Intraoperative Right Ventricular Fractional Area Change Is a Good Indicator of Right Ventricular Contractility: A Retrospective Comparison Using Two- and Three-Dimensional Echocardiography

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Objective: **Intraoperative two-dimensional echocardiography is technically challenging, given the unique geometry of the right ventricle (RV). It was hypothesized that the RV fractional area change (RVFAC) could be used as a simple method to evaluate RV function during surgery. Therefore, the correlation between the intraoperative RVFAC and the true right ventricular ejection fraction (RVEF), as measured using newly developed three-dimensional (3D) analysis software, was evaluated.**

Design: **Retrospective study.**

Setting: **University hospital.**

Participants: **Patients who underwent cardiac surgery with transesophageal echocardiography monitoring between March 2014 and June 2014.**

Interventions: **None.**

Measurements and Main Results: **Sixty-two patients were included in this study. After the exclusion of poor imaging data and patients with arrhythmias, 54 data sets were analyzed. RVFAC was measured by one anesthesiologist during surgery, and full-volume 3D echocardiographic data were recorded simultaneously. The 3D data were analyzed postoperatively using off-line 3D analysis software by a second anesthesiologist, who was blinded to the RVFAC results. The mean RVFAC was 38.8% ± 8.7%, the mean RVEF was 41.4% ± 8.3%, and there was a good correlation between the RVFAC and the RVEF ($r^2 = 0.638$; $p < 0.0001$).**

Conclusions: **The RVFAC was well-correlated with the RVEF calculated using 3D echocardiography; therefore, RVFAC provides a simple and useful method for anesthesiologists to evaluate intraoperative RV function.**

KEY WORDS: right ventricular fractional area change, RVFAC, right ventricular ejection fraction, right ventricular function, three-dimensional echocardiography

ALTHOUGH TWO-DIMENSIONAL echocardiography (2DE) is useful in evaluating the function of the right ventricle (RV) with transthoracic echocardiography (TTE), intraoperative 2DE assessment of RV function with transesophageal echocardiography (TEE) is underutilized due to the complex structural geometry of the RV. However, RV dysfunction is a predictor of postoperative morbidity and mortality in patients undergoing cardiac surgery and should be detected using TTE or intraoperative TEE.[1–4] In addition, RV fractional area change (RVFAC) is a relatively simple method for evaluating RV function, and the guidelines of the American Society of Echocardiography recommend that it be used as a quantitative method for estimating RV function via TTE.[5]

Interestingly, software capable of combining 2DE RV images into a three-dimensional (3D) image recently has been developed.[6] The RV ejection fraction (RVEF) that is calculated using this software is known to be correlated strongly with the RVEF calculated using cardiac magnetic resonance imaging (CMR), which is the gold standard for evaluating RV volumes.[7,9] Therefore, it was hypothesized that the intraoperative measurement of RVFAC provides an accurate estimation of RVEF (as assessed using 3D echocardiography, [3DE]).

METHODS

Approval was obtained from the ethics committee of the authors' institution for this retrospective records-based study. All patients who underwent intraoperative TEE at the authors' institution between March 2014 and June 2014 were included in this study. The attending anesthesiologist determined the necessity of TEE in each case, and the exclusion criteria were poor full-volume 3D data due to arrhythmia or stitch artifact.

Echocardiography

TEE was performed using either the EPIQ 7C or the iE33 ultrasound systems (Philips Medical Systems, Bothell, WA), which were equipped with a 3D matrix array X7-2t transducer (Philips Medical Systems, Bothell, WA) for this study. All 2D and 3D images were acquired simultaneously in the midesophageal (ME) four-chamber view. Data initially were stored in the ultrasound systems and later were transferred to an off-line personal computer for postoperative analysis. Analysis of the RVFAC and 3D full-volume capture was performed by one anesthesiologist, and analysis of the 3D volumetric data was performed by another anesthesiologist; both were blinded to the other's analysis. RVFAC analysis was performed from the TEE

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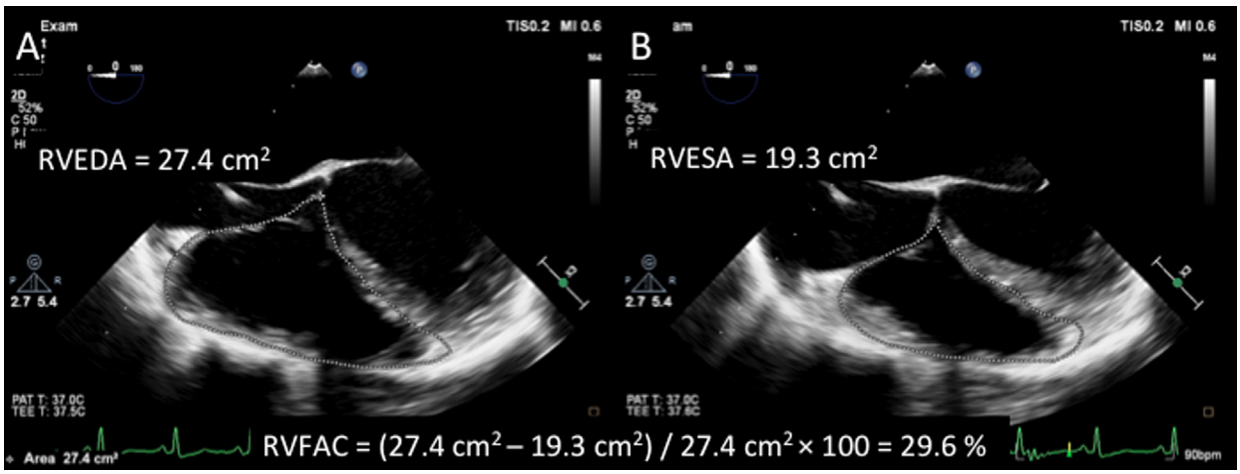

Fig 1. The right ventricular area is traced at end-diastole (A) and end-systole (B). The RVFAC is calculated as [(RVEDA – RVESA)/RVEDA] × 100 (%). Abbreviations: RVEDA, right ventricular end-diastolic area; RVESA, right ventricular end-systolic area; RVFAC, right ventricular fractional area change.

insertion until the initiation of cardiopulmonary bypass, except for the cases of transcatheter aortic valve implantation and noncardiac surgery. In the cases of transcatheter aortic valve implantation and noncardiac surgery, RVFAC was measured until the time of the skin incision. RVEF was calculated postoperatively using the same full-volume data set.

Two-Dimensional Echocardiographic Analysis

The area of the RV was measured by outlining the endocardial borders at end-diastole and end-systole in the ME four-chamber view. End-diastole was identified by the R-wave peak on the electrocardiogram, and end-systole was identified as the frame with the smallest RV. The RVFAC was calculated as follows: [RV end-diastolic area (RVEDA) – RV end-systolic area (RVESA)]/RVEDA] (Fig 1). The other indices of RV function, such as tricuspid annular plane systolic excursion (TAPSE) and the systolic tissue Doppler velocity of the tricuspid annulus (St), were not measured and stored in this study; therefore, those data could not be analyzed.

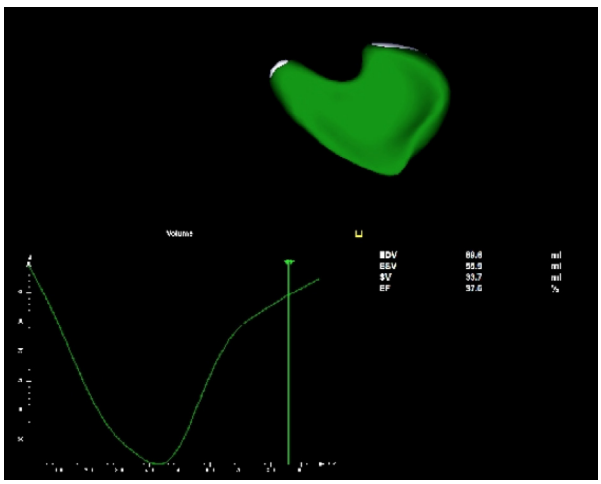

Fig 2. Beutel analysis of the right ventricle using the three-dimensional software program. The upper section of the workspace displays the right ventricle (Beutel). The lower section of the workspace is divided in 2 tiles, which display the dynamic graph of the global volume (left) and the volume measurements and right ventricular ejection fraction (right).

Three-Dimensional Echocardiographic Analysis

The full-volume data sets were acquired over 2 to 6 beats, immediately after the RVFAC measurements, and were exported from the ultrasound system to an off-line personal computer with the "Image Arena" software package (TomTec GmbH, Munich, Germany) after the surgery. The data sets then were analyzed using commercially available software (4D RV-Function; TomTec GmbH, Munich, Germany). 4D RV-function is the first application with a semi-automatic contour-finding algorithm that can automatically calculate 3D clinical results, including RV end-diastolic volume (RVEDV), RV end-systolic volume (RVESV), stroke volume, and RVEF. The RV data analysis was based on the following 4 steps: (1) "view adjustment" using 3 defined landmarks (the center of the mitral and tricuspid valves, as well as the apex of the left ventricle); (2) "set the initial

Table 1. List of Surgical Procedures

Procedure	Number
CABG	14
AVR	8
AVR + CABG	1
MVR	3
MVP	5
MVP + CABG	1
AVR + MVR	1
TAVI	6
Aortic surgery	6
LVAD implantation	5
VSP closure	1
Heart transplantation	1
Noncardiac surgery	2

Abbreviations: AVR, aortic valve replacement; CABG, coronary artery bypass grafting; LVAD, left ventricular assist device; MVP, mitral valve plasty; MVR, mitral valve replacement; TAVI, transcatheter aortic valve implantation; VSP, ventricular septal perforation.