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Does ultrasonographic measurement of the inferior vena cava diameter correlate with central venous pressure in the assessment of intravascular volume in patients undergoing gastrointestinal surgery?

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ABSTRACT

Background: Ultrasonography has been suggested as a useful noninvasive tool for the detection of hypovolemia in critically ill patients. Hypovolemia after preoperative fasting and bowel preparation may compromise hemodynamic function during gastrointestinal surgery. However, there are few data comparing ultrasonographic examination of the inferior vena cava (IVC) diameter with central venous pressure (CVP) measurement in patients undergoing gastrointestinal surgery in the assessment of intravascular volume status.

Materials and methods: Forty American Society of Anesthesiologists I–II patients who underwent elective gastrointestinal surgery and 32 healthy volunteers were enrolled in the study. The IVC diameters, both during expiration (IVCe) and inspiration (IVCi), and right ventricle (RV) were measured with ultrasonography in patients both before and after fluid resuscitation. Volunteers were also measured during the time they participated in the study.

Results: Forty patients (mean age 51 y; 45% female) and 32 volunteers (mean age 46 y; 44% female) underwent IVC and RV sonographic measurements. The diameters of the IVCe, IVCi, and RV in patients (1.83, 1.34, and 3.23 cm) were significantly lower compared with those of healthy volunteers (1.18, 0.62, and 2.71 cm). After fluid resuscitation, IVCe, IVCi, and RV in hypovolemic patients (1.75, 1.25, and 3.27 cm) significantly increased. The pre-IVCe and the post-IVCe were closely correlated to the CVP ($r = 0.585$ and $r = 0.609$, respectively). Similarly, the pre-RV and the post-RV were correlated to the CVP ($r = 0.347$ and $r = 0.439$, respectively).

Conclusions: Our data demonstrate that the IVC and RV diameters are consistently low in patients undergoing gastrointestinal surgery when compared with healthy subjects. Ultrasonographic measurements of the IVC and RV diameters are useful supplement of CVP for the evaluation of preoperative patients with hypovolemia.

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1. Introduction

The estimation of volume status in patients undergoing elective gastrointestinal surgery is a prerequisite for volume replacement, which may affect treatment, prognosis, and patient management during surgery [1].

Central venous pressure (CVP) has been considered to be the criterion standard when evaluating intravascular volume. However, measurement of CVP requires an invasive procedure and may cause many potential complications, including infection, thrombosis, arterial puncture, data interpretation errors, and iatrogenic injury [2].

More recently, a number of less invasive techniques have been introduced in practice, such as stroke volume variation, left ventricular end-diastolic area index, and ultrasonography. Ultrasonography has been suggested as a useful noninvasive tool for assessing volume status in a rapid, objective way [3]. Studies have shown that ultrasonographic evaluation of inferior vena cava (IVC) and right ventricle (RV) maybe a reliable predictor of both blood loss and intravascular volume status in critically ill patients [4,5].

However, there are few data comparing the IVC diameter or RV with CVP measurement in patients undergoing gastrointestinal surgery in the assessment of intravascular volume status. The primary aim of this study was to determine if ultrasonographic measurements of the IVC or RV diameters correlate with CVP measurement as an indicator of intravascular volume status in preoperative patients undergoing gastrointestinal surgery.

2. Methods

2.1. Study design

The study protocol was approved by the local ethical review boards of the participating medical centers, and written informed consent was obtained from each patient before study. The study protocol complies with the Declaration of Helsinki. American Society of Anesthesiologists I–II patients ($n = 40$) aged 33–71 y who underwent major elective gastrointestinal tract cancer surgery were enrolled in the study as the experimental group. The control group ($n = 32$) consisted of healthy volunteers such as medical personnel and relatives. Patients with history of heart disease, portal hypertension, severe peripheral vascular disease, and obstructive lung disease were excluded from the study. Patients whose ultrasonographic measurements could not be performed because of technical and anatomical reasons such as obesity and excessive abdominal gas were also excluded from the study.

2.2. Hemodynamic monitoring

All patients undergoing gastrointestinal surgery received bowel preparation (a clear liquid diet, magnesium citrate solution, and phosphate enema the night before and the morning of surgery) and preoperative fasting for at least 12 h. The patients who were enrolled in the study were monitored. Before anesthesia induction, a 7.5-F central venous catheter was introduced via right internal jugular vein under local analgesia with 2% lidocaine for measuring the CVP. Patient data, including pulse, mean arterial pressure, IVC diameter both during expiration (IVCe) and inspiration (IVCi), RV diameter, and CVP were collected.

2.3. Ultrasonographic technique and equipment

The ultrasonographic measurements were obtained with a SonoSite (SonoSite Inc, Bothell, WA) M-mode using the 3.5-5 MHz phased array transducer. All the ultrasonographic measurements for the study were performed by the same investigator. M-mode probe was used to identify the measurement of the minimum and maximum venous dimensions over the respiratory cycle. IVC diameters were obtained in the supine position with a convex probe. The probe was placed in the subxiphoid region, and the sagittal section of the IVC was imaged. To standardize the measurements, measuring of the IVC diameter was performed at 2 cm caudal of the junction point of the right atrium and IVC. The IVC diameter was measured as the maximum anterior-posterior dimension at end-IVCe using the leading edge technique (from one interior wall to the opposite interior wall). In addition, minimum IVC diameter was measured at end-IVCi during normal spontaneous breathing (Figure). The IVC collapsibility index (CI) was normalized according to the standard formula as the IVC provided respiratory variance ($CI = [\{IVCe - IVCi\}/IVCe]$). The diameter of the RV was measured at the left lateral decubitus position, and the probe was placed between the third and fourth intercostals spaces. Measurement of diameter of the RV was performed at the time when the mitral valve started to close.

2.4. Study protocol

All patients received intramuscular atropine (0.5 mg) at 30 min before surgery. After all data were collected, 8 mL/kg of 6% hydroxyethyl starch (HES) solution (mean molecular weight, 130,000 d/mean degree of substitution, 0.4; Tianqing; Nanjing, China) was administered to patients within 30 min as intravenous fluid. After the volume therapy, all measurements (pulse and mean arterial pressure, IVCe, IVCi, RV, and CVP) were repeated. Healthy volunteers in the control group were also monitored in the supine or left lateral decubitus position. All measurements (except CVP) were performed, and liquid therapy was not performed because CVP measurement and liquid therapy were invasive procedures.

2.5. Statistical analysis

Statistical analysis was conducted using SPSS version 13.0 (SPSS, Inc, Chicago, IL). Descriptive statistics were used to summarize patient characteristics and study measurements. A paired t-test was used to compare hemodynamic data before and after fluid infusion, whereas an independent-sample t-test was used to compare the variables that gave a normal distribution between the patient group and the control group. The correlation between CVP and other hemodynamic variables was analyzed using the Pearson correlation test.

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