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Original Article

Comparison of right ventricular measurements by perioperative transesophageal echocardiography as a predictor of hemodynamic instability following cardiac surgery

Pei-Chi Ting [a,b], An-Hsun Chou [b], Chia-Chih Liao [b], Victor Chien-Chia Wu [c], Feng-Chun Tsai [d], Jaw-Ji Chu [d], Min-Wen Yang [b], Shi-Chuan Chang [a,*]

[a] Institute of Emergency and Critical Care Medicine, National Yang-Ming University, Taipei, Taiwan, ROC
[b] Department of Anesthesiology, Chang Gung Memorial Hospital, Linkou, Taiwan, ROC
[c] Department of Cardiology, Chang Gung Memorial Hospital, Linkou, Taiwan, ROC
[d] Division of Cardiovascular Surgery, Department of Surgery, Chang Gung Memorial Hospital, Linkou, Taiwan, ROC

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Abstract

Background: The relationship between perioperative right ventricular (RV) performance and hemodynamic instability after cardiac surgery seemed less portrayed. Therefore, we sought to elucidate this relationship and compare the accuracy of different RV systolic indices in predicting outcome of cardiac surgery.
Methods: This study enrolled consecutive patients referred for cardiac surgeries. Exclusion criteria were non-sinus rhythm or contraindications to transesophageal echocardiography (TEE). TEE exam and simultaneous pulmonary hemodynamics were recorded in two stages: after induction of anesthesia and before sternotomy (stage 1), and after sternal closure (stage 2). RV measurements performed offline included fractional area change (RVFAC), tricuspid annular plane systolic excursion (TAPSE), peak systolic tricuspid annular velocity (RVS′), myocardial performance index (RVMPI), and global longitudinal strain (RVGLS). The end point was defined as prolonged use (>24 h) of postoperative inotropic agent in the intensive care unit (ICU).
Results: The study population included 68 patients (mean age 61 ± 11 y; 49 men). Twenty-two of these patients (32%) were administered inotropic agents for a prolonged period with a mean duration of 63.9 ± 5.3 h, accompanied with significantly longer ventilator use ($p = 0.006$) and longer ICU stay ($p = 0.001$) than patients without a prolonged inotropic agent use. Multivariable analysis demonstrated that only RVGLS in either stage 1 (odds ratio [OR] 1.11, $p = 0.048$) or stage 2 (OR 1.15, $p = 0.018$) was significantly associated with the outcome, especially a RVGLS > −13.5% in stage 2 demonstrating high risk of prolonged inotropic agent use after cardiac surgery (OR 7.37, $p = 0.016$).
Conclusion: RVGLSs performed using perioperative TEE are reliably associated with hemodynamic instability following cardiac surgery. This finding adds substantial information to postoperative critical care.

Keywords: Cardiac surgery; Global longitudinal strain; Hemodynamic instability; Perioperative transesophageal echocardiography; Right ventricle

1. Introduction

Right ventricular (RV) dysfunction has been identified as a prognostic parameter to patients' outcomes after cardiac surgeries. Previous studies demonstrated that impaired RV systolic function, measured using conventional echocardiographic techniques, had a significant association with postoperative

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* Corresponding author. Dr. Shi-Chuan Chang, Department of Chest Medicine, Taipei Veterans General Hospital, 201, Section 2, Shi-Pai Road, Taipei 112, Taiwan, ROC.
E-mail address: scchang@vghtpe.gov.tw (S.-C. Chang).

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morbidities and mortality.[1,2] According to the reviewed pathophysiology,[3,4] RV dysfunction also presents hemodynamic instability, which remains a formidable clinical challenge in the intensive care unit (ICU), although it is usually overshadowed by other causes of low cardiac output syndrome. However, the relationship between RV measurements, especially in perioperative circumstances, and postoperative hemodynamic instability was less investigated. This relationship has the potential to substantially influence postoperative critical care of patients undergoing cardiac surgeries.

Conventional RV measurements, such as RV fractional area change (RVFAC), RV myocardial performance index (RVMPI), peak systolic tricuspid annular velocity (RVS′) using tissue Doppler imaging, or tricuspid annular plane systolic excursion (TAPSE), were assessed through precordial echocardiography.[5] To attenuate the influences of angle and direction encountered during transesophageal echocardiography (TEE), Matyal et al.[6] and Tousignant et al.[7] proposed methods where intraoperative assessments of RV became feasible.

Due to the specific geometry of RV, the newer means of RV global longitudinal strain (RVGLS) using two-dimensional (2-D) speckle tracking imaging was recommended in the term of perioperative TEE measurement as it is independent of angle.[8] Further, by providing more direct tracking, RV strain imaging has the potential to be more responsive to the possible insults. Therefore, in the present study, we sought to explore the relationship between RV measurements (using perioperative TEE) and postoperative hemodynamic instability in patients referred for cardiac surgery. Secondly, we aimed to evaluate whether RVGLS can better predict the outcome than other conventional indices.

2. Methods

2.1. Study population

This cross-sectional study was approved by the Institutional Review Board of Chang Gung Memorial Hospital, Linkou, and written informed consent was obtained from each patient before entering the study (IRB No. 101-1774B; July 17, 2012). We prospectively enrolled patients >20 years old who underwent cardiac surgery between July 2012 and July 2013. Exclusion criteria included contraindications to TEE and non-sinus rhythm. Comprehensive 2D and tissue Doppler TEE exams were obtained in the operating room under general anesthesia with endotracheal intubation. Echocardiographic and hemodynamic measurements were recorded at two stages: after induction of anesthesia and before sternotomy (stage 1) and after sternal closure (stage 2). All echocardiographic studies were performed with commercially available echocardiography systems equipped with a 5.0 MHz transducer (Vivid 7, GE Healthcare, Milwaukee, WI, USA) by an experienced investigator. In our protocol, we acquired TEE data from three to five consecutive cardiac cycles with temporary interruption of ventilator support. Special care was taken during acquisition to ensure an adequate sector for the entire RV free wall was recorded throughout the cardiac cycle, and that the frame rate of >60 Hz was maintained to facilitate optimal tracking of the myocardium. The best visualization of RV was achieved from a slightly lower esophageal four-chamber view, with appropriate adjustment of the probe (through posterior tilting and clockwise rotation). We also changed the multiplane angle from 0 to 20° to maximize and center the RV chamber. These images were transferred, via a network for offline analysis, using dedicated software (EchoPAC ′06, GE Healthcare, Milwaukee, WI, USA). The echocardiographic assessment of RV performance included RVFAC, TAPSE, RVMPI, RVS′, and RVGLS. All measurements were performed offline by one experienced investigator blinded to patients' outcomes. Patient demographics, comorbidities, and postoperative data were retrieved from a review of the medical record.

2.2. Echocardiographic measurements

RVFAC was calculated from the modified four-chamber view as RVFAC = (RV end-diastolic area − RV end-systolic area)/RV end-diastolic area × 100%.[1] TAPSE was acquired from the RV-centered four-chamber view with a floating M-mode cursor placed through the lateral tricuspid annulus and aligned with its motion.[7] TAPSE was measured as the tricuspid annulus excursion in mm from end-diastole to end-systole. RVMPI was obtained using pulse wave tissue Doppler from sample volume at the lateral tricuspid annulus in the RV-centered four-chamber view.[6] Filters were set to exclude high-frequency signals, and gain settings were minimized to allow a clear tissue signal with minimal background noise. RVMPI was calculated as the sum of isovolumic contraction time and isovolumic relaxation time, divided by ejection time. Meanwhile, RVS′ was also recorded.

Using 2D speckle tracking in the modified four-chamber view, a region of interest (ROI) was manually traced along the RV endocardial border starting at the basal septum and ending at the lateral tricuspid annulus.[8] Care was taken to maintain the ROI within the myocardium. In each cycle, the RV was then divided into six segments: three in the septum (apical, mid, and basal) and three in the lateral wall (apical, mid, and basal). Quantitative analysis was performed and a tracking score (pass/fail) was generated for each RV segment by the software (Fig. 1A). If some segments failed, the ROI was readjusted by moving the anchor points appropriately. The process was repeated to generate the largest number of pass scores per cycle. The software also detected the onset of QRS from the simultaneous electrocardiographic recordings to define the point of zero strain, and plotted both segmental and global strain curves. Global peak systolic strain values were recorded (Fig. 1B). The cutoff point of −13.5% for RVGLS was used based on a previous study.[9]

2.3. Endpoints

The primary outcome was evaluated by the need for prolonged use of inotropic agent. Administration of vasoactive

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