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Comparison of positive end-expiratory pressure–induced increase in central venous pressure and passive leg raising to predict fluid responsiveness in patients with atrial fibrillation

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Abstract

Background: Positive end-expiratory pressure (PEEP)–induced increase in central venous pressure (CVP) has been suggested to be a robust indicator of fluid responsiveness, with heart rhythm having minimal influence. We compared the ability of PEEP-induced changes in CVP with passive leg raising (PLR)–induced changes in stroke volume index (SVI) in patients with atrial fibrillation after valvular heart surgery.

Methods: In 43 patients with atrial fibrillation after cardiac surgery, PEEP was increased from 0 to 10 cm H_2O for 5 min and changes in CVP were assessed. After returning the PEEP to 0 cm H_2O, PLR was performed for 5 min and changes in SVI were recorded. Finally, 300 ml of colloid was infused and haemodynamic variables were assessed 5 min after completion of a fluid challenge. Fluid responsiveness was defined as an increase in SVI ≥10% measured by a pulmonary artery catheter.

Results: Fifteen (35%) patients were fluid responders. There was no correlation between PEEP-induced increases in CVP and changes in SVI after a fluid challenge (β coefficient −0.052, P=0.740), whereas changes in SVI during PLR showed a significant correlation (β coefficient 0.713, P<0.001). The area under the receiver operating characteristic curve of the PEEP-induced increase in CVP and changes in SVI during PLR for fluid responsiveness was 0.556 [95% confidence interval (CI) 0.358–0.753, P=0.549) and 0.771 (95% CI 0.619–0.924, P=0.004), respectively.

Conclusions: A PEEP-induced increase in CVP did not predict fluid responsiveness in patients with atrial fibrillation after cardiac surgery, but increases in SVI during PLR seem to be a valid predictor of fluid responsiveness in this subset of patients.

Key words: atrial fibrillation; central venous pressure; fluid responsiveness; passive leg raising; positive end-expiratory pressure

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Editor's key points

- Dynamic tests of fluid responsiveness are often used but their accuracy in patients with cardiac arrhythmias is not established.
- In this study of patients with atrial fibrillation after heart valve surgery, increasing CVP in response to increased PEEP did not predict fluid responsiveness.
- This differs from previous data in patients in sinus rhythm.
- In contrast, the effects of passive leg raising on stroke volume were more predictive.

Before initiating any fluid therapy, proper knowledge of the patient''s circulatory status on the Frank–Starling curve should be a prerequisite to prevent harmful fluid excess and oedema. During the past decade, dynamic indices derived from the arterial waveform have arisen as the most practical and robust guide to predict fluid responsiveness.[1–3] Due to their dependence on heart–lung interaction, however, the accuracy of these dynamic indices is confounded by ventilatory conditions and their clinical applicability is limited to patients with sinus rhythm.[4]

Evidence remains scarce on a practical and reliable preload index preventing harmful fluid loading in critically ill patients with valvular heart disease and arrhythmia, which is most commonly atrial fibrillation.[5–7] Although passive leg raising (PLR)–induced changes in stroke volume index (SVI) have shown promising results,[8–11] proper PLR testing requires position changes from a semi-recumbent position,[12] which is not always feasible in the critical care setting, and some form of cardiac output measurement.[13] Furthermore, the ability of PLR-induced changes in SVI to predict fluid responsiveness has not been tested prospectively in only cardiac surgical patients with atrial fibrillation.

Recently, positive end-expiratory pressure (PEEP)–induced changes in central venous pressure (CVP) have been shown to be an easy-to-use and valid predictor of fluid responsiveness in mechanically ventilated patients, with minimal risk of being influenced by ventilatory conditions or heart rhythm.[14] Still, evidence regarding its ability to predict fluid responsiveness in critically ill patients with rhythm other than sinus is lacking.

We therefore performed a prospective trial to compare the predictive power of PEEP-induced changes in CVP with that of PLR-induced changes in SVI on fluid responsiveness in patients with atrial fibrillation after valvular heart surgery.

Methods

Patients

After approval by the institutional review board of the Yonsei University Health System, Seoul, South Korea, study registration with ClinicalTrials.gov (ref: NCT02224378) and receiving informed consent from all patients, 44 consecutive patients with atrial fibrillation who underwent elective valvular heart surgery were enrolled. Exclusion criteria were left ventricular ejection fraction <40%, systolic pulmonary arterial pressure ≥50 mm Hg after surgery, history of pulmonary disease, end-stage renal disease, deep vein thrombosis, tricuspid regurgitation grade ≥2 after surgery and patients who received concomitant maze procedure. Patients who exhibited haemodynamic instability requiring rapid adjustments of cardiotonic drugs or with chest tube drainage >200 ml h^{-1} during the immediate postoperative period were also excluded.

Protocol and measurements

After induction of anaesthesia, a pulmonary artery catheter (Swan-Ganz CCOmbo, Edwards Lifesciences, Irvine, CA, USA) was inserted in all patients and used for continuous monitoring purposes for 1–2 days after surgery. All measurements were carried out following stabilization and within the first hour after arrival in the intensive care unit (ICU) following valvular heart surgery. During the observation period, the patients remained supine and doses of sedative and vasoactive agents were unaltered. Patients′ lungs were ventilated with a tidal volume of 8 ml kg^{-1} of the ideal body weight, respiratory rate of 12–16 breaths min^{-1} and a PEEP of 0 cm H_2O, at an inspired oxygen fraction of 40–60% with air to maintain the Pa_{O_2} at >100 mm Hg. Measurements of heart rate (HR), mean arterial pressure (MAP), CVP, pulmonary artery occlusion pressure (PAOP), cardiac index and SVI were made under four experimental conditions: (1) when PEEP was set to 0 cm H_2O (baseline); (2) 5 min after PEEP was increased to 10 cm H_2O; (3) 5 min after PLR and (4) 5 min after completion of fluid challenge (300 ml of 6% hydroxyethyl starch 130/0.4 [Volulyte, Fresenius Kabi, Stans, Switzerland]). Condition (3) was performed from the semi-recumbent position to ensure maximal endogenous fluid challenge as was recommended.[12] Positional change from the semi-recumbent position to the supine position was done using the automated bed motion followed by immediate leg elevation at 30 degrees, which was done manually using a goniometer. After performing conditions (2) and (3), all the settings were returned to baseline, adjusting PEEP from 10 to 0 cm H_2O and returning the patient to the supine position, respectively. Every step was done with a sufficient time interval when the patients were haemodynamically stable enough to follow the next step (i.e. with return of haemodynamic variables to their corresponding baseline values without requiring rapid adjustments of cardiotonic drug delivery or fluid loading, and the absence of excessive bleeding as described above). All pressure transducers were repositioned and zeroed after each positional change of the patients and CVP and PAOP were measured at end expiration. Fluid challenge was performed within 10 min in all patients.

Patients were classified as fluid responders if they showed an increase in SVI ≥10% after fluid challenge. Cardiac index and subsequently SVI values were obtained from the pulmonary artery catheter and three consecutive STAT mode values from the continuous cardiac output monitoring device (Vigilance, Edwards Lifesciences, Irvine, CA, USA) were averaged and recorded for analysis.

Statistical analysis

All haemodynamic data were analysed as continuous variables and are expressed as mean (sd) or frequency and percentage. Based on previous studies,[14 15] a difference in the area under the receiver operating characteristics curve (AUROC) of 0.2 was assumed between the null hypothesis of 0.7 and the alternative hypothesis of 0.9, and a sample size of 44 patients was estimated at a two-sided α=0.05 with 80% power. Intergroup comparisons of variables between responders and non-responders were conducted using Student's *t*-test for continuous variables and χ^2 or Fisher's exact test as appropriate for categorical variables. Pearson's correlation was used to evaluate the association between the assessed preload indices of interest and changes in SVI after fluid administration. From the ROC curves, the optimal cut-off value yielding the greatest combined sensitivity and specificity was measured. Statistical analyses were performed using SPSS software (version 20.0, SPSS, Chicago, IL, USA). A *P*-value <0.05 was considered statistically significant.