Accuracy of Passive Leg Raising Test in Prediction of Fluid Responsiveness in Children

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\textbf{Abstract}

\textbf{Aim:} To assess the accuracy of the passive leg raising (PLR) test to anticipate fluid responsiveness in critically ill children under age of 5 years.

\textbf{Materials and methods:} A prospective observational study was conducted, in a university hospital pediatric intensive care unit from June 1, 2017, to January 30, 2018. Hemodynamic parameters including stroke volume using bedside transthoracic echocardiography were assessed at baseline (45° semi-recumbent position), after PLR, at baseline II, and following fluid challenge. Changes in the stroke volume (delta SV) and in the cardiac index (CI) were recorded after PLR and fluid challenge.

\textbf{Findings:} Delta SV of 10% after PLR was an excellent discriminator of the fluid responsiveness with an area under ROC (AUC) of 0.81 (95% CI 0.68–0.9) with a sensitivity of 65.38% and a specificity of 100%. The change in CI of 8.7% after PLR was a significant discriminator of fluid responsiveness with an AUC of 0.7 (95% CI 0.56–0.81) with 57.78% sensitivity and 91.67% specificity.

\textbf{Conclusion:} Passive leg raising can identify nonresponders among seriously ill children under the age of 5 years but it cannot identify all responders with certainty.

\textbf{Clinical significance:} Passive leg raising is a reliable test in under 5 year-old-children if performed appropriately using bedside echocardiography for the measurement of its transient effect.

Keywords: Critically ill children, Fluid overload, Fluid responsiveness, Hemodynamic monitoring, Passive leg raising.

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\textbf{Introduction}

Intravenous fluid administration is the cornerstone of resuscitation in seriously ill patients. Moreover, all patients admitted to pediatric intensive care units (PICUs) would receive intravenous fluid for one reason or another.\textsuperscript{7} Fluid replacement is often necessary to optimize the cardiovascular function by maintaining adequate cardiac preload and output providing enough tissue oxygen delivery, which is essential in the management of critically ill patients.\textsuperscript{2} Optimal fluid management is crucial to avoid the deleterious effect of over, under, or inappropriate resuscitation.\textsuperscript{2,3} The aim of volume management is to maintain the adequate circulating volume to improve oxygen delivery to tissues while avoiding interstitial edema. Nonoptimized fluid administration, cardiovascular derangements, as well as aggressive uncontrolled infection are the main causes of multiple organ dysfunction syndrome (MODS), which is a significant cause of mortality in the intensive care units worldwide.\textsuperscript{4–6} Fluid overload impedes organ oxygenation and causes peripheral and pulmonary edema with prolonged hospital stay and higher mortality.\textsuperscript{5}

The heart in the early phase of the Frank-Starling curve still has a preload reserve. Increasing the heart preload will lead to expansion of stroke volume (SV). The patient responds positively to fluid administration during this phase. On the other hand, if the heart is functioning near the flat part of the Frank-Starling curve, with exhausted preload reserve, SV will not expand significantly in spite of fluid administration.\textsuperscript{7,8}

The fluid challenge is the gold standard method for evaluating fluid responsiveness to direct fluid therapy in seriously ill patients.\textsuperscript{7,9} Fluid responsiveness is generally defined as an increase in SV or cardiac output (CO) of 10–15% in response to a crystalloid fluid bolus.\textsuperscript{7} The main disadvantage of a fluid challenge is the unavoidable fluid volume given that when it is repeated in a short time may cause fluid overload.\textsuperscript{10} The idea of “mini-fluid challenge” has come out to conduct a fluid challenge with a fluid volume less than the “conventional” challenge. The reduced volumes of fluid cause little increase in cardiac preload and only minimal changes in CO. Therefore, it is doubtful that the mini-fluid challenge is valid.\textsuperscript{11}

Lately, the passive leg raising (PLR) test has been proposed as a simple bedside method to assess fluid responsiveness, which is similar to an “auto-fluid challenge” without external fluid. The effects of PLR must be evaluated with a real-time measurement of CO.\textsuperscript{10,12} The smaller lower body size in children makes this reservoir less functioning as compared to adults.\textsuperscript{11,12} Thus, PLR evaluation in children is more challenging. The rationale of the current study was to assess the ability of PLR to anticipate fluid responsiveness in critically ill, under age of 5 years, when compared with the standard fluid challenge.

\textbf{Materials and Methods}

This prospective observational study was conducted in the PICU of a tertiary university hospital from June 1, 2017 to January 30, 2018. This study was registered in the Cochrane Library under registration number PACTR201707002408136.
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Sample Size
A sample size of 55 was the minimum required to detect an area under the ROC curve (AUC) of 0.65, relative to a null value of 0.5, as statistically significant with 80% power and at a significance of 0.05. The sample size was calculated using the Medcalc Program version 12.2.13

Inclusion Criteria
Children from 1 month to 5 years were included for whom fluid was decided to be given based on the existence of at least one sign of poor tissue perfusion: (a) tachycardia defined as a mean heart rate >2 SD above normal for age, (b) decrease in blood pressure <5th percentile or systolic blood pressure <2 SD below normal for age, (c) urine output <0.5 mL/kg/hour, and (d) prolonged capillary refill: >5 seconds.

Exclusion Criteria
Patients having a shock that required immediate resuscitation with rapid changing hemodynamic conditions or patients who needed prompt change in inotropic or vasoactive drug infusion were excluded during the resuscitation phase. They were then included after the resuscitation phase when further fluid was needed. Patients having irregular dysrhythmia or increased intra-abdominal/intracranial pressure were also excluded. Contraindications to fluid bolus or leg elevation were considered exclusion criteria.

The main aim was to assess fluid responsiveness when a patient apparently required fluid administration. Sonosite Doppler echocardiography (WK2LN3, USA) was used with the standard transthoracic probe (S8-3). Echocardiography was performed by a 5-year experienced operator who received adequate training course in functional echocardiography for an intensivist. All results were reviewed instantaneously by a pediatric cardiologist who was blinded to the clinical condition of the studied patients and the purpose of the study. All readings were repeated in three consecutive cycles and results were averaged. A pilot study including 15 patients showed an excellent degree of intraobserver reliability in three baseline measurements of SV. The average measure intra-class correlation (ICC) was 0.93 [95% confidence interval (CI) = 0.91–0.95, p < 0.001].

In the left parasternal view, the diameter of the aortic annulus was measured. The left ventricular outflow tract (LVOT) area was calculated by the device using the following equation: [LVOT area = 0.785 × (diameter of the aortic annulus)²]. Velocity time integral (VTI) of aortic blood flow is equivalent to the product of the mean velocity (obtained by tracing the spectrum of LVOT flow) and ejection time. The pulsed wave Doppler signal from the five chambers apical view is directed parallel to flow through the LVOT below the aortic valve and the velocity was recorded (cm/systole). When the velocity signal was integrated with respect to time, the distance blood moves with each systole was calculated in cm/systole. The device calculated SV [SV = VTI × LVOT area] and CO [CO = SV × heart rate]. The CO was expressed in the form of a cardiac index (CI) [CI = CO/body surface area].

Study Design
Measurements were taken in a semi-recumbent position (baseline I). Then, the patient’s lower limbs were elevated 45° from the horizontal passively by the automatic raising of the bed’s leg while simultaneously lowering the bed’s head to the horizontal position (PLR). After 1 minute, all hemodynamic parameters were remeasured. The change in SV (delta SV) and the change in CI were calculated after PLR compared to baseline I. Next, the patient was replaced in the initial position (baseline II) and all hemodynamic parameters were remeasured after 1 minute. Finally, all hemodynamic parameters were remeasured immediately following a bolus of 10 mL/kg of isotonic saline infused intravenously over 10 minutes (fluid challenge). Delta SV and change in CI were recalculated after fluid challenge compared to baseline II. Ventilator settings (in ventilated patients), as well as infusion rates of inotropic/vasopressor agents and sedation/analgesia, were held constant during fluid bolus administration. According to previous studies, fluid responsiveness was considered positive when delta SV was more than 10% after fluid challenge,1,17

Statistical Analysis
Collected data were revised, coded, and fed into the statistical software SPSS-IBM version 21.18 The Kolmogorov-Smirnov test of normality revealed significance in the distribution of the variables, so the nonparametric statistical tests were adopted.19 Comparisons were carried out among related samples by the Friedman's test “alternative to the one-way ANOVA with repeated measures.”20 Pairwise comparison when the Friedman's test was significant was carried out using the Dunn-Sidak method by the mean rank of the median.21 The area under the ROC curve (AUC) was carried using the MedCalc Software version 14. The best cut-off value was determined using the Youden index.22 The statistical significance level of ≤0.05 was accepted.

University ethical committee approval and informed consent from the patients’ parents/legal guardians were obtained.

Results
Eighty-two patients were admitted during the study. Twenty-five patients were excluded per exclusion criteria. Fifty-seven patients were included in which 91% (52/57) were fluid responders (delta SV was more than 10% after fluid challenge) (Flowchart 1).

Baseline characteristics and initial assessment are presented in Table 1. The comparisons of hemodynamic parameters between responders and nonresponders are shown in Table 2. Table 3 shows that there was insignificant difference in heart rate by the repeated measure analysis between all four situations (X² = 0.67, p = 0.88). However, SV, CO, and CI differed significantly among different situations (X² = 83.31, X² = 69.64, X² = 86.47, respectively);

Flowchart 1: Flow diagram of the study

82 patients were admitted during the study period

25 patients were excluded

[6 ARDS, 5 on perroneal dialysis, 4 organoangemial, 4 suspected lower limit deep vien thrombosis, 3 ascites, 2 suspected increased intracranial pressure, 1 lower limbs contractures]

57 were included

Responders (n = 52) Non responders (n = 5)
**Table 1: Baseline characteristics and initial assessment**

|                          | Nonresponder | Responder | p value |
|--------------------------|--------------|-----------|---------|
| Age (month)              | 5 (2–9)      | 5.5 (2–13.5) | $p_{(MW)} = 0.67$ |
| Sex n (%)                |              |           |         |
| Males                    | 4 (80%)      | 27 (51.92%) | $p_{(U2)} = 0.463$ |
| Females                  | 1 (20%)      | 25 (48.08%) |         |
| Provisional diagnosis n (%) |            |            |         |
| Sepsis and septic shock  | 4 (80%)      | 27 (51.92%) | $p_{(MC)} = 1.00$ |
| Hypovolemic shock        | 1 (20%)      | 11 (21.15%) |         |
| Encephalitis             | 0            | 3 (5.77%)  |         |
| Inborn error of metabolism | 0           | 2 (3.85%)  |         |
| Pneumonia                | 0            | 6 (11.54%) |         |
| Hepatic encephalopathy   | 0            | 1 (1.92%)  |         |
| Bronchiolitis            | 0            | 2 (3.85%)  |         |
| Mortality                | 3 (60%)      | 8 (15.38%) | $p_{(U2)} = 0.069$ |
| PELOD day 1              | 24.6 (21.4–38.2) | 22.4 (13.8–26.5) | $p_{(MW)} = 0.072$ |
| PIM 2                    | 33.7 (20–33.7) | 16.7 (13.4–37.4) | $p_{(MW)} = 0.270$ |
| Mechanical ventilation n (%) | 3 (60%)  | 32 (61.54%) | $p_{(U2)} = 1.00$ |
| Days of ventilation      | 3 (2–7)      | 3.5 (2–5)  |         |
| Use of vasopressors/inotropes n (%) | 4 (80%) | 21 (40.38%) | $p_{(U2)} = 0.217$ |
| VIS (before PLR test)     | 50 (35–75)   | 50 (20–80) | $p_{(MW)} = 0.677$ |
| Urine output (day 1)      | 1.10 (1.10–1.20) | 2.50 (2.15–3.15) | $p_{(MW)} = 0.001^*$ |
| Lactate                  | 3.40 (3.00–3.60) | 1.35 (1.10–2.00) | $p_{(MW)} = 0.001^*$ |

1 Median (IQR); ELOD2, pediatrics logistic organ dysfunction 2; PIM2, pediatric index of mortality 2; VIS, vasopressor-inotropic score $p_{(MW)} = p$ value of Mann–Whitney U test, $p_{(U2)} = p$ value of Chi-square test, $p_{(MC)} = p$ value of the Monte Carlo's exact probability test

*Statistically significant ($p < 0.05$)

**Table 2: Hemodynamic parameters among responders and non-responders**

|                          | Baseline I | PLR | Baseline II | FC | p value |
|--------------------------|------------|-----|-------------|----|---------|
| Heart rate (bpm)         |            |     |             |    |         |
| Responders               | 142 (129–157) | 145 (131–158) | 143 (131.5–157) | 145 (126–157) | $p_{(MW)} = 0.06$ |
| Nonresponders            | 165 (154–167) | 170 (162–174) | 165 (155167) | 176 (156–176) | $p_{(MW)} = 0.006^*$ |
| p value                  | $p_{(MW)} = 0.06$ | $p_{(MW)} = 0.006^*$ | $p_{(MW)} = 0.057$ | $p_{(MW)} = 0.016$ | |
| CO(L/minute)             |            |     |             |    |         |
| Responders               | 1.2 (0.7–1.6) | 1.3 (0.8–1.75) | 1.2 (0.7–1.6) | 1.4 (1–1.9) | $p_{(MW)} = 0.420$ |
| Nonresponders            | 0.9 (0.62–1.2) | 0.9 (0.63–1) | 0.9 (0.7–1.2) | 0.7 (0.6–1.3) | $p_{(MW)} = 0.154$ |
| p value                  | $p_{(MW)} = 0.829$ | $p_{(MW)} = 0.121$ | $p_{(MW)} = 0.259$ | $p_{(MW)} = 0.019^*$ | |
| SV (mL)                  |            |     |             |    |         |
| Responders               | 7.75 (4.88–11) | 8.49 (5.24–13.5) | 7.75 (4.88–11) | 10.2 (6.47–13.2) | $p_{(MW)} = 0.0259$ |
| Nonresponders            | 5.74 (3.78–7.23) | 5.74 (3.69–7.36) | 5.74 (3.78–7.23) | 4.48 (3.87–7.42) | $p_{(MW)} = 0.121$ |
| p value                  | $p_{(MW)} = 0.888$ | $p_{(MW)} = 0.146$ | $p_{(MW)} = 0.724$ | $p_{(MW)} = 0.057$ | |
| CI (L/minute/m²)         |            |     |             |    |         |
| Responders               | 2.93 (2.29–3.91) | 3.47 (2.83–4.17) | 2.83 (2.25–3.83) | 4.15 (3.26–4.93) | $p_{(MW)} = 0.888$ |
| Nonresponders            | 2.72 (2.69–3.63) | 2.72 (2.6–3) | 2.72 (2.69–3.63) | 2.72 (2.70–3.93) | $p_{(MW)} = 0.146$ |
| p value                  | $p_{(MW)} = 0.888$ | $p_{(MW)} = 0.146$ | $p_{(MW)} = 0.724$ | $p_{(MW)} = 0.057$ | |
| Mean arterial pressure (mmHg) |        |     |             |    |         |
| Responders               | 51 (48–60) | 57 (51–66) | 51 (48–60) | 56 (53–66) | $p_{(MW)} = 0.053$ |
| Nonresponders            | 59 (52–62) | 54 (48–57) | 62 (56–61) | 58 (54–67) | $p_{(MW)} = 0.153$ |
| p value                  | $p_{(MW)} = 0.053$ | $p_{(MW)} = 0.053$ | $p_{(MW)} = 0.053$ | $p_{(MW)} = 0.723$ | |

Data presented in median (IQR); PLR, passive leg raising; FC, fluid challenge $p_{(MW)} = p$ value of Mann–Whitney U test, *Statistically significant ($p < 0.05$)
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**Discussion**

In the current study, delta SV of ≥10% after PLR was an excellent discriminator of fluid responsiveness with a sensitivity of 65.4%. In other words, 65.4% of fluid responders were correctly identified by having delta SV of ≥10% after PLR, i.e., 35.5% false-negative. Passive leg raising is inconvenient in profound hypovolemia as the blood volume mobilized by leg raising, which is dependent on total blood volume, could be minimal and can show slight or no increase in SV and CO even in fluid responsive patients.

Most of the patients were diagnosed as septic or hypovolemic shock, which explains underdiagnosis of some responders by the PLR test. With a specificity of 100%, all fluid nonresponders were correctly identified by having delta SV of <10%, which is crucial to avoid administration of unnecessary fluids to prevent fluid overload. This could not be estimated by clinical examination alone, which is the method used to detect a fluid need in critically ill children. Using a fluid challenge in these patients would be deleterious.

Change in CI ≥8.7% was also a significant discriminator of fluid responsiveness after PLR with AUC of 0.7 (95% CI 0.56–0.81) with a sensitivity of 57.8% and a specificity of 91.7%. This means that 57.8% of fluid responders and that almost all fluid nonresponders were correctly identified by having a change in CI of ≥8.7%. Change in CI had less sensitivity and specificity compared with delta SV to detect responders after PLR. In accordance with Lukito et al. who stated that in shock, the fluid challenge that is applied to expand SV does not always achieve the required rise in CO and CI.

Lu et al. demonstrated that the PLR test is an unreliable marker in children under 5 years of age due to wide range of variations in CI with PLR. Unlike the current study, Lu et al. used the bioimpedance-based noninvasive cardiac output monitoring (NICOM) technique for measuring SV and CO rather than real-time echocardiography, which is the gold standard method. In the current study, starting from the semi-recumbent position followed by trunk lowering and leg raising led to the mobilization of venous blood from the splanchnic area besides that from the lower limbs. This technique was not mentioned by Lu et al. depending on the lower limbs reservoir only, which varies greatly among young children below 5 years. However, Lu et al. found that 10% increase in CI after the PLR test would predict fluid responsiveness with a higher sensitivity (100% vs 91%) and similar specificity (27% vs 25%) for those over 5 years as compared to under 5 years, respectively.

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**Table 3: Hemodynamic parameters measured by echocardiography**

|                | Heart rate (bpm) | SV (mL) | CO (L/minute) | CI (L/minute/m²) |
|----------------|------------------|---------|---------------|-----------------|
| Baseline I     | 148 (132–158)    | 7.45ac  | 1.20ac (0.70–1.5) | 2.90ac (2.36–3.88) |
| PLR            | 146 (135–160)    | 7.81b   | 1.20bc (0.80–1.7) | 3.40b (2.72–4.21) |
| Baseline II    | 146 (132–159)    | 7.45ac  | 1.20bc (0.7–1.5)  | 2.81ac (2.29–3.82) |
| Fluid challenge| 146 (130–159)    | 8.96a   | 1.40a (1–1.8)    | 4.00a (3.4–4.86)  |
| Repeated measure | \(X^2_{(Fr)(df=3)}=0.67\) | \(X^2_{(Fr)(df=3)}=83.31\) | \(X^2_{(Fr)(df=3)}=69.64\) | \(X^2_{(Fr)(df=3)}=86.47\) |
| analysis       | \(p=0.880\)      | \(p\leq 0.0001^*\) | \(p\leq 0.0001^*\) | \(p\leq 0.0001^*\) |

Data presented in median (IQR); n: number of patients
Fr, Friedman test; df, degree of freedom
Different superscript letters indicate significant pairwise comparison using the Dunn-Sidak method of adjustment; a: baseline I, b: PLR, c: baseline II, d: fluid challenge
*Statistically significant (\(p \leq 0.05\))

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![Fig. 1: Receiver’s operating characteristic curve of delta stroke volume after passive leg raising test as a predictor of fluid responsiveness](image1)

![Fig. 2: Receiver’s operating characteristic curve of the change in cardiac index as a predictor of fluid responsiveness](image2)
The effects of PLR are rapidly reversed after the legs are put back in a horizontal position; therefore, PLR is a transient reversible challenge.\textsuperscript{5,26,27} It can be repeated several times to reevaluate fluid responsiveness safely without development of fluid overload in potential nonresponders. Monnet et al.\textsuperscript{10,12,26} demonstrated that CO must be assessed before, during, and after PLR to ensure that it comes back to its baseline. In the current study, there was insignificant difference between baseline I and II as regards to SV, CO, and CI before and after PLR denoting that CO variations during PLR did not result from inevitable changes related to the original illness of the unstable patients. This shows without doubt that PLR is reversible with a transient effect that avoids inevitable administration of fluids to nonresponders surpassing the standard fluid challenge. Hemodynamic parameters were measured 1 minute from the start of PLR, which is in accordance with Monnet et al.\textsuperscript{12} who stated that the hemodynamic changes take place within seconds and are maximal just about 1 minute after initiating the maneuver.

Passive leg raising is a reliable test on condition that its effects are evaluated by a real-time fast response device used to measure transient changes in SV and CO.\textsuperscript{26} In the present study, echocardiography was used to measure hemodynamic parameters in the different situations providing real-time assessments of SV and CO.

The method of applying PLR has a major significance because it affects greatly the hemodynamic effects and thus the test reliability.\textsuperscript{12,28} In the present study, the test was started in the semi-recumbent position. Adding trunk lowering to leg raising resulted in the mobilization of additional venous blood from the splanchnic area, augmenting the effect of leg elevation on cardiac preload and thus maximizing the test’s sensitivity.\textsuperscript{12,29} Pain, cough, and discomfort could induce adrenergic stimulation, resulting in an inaccurate evaluation of CO changes after PLR.\textsuperscript{12,14,26,29} When there is a marked increase of heart rate accompanying PLR, sympathetic stimulation should be suspected, which may be an indicator of an altered test result.\textsuperscript{12,26} Several researchers noted that PLR did not produce changes in the heart rate, suggesting that catecholamine stimulation is not present.\textsuperscript{12,26,30} In the present study, PLR was performed by adjusting the bed automatically to keep it horizontal. In the current study, PLR did not produce changes in the heart rate, suggesting that catecholamine stimulation is not present.\textsuperscript{12,26,30}

An important limitation of the current study is that 77% of patients were infants. The young age of the study cohort may affect external validity and generalizability of the results. However, few studies dealt with this age group. Also, the need of well-trained staff to perform echocardiography around the clock is another limitation. So, it is recommended that PICU staff should receive echocardiogram hands-on training courses.

**Clinical Significance**
Passive leg raising is a reliable test in children under the age of 5 years if performed appropriately using bedside echocardiography for the measurement of its transient effect.

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**References**
1. Assadi F. Passive leg raising: Simple and reliable technique to prevent fluid overload in critically ill patients. IJPM 2017;8(1):48. DOI: https://doi.org/10.4103/ijpvm.IJPVM_11_17.
2. Benington S, Ferris P, Nirmalan M. Emerging trends in minimally invasive haemodynamic monitoring and optimization of fluid therapy. Eur J Anaesthesiol 2009;26(11):893–905. DOI: 10.1097/EJA.0b013e32832308e50.
3. Kelm D, Perrin JT, Carlin-Ceba R, Gajic O, Schenck L, Kennedy CC. Fluid overload in patients with severe sepsis and septic shock treated with early goal-directed therapy is associated with increased acute need for fluid-related medical interventions and hospital death. Shock 2015;43(1):68–73. DOI: 10.1097/SHK.0000000000000268.
4. Watson RS, Crow SS, Hartman ME, Lacroix J, Odetola FO. Epidemiology and outcomes of pediatric multiple organ dysfunction syndrome. Pediatr Crit Care Med 2017;18(3):4–16. DOI: 10.1097/PCC.0000000000001047.
5. Ricci Z, Iacoella C, Cogo P. Fluid management in critically ill pediatric patients with congenital heart disease. Minerva Pediatr 2011;63(5):399–410.
6. Favia I, Garisto C, Rossi E, Picardo S, Ricci Z. Fluid management in pediatric intensive care. Contrib Nefrol 2010;4:164-217-226. DOI: 10.1159/000313733.
7. Toscani L, Hollmann D, Antonakaki D, Bastoni D, Watson X, Arulkumaran N, et al. What is the impact of the fluid challenge technique on diagnosis of fluid responsiveness? A systematic review and meta-analysis. Crit Care 2017;21(1):207. DOI: 10.1186/s13054-017-1796-9.
8. Mark P, Monnet X, Teboul J. Hemodynamic parameters to guide fluid therapy. Ann Intensive Care 2011;1(1):1. DOI: 10.1186/2110-5820-1-1.
9. He H, Liu D. Fluid bolus therapy is a medical therapy or a diagnostic method? Crit Care 2015;19(11):360. DOI: 10.1186/s13054-015-0783-3.
10. Monnet X, Mark P, Teboul J. Prediction of fluid responsiveness: an update. Ann Intensive Care 2016;6(1):111–115. DOI: 10.1186/s13613-016-0216-7.
11. Guinot PG, Bernard E, Defrançq F, Petiot S, Majoub Y, Dupont H, et al. Mini-fluid challenge predicts fluid responsiveness during spontaneous breathing under spinal anaesthesia: an observational study. Eur J Anaesthesiol 2015;32(9):645–649. DOI: 10.1097/EJA.0000000000000175.
12. Monnet X, Teboul J. Passive leg raising: five rules, not a drop of fluid! Ann Intensive Care 2015;5:19. DOI: 10.1186/s13613-015-0188-3.
13. DeLong ER, DeLong DM, Clarke-Pearson DL. Comparing the areas under two or more correlated receiver operating characteristic curves: a nonparametric approach. Biometrics 1988(3):837–845. DOI: 10.2307/2531595.
14. Lukito V, Djer MM, Pudjiadi AH, Munasir Z. The role of passive leg raising to predict fluid responsiveness during spontaneous breathing under spinal anaesthesia: an observational study. Eur J Anaesthesiol 2015;32(9):645–649. DOI: 10.1097/EJA.0000000000000175.
15. Blanca P, Aguier FM, Blaivas M. Rapid ultrasound in shock (RUSH) velocity-time integral. J Ultrasound Med 2015;34(9):1691–1700. DOI: 10.7863/ultra.15.14.08059.
16. Huntsman LL, Stewart DK, Barnes SR, Franklin SB, Colocosis JS, Hessel EA. Noninvasive Doppler estimation of cardiac output in man,
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17. Miller A, Mandeville J. Predicting and measuring fluid responsiveness with echocardiography. Echo Res Pract 2016;3(2):G1–G12. DOI: 10.1530/ERP-16-0008.

18. IBM Corp. IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY: IBM Corp, Released 2012.

19. Field A. Discovering statistics using IBM SPSS statistics 4th ed., London, California, New Delhi: SAGE Publications Ltd.; 2013.

20. Friedman M. The use of ranks to avoid the assumption of normality implicit in the analysis of variance. J Am Stat Assoc 1937;32(200):675–701. DOI: 10.1080/01621459.1937.10503522.

21. Dunn OJ. Multiple comparisons using rank sums. Technometrics 1964;6(3):241–252. DOI: 10.1080/00401706.1964.10490181.

22. Hajian-Tilaki K. Receiver operating characteristic (ROC) curve analysis for medical diagnostic test evaluation. Caspian J Intern Med 2013;4(2):627–635.

23. Lafanechère A, Pène F, Goulenok C, Delahaye A, Mallet V, Choukroun G, et al. Changes in aortic blood flow induced by passive leg raising predict fluid responsiveness in critically ill patients. Crit Care 2006;10(5):R132. DOI: 10.1186/cc5044.

24. EL-Nawawy AA, Abdelmohsen AM, Hassouna HM. Role of echocardiography in reducing shock reversal time in pediatric septic shock: a randomized controlled trial. J Pediatr (Rio J) 2018;94(1):31–39. DOI: 10.1016/j.jped.2017.02.005.

25. Lu GP, Yan G, Chen Y, Lu ZJ, Zhang LE, Kissoon N. The passive leg raise test to predict fluid responsiveness in children—preliminary observations. Indian J Pediatr 2015;82(1):5–12. DOI: 10.1007/s12098-013-1303-5.

26. Monnet X, Teboul J-L. Passive leg raising. Intensive Care Med 2008;34(4):659–663. DOI: 10.1007/s00134-008-0994-y.

27. Lamia B, Ochagavia A, Monnet X, Chemla D, Richard C, Teboul J-L. Echocardiographic Prediction of volume responsiveness in critically ill patients with spontaneous breathing activity. Intensive Care Med 2007;33(7):1125–1132. DOI: 10.1007/s00134-007-0646-7.

28. Li W, Yu X, Xu J. An indispensable procedure to complete passive leg raising. Ann Emerg Med 2016;68(3):394–395. DOI: 10.1016/j.annemergmed.2016.04.009.

29. Jabot J, Teboul JL, Richard C, Monnet X. Passive leg raising for predicting fluid responsiveness: Importance of the postural change. Intensive Care Med 2009;35(1):85–90. DOI: 10.1007/s00134-008-1293-3.

30. Cherpanath T, Aarts L, Groeneveld J, Geerts B. Defining fluid responsiveness: a guide to patient-tailored volume titration. J Cardiothorac Vasc Anesth 2014;28(3):745–754. DOI: 10.1053/j.jvca.2013.12.025.