Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.JournalofSurgicalResearch.com

Evaluation of the fluid responsiveness in patients with septic shock by ultrasound plus the passive leg raising test

Jingyi Wu, MD,[a,1] *Zhen Wang, MD,*[a,1] *Tao Wang, MS,*[a] *Tao Yu, PhD,*[a] *Jing Yuan, MS,*[a] *Qingling Zhang, MS,*[b] *Weihua Lu, MS,*[a] *and Xia Zhang, MS*[b,*]

[a] *Department of Intensive Care Unit, The First Affiliated Hospital of Wannan Medical College, Wuhu, Anhui, China*
[b] *Department of Ultrasound, The First Affiliated Hospital of Wannan Medical College, Wuhu, Anhui, China*

ARTICLE INFO

Article history:
Received 24 June 2017
Received in revised form
14 November 2017
Accepted 13 December 2017
Available online xxx

Keywords:
Ultrasound
Passive leg raising
Fluid responsiveness

ABSTRACT

Background: Prompt, accurate, and noninvasive prediction of fluid responsiveness is still lacking in intensive care unit. This study is to investigate the value of the Doppler ultrasound evaluation of variation in brachial artery peak velocity ($VVpeak_{brach}$) and passive leg raising (PLR)-induced changes in the brachial artery peak velocity ($\Delta Vpeak_{PLR}$) in predicting the fluid responsiveness in mechanically ventilated patients with severe sepsis or septic shock.
Methods: A prospective study was conducted involving 62 patients. Semirecumbent positioning, PLR, and a return to the semirecumbent position were performed with all patients before volume expansion. $VVpeak_{brach}$, $\Delta Vpeak_{PLR}$, and stroke volume were observed by Doppler ultrasound. A patient with an increase of $\geq$15% in the stroke volume on volume expansion was defined as a responder. The predictive value was evaluated on the receiver operating characteristic curve analysis.
Results: A total of 28 patients were classified as responders. The area under the receiver operating characteristic curve of $\Delta Vpeak_{PLR}$ and $VVpeak_{brach}$ was 0.898 and 0.891, respectively. A $\Delta Vpeak_{PLR}$ value of more than 10.6% predicted the fluid responsiveness with a sensitivity of 82.1% and a specificity of 88.2%. A $VVpeak_{brach}$ value of more than 10.95% predicted the fluid responsiveness with a sensitivity of 78.6% and a specificity of 91.2%. The positive predictive value was 94.4% when both were positive. In contrast, the negative predictive value was 96.6%.
Conclusions: Doppler ultrasound evaluation of $VVpeak_{brach}$ and $\Delta Vpeak_{PLR}$ could be a feasible method for the noninvasive assessment of fluid responsiveness in mechanically ventilated patients with severe sepsis or septic shock. The combination of two indicators can improve the predictive value.

Introduction

Hemodynamic disturbances are common clinical manifestations in patients with severe sepsis, as well as septic shock and multiple organ dysfunction syndrome. The evaluation of the fluid responsiveness has an important clinical significance in hemodynamic monitoring and management. The classical method for evaluating the fluid responsiveness is the fluid

* *Corresponding author*. Department of Ultrasound, The First Affiliated Hospital of Wannan Medical College, Wuhu, Anhui, China. Tel.: +86 553 5739781; fax: +86 553 5738100.
E-mail address: yjsusd@163.com (X. Zhang).
[1] These authors contribute equally to the article.
0022-4804/$ – see front matter
https://doi.org/10.1016/j.jss.2017.12.014

challenge. However, this method creates an extra fluid burden on patients and can cause a series of side effects, such as exacerbated tissue edema, organ failure, and increased mortality.[1-3] Research showed that the positive rate of the fluid responsiveness in intensive care unit (ICU) patients is only about 30%-58%.[4-8] Therefore, it is crucial to explore a simple, effective, and noninvasive method to evaluate the fluid responsiveness and volume status.

At present, there are many methods to predict the fluid responsiveness, such as pulse indicator continuous cardiac output (PICCO), pulse pressure variation (PPV) and stroke volume variation (SVV), noninvasive cardiac output monitoring and so on, but these devices have their own shortcomings. PICCO monitoring stroke volume (SV) and other indicators are considered to be the "gold standard", but it is expensive, invasive, and could cause catheter infection. SVV and PPV are also invasive methods, and their accuracy is susceptible to arrhythmia, vasoactive drugs, spontaneous breathing, and intrathoracic pressure.[8-10] Noninvasive cardiac output monitoring is a newly developed noninvasive monitoring of hemodynamics, but its value might be limited by variations in thoracic impedance due to other causes (lung injury and variations in the thoracic blood volume due to respiration, arrhythmias, etc.).[11-13]

Through postural change, passive leg raising (PLR) rapidly returns around 150-300 mL of fluid from the veins of the lower extremities to the right side of the heart and increases the cardiac preload. It is a simple, safe, and reversible method to change the cardiac preload in clinics.[14,15] However, since the hemodynamic changes are rapid and transient during PLR, effective observational methods are still lacking.[16,17] Echocardiography, with real-time, continuous, and convenient advantages, can be used to observe PLR-induced changes in hemodynamics. Our previous study has shown that, compared with PICCO, echocardiography evaluation of SV and aortic blood flow can efficiently predict fluid responsiveness in mechanically ventilated patients with severe sepsis or septic shock,[17-19] but the need for specialized training limited its applicability.

More recently, the measurement of brachial artery peak velocity ($Vpeak_{brach}$) has been proposed: this superficial vessel is easily accessible with Doppler ultrasound, and the measurement can be performed quickly at the bedside with a high-frequency linear transducer that is readily available. Furthermore, recent research showed that Doppler ultrasound could be used to evaluate the fluid responsiveness by monitoring the respiratory variations in the brachial artery peak velocity ($VVpeak_{brach}$), with a sensitivity of 74% and a specificity of 95%.[20] The Doppler ultrasound measurements of $VVpeak_{brach}$ and the $Vpeak_{brach}$ uses similar "science" to SVV and SV index measured more distally on the extremity with other techniques (Vigileo). Then, in theory, the brachial artery is less susceptible to vasoconstriction and thus maybe better suited to hypotensive patients and those in shock.

Therefore, the aim of this study is to investigate the value of the Doppler ultrasound evaluation of $VVpeak_{brach}$ and PLR-induced changes in the brachial artery peak velocity ($\Delta Vpeak_{PLR}$) in predicting the fluid responsiveness in mechanically ventilated patients with severe sepsis or septic shock.

Material and methods

Study subjects and selection criteria

A prospective observation study was performed in the ICU of Yijishan Hospital at Wannan Medical College from June 2013 to December 2015. The study protocol was approved by the Hospital Ethics Committee, and informed consents were obtained from the families of all patients.

Inclusion criteria are as follows: 1. The 2001 SCCM/ESICM/ACCP/ATS/SIS (Society of Critical Care Medicine/European Society of Intensive Care Medicine/American College of Chest Physicians/American Thoracic Society/Surgical Infection Society) international sepsis definitions were used as the diagnostic criteria.[21] 2. Patients admitted to the ICU due to septic shock or those who exhibited septic shock in the ICU who showed unstable hemodynamic conditions or tissue hypoperfusion even after hours or days of active fluid resuscitation. 3. Patients who had at least one of the following clinical signs of tissue hypoperfusion: systolic blood pressure <90 mm Hg (1 mm Hg = 0.133 kPa), a decrease >40 mm Hg, or the need for vasopressive drugs; urine output <0.5 mL/kg/h for ≥2 h; heart rate >100/min; skin mottling; or persistent lactic acidosis (lac ≥4 mmol/L). 4. Mechanical ventilation was prescribed and administered by clinical physicians. Ventilator settings followed the hospital's written protocols. and 5. Aged over 18 y.

Exclusion criteria are as follows: Pregnancy, intracranial hypertension, pulmonary hypertension, abdominal hypertension, arrhythmia, wearing elastic stockings or exhibiting deep vein thrombosis, aortic valve or mitral valve disease, or ascending aortic aneurysm. Presence of contradictions to the fluid challenge (heart failure, acute coronary syndrome, cardiogenic shock, and evidence of a volume overload).

Methods

Study protocol

The first stage (baseline) was semirecumbent (45°), and the second was PLR. Using an automatic bed elevation technique, the patient's trunk was lowered from the semirecumbent position to the supine position while the lower limbs were raised to a 45° angle. The patient was kept in this position for 4 min while the hemodynamic indicators were monitored and recorded. The third stage included slowly returning the patient to the semirecumbent position, as in the first stage. The fourth stage was the volume expansion (VE); the VE was performed after the patient had rested for 5 min in the semirecumbent position. Over a period of 15 min, 250 mL of normal saline was given to the patient (Fig. 1). An increase of ≥15% in the SV, monitored by ultrasound after the VE, was defined as fluid responsiveness positive, and a value <15% was negative.[6,22]

Patients were adequately sedated when the hemodynamic indices were collected. The vasoactive drugs, sedatives, and mechanical ventilation parameters remained constant during the whole procedure. The ventilator was set to the volume control ventilation mode, with a tide volume of 8-10 mL/kg