness: an update. *Ann Intensive Care.* 2016;6:111.
- Cherpanath TG, Hirsch A, Geerts BF, Lagrand WK, Leeftang MM, Schultz MJ, et al. Predicting fluid responsiveness by passive leg raising: a systematic review and meta-analysis of 23 clinical trials. *Crit Care Med.* 2016;44:981–91.
- Krige A, Bland M, Fanshawe T. Fluid responsiveness prediction using Vigileo FloTrac measured cardiac output change during passive leg raise test. *J Intensive Care.* 2016;4:63.
- Boyd JH, Forbes J, Nakada TA, Walley KR, Russell JA. Fluid resuscitation in septic shock: a positive fluid balance and elevated central venous pressure are associated with increased mortality. *Crit Care Med.* 2011;39:259–65.
- Murphy CV, Schramm GE, Doherty JA, Reichley RM, Gajic O, et al. The importance of fluid management in acute lung injury secondary to septic shock. *Chest.* 2009;136:102–9.
- Lee WL, Slutsky AS. Sepsis and endothelial permeability. *N Engl J Med.* 2010;363:689–91.
- Tagami T, Nakamura T, Kushimoto S, Tosa R, Watanabe A, Kaneko T, et al. Early-phase changes of extravascular lung water index as a prognostic indicator in acute respiratory distress syndrome patients. *Ann Intensive Care.* 2014;4:27.
- Alsous F, Khamiees M, DeGirolamo A, Amoateng-Adjepong Y, Manthous CA. Negative fluid balance predicts survival in patients with septic shock: a retrospective pilot study. *Chest.* 2000;117:1749–54.
- Murugan R, Hoste E, Mehta RL, Samoni S, Ding X, Rosner MH, Acute Disease Quality Initiative (ADQI) Consensus Group, et al. Precision fluid management in continuous renal replacement therapy. *Blood Purif.* 2016;42:266–78.
- Rimmelé T, Karajala V, Murugan R, Kellum JA. Use of loop diuretics in the critically ill. *Contrib Nephrol.* 2010;165:219–25.
- Paterna S, Di Gaudio F, La Rocca V, Balistreri F, Greco M, Torres D, et al. Hypertonic saline in conjunction with high-dose furosemide improves dose-response curves in worsening refractory congestive heart failure. *Adv Ther.* 2015;32:971–82.
- Wang N, Jiang L, Zhu B, Wen Y, Xi XM. The Beijing Acute Kidney Injury Trial (BAKIT) workgroup. Fluid balance and mortality in critically ill patients with acute kidney injury: a multicenter prospective epidemiological study. *Crit Care.* 2015;19:371.
- Ostermann M, Oudemans-van Straaten HM, Forni LG. Fluid overload and acute kidney injury: cause or consequence? *Crit Care.* 2015;19:443.
- Kuipers S, Klein Klouwenberg PM, Cremer OL. Incidence, risk factors and outcomes of new-onset atrial fibrillation in patients with sepsis: a systematic review. *Crit Care.* 2014;18:688.
- Monnet X, Cipriani F, Camous L, Sentenac P, Dres M, Krastinova E, et al. The passive leg raising test to guide fluid removal in critically ill patients. *Ann Intensive Care.* 2016;6:46.

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