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Ultrasonographic measurements of the inferior vena cava variation as a predictor of fluid responsiveness in patients undergoing anesthesia for surgery

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ABSTRACT

Background: Both hypovolemia and hypervolemia are connected with increased morbidity and mortality in the treatment and prognosis of patients. An accurate assessment of volume state allows the optimization of organ perfusion and oxygen supply. Recently, ultrasonography has been used to detect hypovolemia in critically ill patients and perioperative patients. The objective of our study was to assess the correlation between inferior vena cava (IVC) variation obtained with ultrasound and stroke volume variation (SVV) measured by the Vigileo/FloTrac monitor, as fluid responsiveness indicators, in patients undergoing anesthesia for surgery.

Methods: Forty patients (American Society of Anesthesiologists grades I and II) scheduled for elective gastrointestinal surgery were enrolled in our study. After anesthesia induction, 6% hydroxyethyl starch solution was administered to patients as an intravenous (IV) fluid. The IVC diameters were measured with ultrasonography. SVV and stroke volume index (SVI) were obtained from the Vigileo monitor. All data were collected both before and after fluid challenge.

Results: Forty patients underwent IVC sonographic measurements and SVV calculation. After fluid challenge, mean arterial pressure, central venous pressure, SVI, and IVC diameters increased significantly, whereas SVV decreased markedly. The correlation coefficient between the increase in SVI and the baseline of IVC variation after an IV fluid was 0.710, and receiver operating characteristic (ROC) curve was 0.85. The correlation coefficient between the increase in SVI and the baseline of SVV was 0.803 with an ROC curve of 0.93. Central venous pressure had no significant correlation with SVI.

Conclusions: Our data show that IVC variation and SVV proved to be reliable predictors of fluid responsiveness in patients undergoing anesthesia for surgery with mechanical ventilation.

X. Zhang and J. Feng contributed equally to this study.

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Introduction

Hypovolemia is often related to low blood pressure and low organ perfusion in perioperative patients.[1] Fluid therapy improves hemodynamic parameters by increasing organ preload.[2] However, inappropriate fluid challenge may prove ineffective and deteriorate organ perfusion by compromising oxygen delivery and degrading gas exchanges in ventilated patients.[3] Therefore, it is important to predict the efficacy of fluid challenge.

More recently, a number of minimal or noninvasive techniques, such as pulse pressure variation (PPV) and stroke volume variation (SVV), have gained wide acceptance in practice to evaluate patients' hemodynamics status.[4-8] Transthoracic ultrasonography of the inferior vena cava (IVC) is accessible for volume status in a noninvasive, rapid way.[9] Several articles indicated that IVC variation may be an obvious signal of volume loss in many medical cases.[10-12] IVC variation has been proved as a sure fluid responsiveness predictor in critical ill patients under mechanical ventilation.[13,14]

The primary aim of our study was to compare the accuracy of IVC variation to that of the SVV in predicting fluid responsiveness in patients undergoing anesthesia for surgery.

Materials and methods

Subjects

The protocol of this study was approved by the hospital ethical review boards, and our study protocol complies with the Helsinki Declaration of 1975, revised in 1983. After obtaining written informed consent from patients, our study went along with 40 patients of American Society of Anesthesiologists grades I or II undergoing elective gastrointestinal tract surgery.

Exclusion criteria were cardiac arrhythmias, obstructive lung disease, pre-existing heart dysfunction, portal hypertension, inability to perform artery cannulation or ultrasonography, and severe peripheral vascular disease.

Study protocol

Patients who were enrolled in our study received at least 12-h preoperative fasting. All patients were monitored with blood pressure, electrocardiogram, and pulse oximetry. A 20-G catheter was introduced via inserted in the radial artery for measuring invasive arterial blood pressure. Central venous pressure (CVP) monitoring was established via a 7.5-F central venous catheter inserted in the right internal jugular vein. Invasive hemodynamic monitoring was carried out after anesthesia induction.

A Vigileo/FloTrac monitor (software version 4.0; Edwards Lifesciences, Irvine, CA) was connected to the arterial catheter for continuous monitoring of stroke volume (SV), stroke volume index (SVI), and SVV. The Vigileo system consists of an algorithm based on arterial pulse-contour analysis which relies on an arterial catheter for SV estimation. SV was measured every 20 seconds during one respiratory cycle. SVV represents a percentage of SV while being higher on expiration and lower on inspiration, which is calculated with the following equation: SVV (%) = (maximum SV−minimum SV)/mean SV.[15,16]

Anesthesia was induced with IV midazolam (0.04 mg/kg), propofol (2-4 mg/kg), fentanyl (3 μg/kg), and cisatracurium (0.15 mg/kg) before tracheal intubation. All patients were ventilated with a tidal volume of 8 to 10 mL/kg at a frequency of 12 bpm and zero positive end-expiratory pressure in volume-controlled mode. The settings of ventilator remained unchanged, and the peak airway pressures of patients were not exceeded 30-cm H_2O during the study.

Patient data, including SVV, SVI, IVC diameters, mean arterial pressure (MAP), CVP, and pulse, were collected before fluid challenge. Then, the patients received 6% hydroxyethyl starch solution (7 mL/kg, mean molecular weight, 130,000 d/mean degree of substitution; Tianqing Company, Jiangsu, China) within 30 min as IV fluid.[17] All hemodynamic and ultrasonographic data were collected before and immediately after fluid challenge.

Ultrasonography

We use SonoSite ultrasound equipment (SonoSite, Inc., Bothell, WA) with M-mode phased array transducer (3.5 to 5 MHz) to measure ultrasonographic data. The maximum and minimum venous dimensions in mechanical ventilation cycle were identified by the convex probe. Convex probe was used to measure IVC diameters of the patients in supine position. The IVC sagittal section was described with the probe in the area of subxiphoid. We got the patients' IVC diameters at the junction point of the IVC and right atrium (2 cm caudal) to standardize the measurements.

The leading edge technique was used to measure IVC diameters (from the interior wall to the opposite interior wall). The maximum anterior-posterior dimension came out from end-inspiration (IVCi), whereas the minimum IVC diameter was shown in end-expiration (IVCe). The IVC variation was normalized according to IVC providing respiratory variance (IVC variation = [(IVCi − IVCe)/IVCe]). All ultrasonographic measurements were carried out by the same experienced investigator. The investigators were not involved in the treatment and were blinded to the hemodynamic parameters.

Statistical analysis

SPSS version 18.0 (SPSS, Inc., Chicago, IL) was applied in analyzing all data. Descriptive statistics was useful in the conclusion of study measurements and patient characteristics. Meanwhile, the Kolmogorov−Smirnov test was used to determine whether the measurements were normally distributed. A paired *t* test was applied to compare measurements before and after fluid infusion. The Pearson's correlation test was used to analyze the correlation between SVI and other hemodynamic variables.

The ability of IVC variation, SVV, and CVP to predict fluid responsiveness was assessed by receiver operator characteristic (ROC) curves. Fluid responsiveness was defined as