Original Article

Right Ventricular Assessment by 2D Speckle-Tracking Echocardiography Before CABG in Patients With Preserved or Mild Left Ventricular Systolic Function

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ABSTRACT

Background: Data indicate the predictive role of abnormal right ventricular (RV) strain values in postoperative outcomes after coronary artery bypass grafting (CABG). Hence, we aimed to investigate the impact of RV strain assessment by 2D speckle-tracking echocardiography in predicting post-CABG complications.

Methods: This study analyzed 149 consecutive low-risk patients with preserved left ventricular (LV) and normal RV function concerning echo parameters, including LV ejection fraction and right ventricular free wall longitudinal strain (RVFWLS), undergoing isolated CABG. RVFWLS was assessed with 2D speckle-tracking echocardiography before surgery. Abnormal RVFWLS was defined as absolute RVFWLS < 19%. The adjusted effects of absolute RVFWLS strain and abnormal RVFWLS on the risk of ICU complications were assessed.

Results: Of 149 patients, 90 (60.4%) had abnormal preoperative RVFWLS (−16.5 ± 1.98). There were no significant associations between abnormal RVFWLS and postoperative serum creatinine rise, atrial fibrillation, ventilation time, inotrope use, cumulative dose, on-pump CABG, cardiopulmonary bypass duration, and length of ICU stay (all *P*s > 0.05). Postoperative ICU complications were not correlated with absolute RV strain values, except for ventilation time, which had a statistically significant but clinically negligible association with absolute RV strain values (regression coefficient = 1.035; $P = 0.016$). Since ventilation time is short (< 2 min), despite the positive statistical correlation, it had no clinical value.

Conclusions: RV strain measurements by 2D speckle-tracking echocardiography added no benefits to the prediction of ICU complications in low-risk patients undergoing CABG who had preserved or mildly impaired systolic LV function. ***(Iranian Heart Journal 2024; 25(1): 82-92)***

KEYWORDS: Two-dimensional speckle-tracking; Echocardiography, Coronary artery bypass, Outcome

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The functional assessment of the right ventricle (RV) has gained growing interest over the recent years. Several studies have evaluated the effects of RV dysfunction on outcomes among a broad spectrum of patients with cardiovascular diseases, including cardiac surgery, heart transplantation, heart failure with reduced ejection fraction, acute coronary syndromes, and cardiomyopathies, given that RV dysfunction is associated with adverse outcomes in the heart. [1-4] However, data have emerged on the importance of RV functional assessment in patients undergoing cardiac surgery. [5, 6] Evidence supports the notion that abnormal preoperative RV function might be associated with poor outcomes in patients undergoing coronary artery bypass grafting (CABG). [7-9]

Several diagnostic strategies and indices have been proposed to assess RV function. [10] Nonetheless, owing to technical difficulties and the unique anatomy of the RV, no consensus exists on the optimal method for assessing RV function. A few studies have investigated the association between RV dysfunction and adverse outcomes in CABG patients. These studies have reported that RV dysfunction could be associated with an increased risk of cardiovascular death, rehospitalization, and poor in-hospital outcomes. [7, 8] Still, they were limited by the small sample size and included high-risk patients with reduced left ventricular ejection fraction (LVEF). Two-dimensional (2D) speckle-tracking echocardiography has been suggested as a novel approach for assessing RV function and strain pattern. Nevertheless, most previous studies have used conventional echocardiography parameters, such as tricuspid annular plane systolic excursion (TAPSE), right ventricular systolic longitudinal velocity on tissue Doppler imaging (RV Sm), and fractional area change (FAC), or cardiac magnetic resonance imaging techniques to evaluate RV function. [11, 12]

The predictive role of RV functional assessment by 2D speckle-tracking echocardiography in the postoperative outcomes of CABG patients remains unclear. Moreover, data are scarce on the impact of abnormal RV strain on adverse cardiovascular outcomes among low-risk CABG candidates with normal or mildly reduced LVEF. Hence, we aimed to investigate the role of preoperative RV functional assessment by 2D speckle-tracking echocardiography in predicting the in-hospital outcomes of low-risk patients undergoing isolated CABG.

METHODS

Ethics Approval

The research followed the tenets of the Declaration of Helsinki. The Ethics Committee of Tehran University of Medical Sciences approved this study (ethics code # IR.TUMS.THC.REC.1400.072). Informed consent was obtained for the use of data and medical records of patients in the study according to the recommendation of the ethics committee. [15] Additionally the authors completely observed ethical issues, including plagiarism, data fabrication, and double publication.

Study Design and Population

This prospective observational study assessed consecutive patients undergoing CABG at Tehran Heart Center between May and October 2019. [13] Patients were included if all of the following criteria for low-risk cardiac surgery were present:

- LVEF ≥ 45%
- Pulmonary artery pressure < 35 mm Hg
- Preoperative serum creatinine level < 1.5 mg/dL
- EuroSCORE < 5 [14]

- Normal traditional indices of RV function (RV Sm > 9 cm/s and TAPSE > 17 mm)

(If one of these criteria was not satisfied, FAC was utilized for additional research. FAC needed to be > 35% for consideration in the study.)

Only mild valvular regurgitation levels were considered, and all other valvular, congenital, and vascular or structural disorders were excluded. Notwithstanding the fact that just 2% of the patients, as per the guidelines, exhibited diastolic dysfunction, diastolic measurements were not taken into consideration for the entry and departure criteria.

Data Collection and Echocardiography

Data regarding demographic characteristics, a history of hypertension, diabetes, dyslipidemia, and current smoking status were obtained. A single highly experienced echocardiologist performed a complete echocardiographic study within the prior week of the surgery with the Philips Ultrasound System (Affinity 70). The Biplane Simpson method and tricuspid regurgitation gradient were used to measure LVEF and pulmonary artery pressure. For the evaluation of LV diastolic function, average E/e', em septal or em lateral, LA volume index, and pulmonary artery pressure were assessed. Furthermore, several indices of RV function, including TAPSE, RV Sm, and RV dimensions, were measured for all the patients. In patients with equivocal results regarding RV dysfunction, RV fractional area change (RV FAC), defined as RV end-diastolic area – RV end-systolic area/RV end-diastolic area, was also measured. FAC was employed if the patient's TAPSE was > 17 mm and their RV Sm was < 9 cm/s or if their TAPSE was < 17 mm and their RV Sm was > 9 cm/s. In this instance, the patient was excluded from the research if FAC was < 35%. RV function was assessed using FAC for 24 patients.

Right ventricular free wall longitudinal strain (RVFWLS) was assessed via the 2D speckle-tracking method in at least 3 different RV-focused views (3 specialized echocardiographic views to observe the RV) recorded for at least 3 beats. RV free wall endocardial peak longitudinal strain at apical, mid, and basal segments was measured using the offline QLab Cardiac Analysis V12 (Philips Healthcare, Best, Netherlands). For the software analysis, the endocardium and epicardium were the inner and outer layers of the region of interest, respectively. In cases with no distinct boundary between the inner and outer layers, a default value of 5 mm was used. [16] Ultimately, the average of these measurements, calculated by the application, was considered the global RVFWLS value. The patients were categorized into groups with and without preoperative abnormal RVFWLS values. Based on previous literature, an abnormal RVFWLS value was defined as an RVFWLS with an absolute value < 19%. (The given RVFWLS value is a negative number.) [17]

Study Outcomes

Intraoperative features, including the use of the on-pump surgery method and cardiopulmonary bypass (CPB) duration, were assessed. The patients were closely followed during their stay at the ICU and the hospitalization period for postoperative complications. The length of ICU stay and complications, including ventilation time, inotrope use, cumulative received dose, postoperative atrial fibrillation, and serum creatinine rise, were further assessed. Postoperative atrial fibrillation was defined as the development of atrial fibrillation rhythm lasting for at least 30 seconds on 12-lead electrocardiograms or cardiac

monitoring devices. The ventilation time was defined as the duration of invasive mechanical ventilation support from intubation and anesthesia induction to extubation and spontaneous breathing. A cumulative dose of received inotropic agents, including epinephrine and norepinephrine, was calculated based on the sum of weight-based amounts. Moreover, serum creatinine rise was considered at least a 0.3 mg/dL rise in serum creatinine levels during ICU admission compared with preoperative values.

Statistical Analysis

Categorical variables were reported as numbers (percentages), while continuous variables were presented as the mean (± standard deviation) or the median (25%–75% percentiles) according to the normality of distribution. The Kolmogorov–Smirnov test and Q-Q plot were employed to check whether the data followed a normal distribution. Group differences were analyzed using the independent *t* test, the Mann–Whitney *U* test, and the χ^2 test for continuous (with/without normal distributions) and categorical variables. As appropriate, the unadjusted and adjusted effects of absolute RV strain values and abnormal RVFWLS on outcomes were evaluated using linear and binary logistic regression models. Logistic regression models were used to assess the effects of absolute RV strain values and abnormal RVFWLS on postoperative atrial fibrillation and serum creatinine rise. The results were reported as an odds ratio (OR) with a 95% confidence interval (CI). The linear regression model was utilized to assess the effects of absolute RV strain values and abnormal RVFWLS on the length of ICU stay and ventilation time. The results were reported based on the regression coefficient with a 95% CI. Since ventilation time and the length of ICU stay both had right-skewed distributions, their logarithm was used when constructing the models. In addition, 2-part models were used to evaluate the effects of the absolute RV strain value and abnormal RVFWLS on the cumulative inotropic dose and CPB duration as these were not universal to all the patients. The first part of the model fitted a logistic regression on inotrope usage (Yes/No) and off- or on-pump surgery. The second part fitted a linear regression model on the cumulative inotropic dose or CPB duration in the subgroup of patients who received inotrope agents or underwent on-pump surgery. All associations were adjusted for age, sex, body mass index, hypertension, diabetes, dyslipidemia, and current smoking status. All the statistical analyses were performed using STATA, version 14.1.

RESULTS

The present study assessed 149 consecutive low-risk patients with normal traditional indices of RV function undergoing isolated CABG. The mean age of the study population was 62.0 ± 8.32 years, and 30.2% were women. Hypertension, dyslipidemia, and diabetes were present in 89 (59.7%), 87 (58.4%), and 73 (49.0%) patients, respectively.

Baseline Characteristics

The mean value of RV free wall strain was −18.5% ± 3.15%. Intraclass correlation coefficient was used for interobserver and intraobserver variabilities. The coefficients were 82.5% and 90.6%, respectively. Moreover, 90 patients (60.4%) had abnormal RVFWLS (absolute value < 19%). There were no significant differences between patients with normal and abnormal RVFWLS regarding demographic and baseline characteristics, except for body mass index, which was higher among those with abnormal RVFWLS (27.7 vs 26.1 kg/m^2; *P* =

0.017). No significant differences existed in the traditional RV echocardiographic findings of RV Sm, RV dimension, and right atrial volume index between patients with and without abnormal RVFWLS, except for TAPSE, which was lower in those with abnormal RVFWL (20.1 vs 21.5 mm; *P* = 0.012). The details of the baseline characteristics and echocardiographic findings of the study population are further shown in Table 1. Average E/e' was > 14 in 7.38% of the patients, em septal was < 8 cm/s or em lateral was < 10 cm/s in 84.56%, and left atrial volume index was > 34 mL/m in 22.82%. According to the revised guidelines used in this study, 130 patients had normal diastolic function, only 3 individuals had diastolic dysfunction, and the remaining patients fell into the category of unknown.

ICU Complications

The patients stayed in the ICU for a median of 1 (1.0–2.0) day and were mechanically ventilated for 17 (14.5–22.5) hours. Postoperative atrial fibrillation was detected in 16 patients (10.7%), and a serum creatinine rise of at least 0.3 mg/dL was observed in 27 (18.1%). There was no significant difference in the occurrence of postoperative atrial fibrillation (12.2% vs 8.5%; *P* = 0.470) and serum creatinine rise (17.8% vs 18.6%; *P* = 0.893) between patients with abnormal RVFWLS and those with normal RV strain values. Similarly, there were similar rates of inotrope administration (28.9% vs 22.0%; *P* = 0.352) and cumulative inotropic dose (68.9 vs 110.5; *P* = 0.670) in patients with and without abnormal RVFWLS. The details of ICU complications and intraoperative features are further shown in Table 2.

Effects of the Absolute RV Strain Value and Abnormal RVFWLS on ICU Complications

After adjustments were made for age, sex, hypertension, diabetes mellitus, dyslipidemia, body mass index, and current smoking, abnormal RVFWLS was not significantly associated with a serum creatinine rise (OR, 0.893; 95% CI, 0.361 to 2.209; *P* = 0.807), atrial fibrillation (OR, 1.718; 95% CI, 0.514 to 5.749; *P* = 0.380), inotrope use (OR, 1.501; 95% CI, 0.678 to 3.326; *P* = 0.317), cumulative received inotropic dose (regression coefficient = 0.518; 95% CI, 0.177 to 1.511; *P* = 0.228), the length of ICU stay (regression coefficient = 0.916; 95% CI, 0.738 to 1.136; *P* = 0.422), the use of the on-pump surgery method (OR, 1.641; 95% CI, 0.536 to 5.023; *P* = 0.385), and CPB duration (regression coefficient = 1.026; 95% CI, 0.915 to 1.151; *P* = 0.656) (Table 3). In addition, there was a nonsignificant trend toward a lower ventilation time with subclinical RV dysfunction (regression coefficient = 0.866, 95% CI, 0.725 to 1.034; *P* = 0.111).

The results of multivariable linear regression analysis and multiple linear regression analysis showed no significant associations between absolute RV free wall strain values and the length of ICU stay, serum creatinine rise, postoperative atrial fibrillation, inotrope use, cumulative received inotropic dose, CPB use, and CPB duration (Table 4). However, there was a statistically significant association between ventilation time and absolute RV free wall strain values after adjustments for confounding variables (regression coefficient = 1.035; 95% CI, 1.006 to 1.064; *P* = 0.016).

Table 1: Baseline Characteristics and Echocardiographic Findings in the Studied Patients With and Without Abnormal RVFWLS

	Total Population (N = 149)	Normal RVFWLS (n = 59)	Abnormal RVFWLS (n = 90)	*P* value
Baseline Characteristics				
Age, y	62.0 ± 8.32	62.2 ± 8.14	61.9 ± 8.49	0.829
Female	45 (30.2)	19 (32.2)	26 (28.9)	0.666
Body mass index, kg/m^2	27.1 ± 4.09	26.1 ± 3.36	27.7 ± 4.41	0.017
Hypertension	89 (59.7)	34 (57.6)	55 (61.1)	0.672
Dyslipidemia	87 (58.4)	31 (52.5)	56 (62.2)	0.241
Diabetes mellitus	73 (49.0)	31 (52.5)	42 (46.7)	0.483
Current smoking	28 (18.8)	10 (16.9)	18 (20.0)	0.641
Echocardiographic Findings				
RVFWLS, %	-18.5 ± 3.15	-21.6 ± 1.92	-16.5 ± 1.98	<0.001
TAPSE, mm	20.7 ± 3.44	21.5 ± 3.78	20.1 ± 3.08	0.012
RV Sm, cm/s	11.5 ± 2.11	11.9 ± 2.12	11.3 ± 2.08	0.095
RV dimension, mm	29.2 ± 3.11	29.3 ± 3.08	29.1 ± 3.14	0.738
RA volume index, mL/m^2	17.9 ± 4.89	18.6 ± 4.86	17.5 ± 4.88	0.170

RA: right atrium; RV: right ventricle; RVFWLS: right ventricular free wall longitudinal strain; RV Sm: right ventricular peak systolic myocardial velocity; TAPSE: tricuspid annular plane systolic excursion

Table 2: Intraoperative Features and ICU Complications in the Studied Patients With and Without Abnormal RVFWLS

	Total Population (N = 149)	Normal RVFWLS (n = 59)	Abnormal RVFWLS (n = 90)	*P* value
Intraoperative Features				
On-pump surgery method	134 (89.9)	51 (86.4)	83 (92.2)	0.251
CPB duration, min	70.5 (60.0 – 95.0)	71.0 (60.0 – 95.0)	70.0 (60.0 – 95.0)	0.833
ICU complications				
Serum Cr rise ≥ 0.3 mg/dL	27 (18.1)	11 (18.6)	16 (17.8)	0.893
Atrial fibrillation	16 (10.7)	5 (8.5)	11 (12.2)	0.470
Ventilation time, h	17 (14.5-22.5)	17 (14.5- 23)	17 (14.5-21.4)	0.529
Inotrope use	39 (26.2)	13 (22.0)	26 (28.9)	0.352
Inotrope dose, mL	75.6 (20.8 – 167.0)	110.5 (16.8 – 519.8)	68.9 (22.8 – 159.4)	0.670
Length of ICU stay, d	1.0 (1.0-2.0)	1.0 (1.0-2.0)	1.0 (1.0-2.0)	0.792

Cr: creatinine; CPB: cardiopulmonary bypass; ICU: intensive care unit; RVFWLS: right ventricular free wall longitudinal strain

Table 3: Unadjusted and Adjusted Effects of Abnormal RVFWLS on ICU Complications and Intraoperative Features

ICU Complication	Unadjusted Effect (95% CI)	*P* value	Adjusted ** Effect (95% CI)	*P* value
Serum Cr rise ≥ 0.3 mg/dL † (odds ratio ± 95% CI)	0.943 (0.404 – 2.206)	0.893	0.893 (0.361 – 2.209)	0.807
Atrial fibrillation † (odds ratio ± 95% CI)	1.504 (0.494 – 4.574)	0.472	1.718 (0.514 – 5.749)	0.380
Ventilation time, h * (coefficient ± 95% CI)	0.882 (0.740 – 1.051)	0.161	0.866 (0.725 – 1.034)	0.111
Inotrope use † (odds ratio ± 95% CI)	1.438 (0.668 – 3.092)	0.353	1.501 (0.678 – 3.326)	0.317
Inotrope dose, mL* (coefficient ± 95% CI)	0.755 (0.282 – 2.022)	0.576	0.518 (0.177 – 1.511)	0.228
Length of ICU stay, d * (coefficient±95% CI)	0.923 (0.741 – 1.150)	0.476	0.916 (0.738 – 1.136)	0.422
CPB				
CPB duration, min * (coefficient ± 95% CI)	1.019 (0.913 – 1.138)	0.734	1.026 (0.915 – 1.151)	0.656

CPB: cardiopulmonary bypass pump; CI: confidence interval; Cr: creatinine; RV: right ventricle; RVFWLS: right ventricular free wall longitudinal strain

** Adjusted for age, sex, hypertension, diabetes mellitus, dyslipidemia, body mass index, and current smoking

* Regression coefficient

† Odds ratio

Table 4: Unadjusted and Adjusted Effects of Absolute RV Strain Values on ICU Complications and Intraoperative Features

ICU Complication	Unadjusted	*P* value	Adjusted **	*P* value
Serum Cr rise ≥ 0.3 mg/dL † (coefficient ± 95% CI)	0.989 (0.866-1.129)	0.868	1.015 (0.883-1.167)	0.836
Atrial fibrillation † (odds ratio ± 95% CI)	1.068 (0.906-1.258)	0.436	1.051 (0.880-1.255)	0.584
Ventilation time, h * (coefficient ± 95% CI)	1.031 (1.004-1.060)	0.025	1.035 (1.006-1.064)	0.016
Inotrope use † (Odds ratio ± 95% CI)	0.991 (0.882-1.113)	0.880	0.992 (0.878-1.120)	0.899
Inotrope dose, mL * (coefficient ± 95% CI)	0.030 (-0.132-0.193)	0.714	0.075 (-0.105-0.256)	0.411
Length of ICU stay, d * (coefficient ± 95% CI)	1.028 (0.994-1.063)	0.112	1.032 (0.997-1.067)	0.070
CPB				
CPB duration, min * (coefficient ± 95% CI)	-0.003 (-0.020-0.014)	0.698	-0.004 (-0.022-0.014)	0.652

CPB: cardiopulmonary bypass pump; CI: confidence interval; Cr: creatinine; RV: right ventricle

** Adjusted for age, sex, hypertension, diabetes mellitus, dyslipidemia, body mass index, and current smoking
* Regression coefficient (multivariable linear regression analysis)
† Odds ratio (using multiple linear regression analysis)

DISCUSSION

The present prospective study investigated the role of RV functional assessment with 2D speckle-tracking echocardiography in predicting postoperative complications among low-risk patients with normal-to-mildly reduced LVEF and normal RV function by traditional echocardiographic parameters undergoing isolated CABG. We observed that abnormal RV free wall strain values was not significantly associated with an increased risk of postoperative serum creatinine rise, atrial fibrillation, ventilation time, inotrope use, cumulative inotropic dose, the length of ICU stay, the use of the on-pump surgery method, and CPB duration. Nonetheless, there was a statistically significant but clinically negligible association between the absolute RV strain values and ventilation time.

Despite the positive statistical correlation, the ventilation period was brief (< 2 min); accordingly, it was of no therapeutic significance.

There is reasonable evidence regarding the importance of LV dysfunction in predicting the short- and long-term outcomes of patients undergoing cardiac surgery. [18, 19] Still, there is a lack of data on the predictive role of RV dysfunction and RV strain values in the risk of postoperative detrimental outcomes and complications after cardiac surgery. In addition, different views exist regarding what constitutes the most reliable technique for assessing RV function in patients undergoing CABG. While some studies emphasize the significance of RV assessment with 3D echocardiography and cardiac magnetic resonance imaging before cardiac surgery, there is an increasing trend toward utilizing 2D speckle-tracking echocardiography since this method provides detailed information about the RV strain pattern and detects earlier stages of RV dysfunction. [11, 20, 21]

Previous studies have reported that preoperative RV dysfunction in patients with severely reduced LVEF undergoing CABG is significantly associated with an increased risk of postoperative complications and long-term adverse outcomes. [7, 8, 12] In a prior study, preoperative RV dysfunction assessed by conventional echocardiography methods significantly prolonged mechanical ventilation, the length of ICU admission, and the length of hospital stay in these patients. [7] Furthermore, it was observed that patients with LVEF ≤ 35% and concomitantly reduced preoperative RV function detected by cardiac magnetic resonance imaging had significantly higher rates of cardiovascular death after CABG

than those with normal RV function. [12] Be that as it may, data are scant on the impact of RV dysfunction on the prognosis of patients with normal LVEF. In addition, as previous studies have assessed RV dysfunction by conventional methods, there is a dearth of information on abnormal RV strain values in predicting adverse outcomes in patients undergoing CABG.

A few studies have investigated the effects of RV strain detected by 2D speckle-tracking echocardiography on the outcome of patients undergoing CABG. Tabernacle et al [22] assessed the prognostic value of RV strain in patients referred for cardiac surgery and showed that an abnormal RV global strain value was associated with a higher mortality rate even after adjustments for confounding covariates. However, only one-third of their study participants underwent isolated CABG, and approximately 35% had LV dysfunction. Their study was retrospective and assessed LV function using solely LVEF via the Simpson biplane technique. The authors included 164 patents with LVEF > 50% and 87 patents with LVEF < 50% in their analysis, while we selected all patients who showed LVEF > 45%. Hence, these findings should be cautiously interpreted in patients with preserved LV function undergoing isolated CABG.

It is also hypothesized that RV dysfunction could increase the chance of postoperative acute kidney injury and renal failure among patients undergoing cardiac surgery. This hypothesis was investigated in a previous study that assessed RV dysfunction by conventional echocardiography in cardiac surgery patients. [6] The mentioned study showed that early postoperative RV dysfunction was associated with a subsequent increase in the serum creatinine level. However, we observed that the mere presence of abnormal RV strain values in the absence of overt RV dysfunction did not significantly increase serum creatinine levels after surgery. This finding was also supported in a previous study reporting no significant association between acute kidney injury and RV strain assessed by 2D speckle-tracking echocardiography. [23]

In addition, there is some evidence that the presence of traditional criteria for RV dysfunction in conventional echocardiography is associated with prolonged intubation, increased norepinephrine use, and a lengthier ICU stay. [6] The relationship between RV dysfunction and septic shock has also been studied in various studies. [24] Nevertheless, the present study showed that mildly abnormal RV strain values in the absence of RV dysfunction based on traditional echocardiographic parameters did not lead to an increased risk of inotropic agent use and a lengthened ICU stay. Although there was a statistically significant association between absolute RV strain values and ventilation time, the effect was negligible and clinically insignificant.

In the current study, we observed no significant relationships between abnormal RVFWLS and postoperative complications in patients undergoing isolated CABG who had preserved LV function and normal RV function based on traditional parameters, including TAPSE and RV SM. We believe that the inclusion of low-risk patients with preserved LV and normal RV function in our study population could result in similar postoperative consequences between patients with and without abnormal RV strain values. Moreover, since we primarily focused on immediate outcomes, we did not evaluate whether abnormal RVFWS could result in long-term problems, even in low-risk individuals after discharge. It is possible that RV dysfunction, as measured by 2D speckle-tracking, is in the early preclinical stages, and the cells of the RV have not been damaged to the extent that its effect will be revealed in the stages after surgery. Interestingly, most of our patients with right coronary artery

stenosis (71.6%) had abnormal RVFWLS, while only 30% of other patients had abnormal RVFWLS ($P < 0.001$). Because there were more patients with coronary involvement in the right coronary artery territory, we believe that the bypass of the right coronary artery during CABG improves RVFWS and over time, this will help the patient's functioning condition.

Consequently, we believe that future studies should investigate the impact of abnormal RV strain values detected by 2D speckle-tracking echocardiography in other patient populations, including high-risk CABG candidates with reduced LVEF and patients undergoing other types of cardiac surgery.

CONCLUSIONS

Using a carefully selected low-risk group of patients who underwent isolated CABG, we found that having mildly abnormal RV free wall strain values before surgery did not affect in-hospital outcomes and complications in low-risk patients. Hence, RV free wall longitudinal strain measurements by 2D speckle-tracking echocardiography before isolated CABG in low-risk patients with normal or mildly impaired LV systolic function and normal RV function based on conventional echocardiographic parameters do not have added value for the prediction of post-surgery ICU course morbidities. Future studies should focus on the predictive role of RV strain values assessed by 2D speckle-tracking echocardiography in high-risk groups of patients undergoing cardiac surgery and those with LV or RV dysfunction.

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Availability of Data and Materials:
The data sets used and analyzed in the current study are archived at Tehran Heart Center and are available from the corresponding author upon reasonable request.

Ethics Approval and Consent to Participate
The Ethics Committee of Tehran University of Medical Sciences approved this study (ethics code # IR.TUMS.THC.REC.1400.072). This study was extracted from the thesis of Somayyeh Norouzi at this university. We confirm that all experiments and methods were performed in accordance with relevant guidelines. Further, we confirm that all patients signed informed consent forms to participate in this study.

Consent for Publication:
Not applicable

Conflict of Interest:
The authors declare that they have no competing interests**.**

REFERENCES

1. Haddad F, Doyle R, Murphy DJ, Hunt SA. Right ventricular function in cardiovascular disease, part II: pathophysiology, clinical importance, and management of right ventricular failure. Circulation. 2008; 117(13):1717-31.

2. Haddad F, Denault AY, Couture P, Cartier R, Pellerin M, Levesque S, et al. Right ventricular myocardial performance index predicts perioperative mortality or circulatory failure in high-risk valvular surgery. Journal of the American Society of Echocardiography: official publication of the American Society of Echocardiography. 2007; 20(9):1065-72.

3. Stämpfli SF, Donati TG, Hellermann J, Anwer S, Erhart L, Gruner C, et al. Right ventricle and outcome in left ventricular non-compaction cardiomyopathy. J Cardiol. 2020; 75(1):20-6.

4. Bening C, Sales VL, Alhussini K, Radakovic D, Benitez RC, Madrahimov N, et al. Clinically inapparent right heart dysfunction is associated with reduced myofilament

force development in coronary artery disease. BMC Cardiovasc Disord. 2021; 21(1):125.

5. Chinikar M, Rafiee M, Aghajankhah M, Gholipour M, Hasandokht T, Imantalab V, et al. Right ventricular dysfunction and associated factors in patients after coronary artery bypass grafting. ARYA atherosclerosis. 2019; 15(3):99-105.

6. Guinot PG, Abou-Arab O, Longrois D, Dupont H. Right ventricular systolic dysfunction and vena cava dilatation precede alteration of renal function in adult patients undergoing cardiac surgery: An observational study. European journal of anaesthesiology. 2015; 32(8):535-42.

7. Maslow AD, Regan MM, Panzica P, Heindel S, Mashikian J, Comunale ME. Precardiopulmonary bypass right ventricular function is associated with poor outcome after coronary artery bypass grafting in patients with severe left ventricular systolic dysfunction. Anesthesia and analgesia. 2002; 95(6):1507-18, table of contents.

8. Lella LK, Sales VL, Goldsmith Y, Chan J, Iskandir M, Gulkarov I, et al. Reduced Right Ventricular Function Predicts Long-Term Cardiac Re-Hospitalization after Cardiac Surgery. PloS one. 2015; 10(7):e0132808.

9. Alam M, Hedman A, Nordlander R, Samad B. Right ventricular function before and after an uncomplicated coronary artery bypass graft as assessed by pulsed-wave Doppler tissue imaging of the tricuspid annulus. Am Heart J. 2003; 146(3):520-6.

10. Haddad F, Hunt SA, Rosenthal DN, Murphy DJ. Right ventricular function in cardiovascular disease, part I: Anatomy, physiology, aging, and functional assessment of the right ventricle. Circulation. 2008; 117(11):1436-48.

11. Kang DK, Lim SH, Park JS, Sun JS, Ha T, Kim TH. Clinical utility of early postoperative cardiac multidetector computed tomography after coronary artery bypass grafting. Scientific reports. 2020; 10(1):9186.

12. Pouleur AC, Rousseau MF, Ahn SA, Amzulescu M, Demeure F, de Meester C, et al. Right Ventricular Systolic Dysfunction Assessed by Cardiac Magnetic Resonance Is a Strong Predictor of Cardiovascular Death After Coronary Bypass Grafting. The Annals of thoracic surgery. 2016; 101(6):2176-84.

13. Poorhosseini H, Abbasi SH. The Tehran Heart Center. Eur Heart J. 2018 Aug 1; 39(29):2695-2696. doi:10.1093/eurheartj/ehy369.

14. Nashef SA, Roques F, Michel P, Gauducheau E, Lemeshow S, Salamon R. European system for cardiac operative risk evaluation (EuroSCORE). European journal of cardio-thoracic surgery : official journal of the European Association for Cardio-thoracic Surgery. 1999; 16(1):9-13.

15. World Medical Association Declaration of Helsinki: ethical principles for medical research involving human subjects. Jama. 2013; 310(20):2191-4.

16. Badano LP, Kolias TJ, Muraru D, Abraham TP, Aurigemma G, Edvardsen T, et al. Standardization of left atrial, right ventricular, and right atrial deformation imaging using two-dimensional speckle tracking echocardiography: a consensus document of the EACVI/ASE/Industry Task Force to standardize deformation imaging. European heart journal cardiovascular Imaging. 2018; 19(6):591-600.

17. Morris DA, Krisper M, Nakatani S, Köhncke C, Otsuji Y, Belyavskiy E, et al. Normal range and usefulness of right ventricular systolic strain to detect subtle right ventricular systolic abnormalities in patients with heart failure: a multicentre study. European heart journal cardiovascular Imaging. 2017; 18(2):212-23.

18. Saxena A, Paramanathan A, Shi WY, Dinh DT, Reid CM, Smith JA, et al. impact of left ventricular dysfunction on early and late outcomes in patients undergoing concomitant aortic valve replacement and coronary artery bypass graft surgery. Cardiology journal. 2013;20(4):423-30.

19. Ji Q, Xia LM, Shi YQ, Ma RH, Shen JQ, Ding WJ, et al. impact of severe left

ventricular dysfunction on in-hospital and mid-term outcomes of Chinese patients undergoing first isolated off-pump coronary artery bypass grafting. Journal of cardiothoracic surgery. 2017; 12(1):87.

20. Mandoli GE, Cameli M, Novo G, Agricola E, Righini FM, Santoro C, et al. Right ventricular function after cardiac surgery: the diagnostic and prognostic role of echocardiography. Heart failure reviews. 2019; 24(5):625-35.

21. Kukulski T, She L, Racine N, Gradinac S, Panza JA, Velazquez EJ, et al. Implication of right ventricular dysfunction on long-term outcome in patients with ischemic cardiomyopathy undergoing coronary artery bypass grafting with or without surgical ventricular reconstruction. The Journal of thoracic and cardiovascular surgery. 2015; 149(5):1312-21.

22. Tabernacle J, Berry M, Cognet T, Kloeckner M, Damy T, Monin JL, et al. Prognostic value of right ventricular two-dimensional global strain in patients referred for cardiac surgery. Journal of the American Society of Echocardiography : official publication of the American Society of Echocardiography. 2013; 26(7):721-6.

23. Yockelson SR, Heitner SB, Click S, Geleto G, Treggiari MM, Hutchens MP. Right Ventricular Systolic Performance Determined by 2D Speckle-Tracking Echocardiography and Acute Kidney Injury After Cardiac Surgery. Journal of cardiothoracic and vascular anesthesia. 2019; 33(3):725-31.

24. Lanspa MJ, Cirulis MM, Wiley BM, Olsen TD, Wilson EL, Beesley SJ, et al. Right Ventricular Dysfunction in Early Sepsis and Septic Shock. Chest. 2021; 159(3):1055-63.