Iranian Heart Journal; 2019; 20 (4)

Original Article

Assessment of the Coronary Sinus Diameter after Successful Coronary Artery Bypass Surgery: A Preliminary Echocardiographic Cardiac Perfusion Study

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ABSTRACT

Background: There is a growing interest in noninvasive methods for the assessment of sufficient coronary flow after coronary artery bypass graft surgery (CABG) by transthoracic echocardiography (TTE).

Methods: We performed this study to evaluate the coronary sinus diameter (CSD), as a confident marker of the coronary blood flow, by TTE among patients undergoing CABG. A total of 104 elective CABG patients with double, triple, or more coronary artery diseases were enrolled in this cross-sectional study. Four patients were lost to follow-up because of poor echocardiographic window or death. One day before and 7 days after CABG, all the patients underwent TTE.

Results: The mean CSD was calculated by averaging the diameters of the middle and terminal segments of the coronary sinus. The left ventricular ejection fraction (LVEF) was calculated using the Simpson methods. The CSD in the middle (11.1%; $P < 0.0001$) and terminal (10.1%; $P < 0.0001$) segments was significantly increased after CABG among all the patients. Additionally, the diameter change was most prominent among those with triple vessel disease. Similarly, a significant increase was observed in the mean CSD after CABG (11.3%; $P < 0.0001$).

Conclusions: No significant changes were observed after CABG with respect to the LVEF in the first postoperative week. The findings showed that the TTE-determined CSD could be a potential surrogate for sufficient coronary perfusion and graft patency after CABG. ***(Iranian Heart Journal 2019; 20(4): 6-12)***

KEYWORDS: Coronary sinus diameter, Transthoracic echocardiography, Coronary artery bypass graft surgery

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Received: December 4, 2018 **Accepted:** March 10, 2019

Coronary artery bypass graft surgery (CABG) provides good results in short and intermediate terms in the management of advanced coronary artery disease. However, its short-term results are affected by the failure of venous grafts in 8%–12% of grafts before hospital discharge. [1] Therefore, early detection of acute graft occlusion and the reconstruction of the graft could improve CABG results.

The gold-standard diagnostic methods to investigate coronary arteries and the bypass flow status are invasive. Some investigators have used intraoperative fluorescence imaging systems [2, 3] or transit time flowmetry [2,4] for the assessment of grafts. Moreover, cardiac catheterization (eg, digital coronary angiography, [5] thermodilution catheters, [6] and intravascular Doppler flow wires) or the use of radioisotope dyes for the evaluation of coronary sinus blood flow (CSBF) are used as a measure of cardiac perfusion. Because of the possible risks of some methods (0.1% mortality and the risk of minor or even major complications), asymptomatic post-CABG patients cannot be recommended for the assessment of graft patency in general. [5] All the abovementioned considerations have prompted investigators to find alternative, noninvasive methods of bypass graft assessment.

A number of studies have shown that transesophageal echocardiography (TEE), a semi-invasive method, could be used to evaluate the CSBF [7,8] and the coronary flow reserve by measuring the coronary sinus diameter (CSD) and the flow velocity. In a previous study, transthoracic echocardiography (TTE) was used for the measurement of the CSBF in 15 post-CABG patients using the same parameters. [9] Another study compared TEE with TTE for the evaluation of the CSBF and described the low accuracy of the coronary sinus study by TTE [10] because of difficulties in the measurement of the velocity-time integral and the flow velocity in the coronary sinus. We aimed to draw upon TTE in a reasonable number of patients candidated for CABG to determine whether the CSD alone could be used as a marker of improved perfusion and graft patency after CABG.

METHODS

The present cross-sectional study was approved by the Ethics Committee of Jundishapur University of Medical Sciences, Ahvaz, Iran. Informed consent was obtained from all the patients. The study was performed in the Cardiology Department of Golestan Hospital, a referral center of cardiovascular disease affiliated with Jundishapur University of Medical Sciences.

Study Population

A total of 104 consecutive patients who underwent elective CABG were enrolled in this study. Four patients were lost to follow-up because of poor echocardiographic window or death. The exclusion criteria were comprised of congenital heart diseases such as shunts or fistulae communicating with the coronary sinus, severe tricuspid or mitral valve regurgitation, a left ventricular ejection fraction (LVEF) < 35%, severe pulmonary artery or right atrial and/or right ventricular hypertension, and non-sinus rhythms on the electrocardiogram (ECG).

Study Protocol

Baseline characteristic data were obtained from all the patients, along with medical history, physical examination data, and laboratory data. The patients' age; sex; weight; body surface area; and risk factors such as diabetes (known diabetes confirmed according to a blood sugar level > 126 mg/dL), hypertension (typical presentation of 2 separate blood pressure levels > 140/90 mm Hg), and a history of myocardial infarction were evaluated. The extent of coronary artery involvement was evaluated according to selective coronary angiography results. The patients with significant coronary stenosis in 2 or 3 vessels > 70% of the diameter of the lumen or > 50% luminal stenosis of the isolated left main not suitable for coronary angioplasty were scheduled for CABG. TTE was conducted by licensed echocardiographers using multiple views 1 day before and 1 week after surgery. All the patients received nitrates, beta-blockers, angiotensin inhibitors, and statins (except for aspirin and clopidogrel) before surgery. After CABG, all the patients were kept for 2 days in the intensive care unit and were treated with the same drugs in addition to aspirin and analgesics. A total of 103 patients were in good condition for up to 1 week after surgery. Clinical follow-up was performed in the outpatient clinic for the first 3 months, and there were no ischemic problems.

TTE

All the patients underwent TTE with a 3-MHz transducer (Vivid 3, GE, Wisconsin, USA) and a 3-MHz probe. ECG monitoring was done simultaneously. The coronary sinus was imaged by posterior tilting of the transducer in the apical 4-chamber view. The LVEF was calculated using the Simpson method. The CSD was measured at the site of the coronary sinus entrance to the right atrium (as the terminal segment) and 10 millimeters away from it (as the middle segment) by using 2D and M-mode echo in each segment. The CSD was measured in 3 consecutive cardiac cycles after the T-wave in ECG. (Usually, the CSD expands in systole and compresses in diastole and cyclic changes are more prominent in the middle segment.) The measurements of each mode in each segment were averaged and used as the mean diameter of the middle and terminal segments of the coronary sinus. In our study, the mean CSD was calculated as follows: the mean diameter of the middle segment (by 2-D or M-mode) + the mean diameter of the terminal segment/2. All the measurements were performed on 2 occasions, and the median was calculated.

Statistical Analysis

The continuous variables were presented as the mean ± the standard deviation (SD). The paired *t*-test was used for paired comparisons and the independent *t*-test was applied for the statistical analyses. Statistical package SPSS, version 16, for Windows was used. All the *P* values were 2-tailed, with a statistical significance defined by a $P < 0.05$.

RESULTS

Of the 104 patients enrolled in the present study, 1 patient died in the perioperative period before 1 week and 3 patients had poor echocardiographic views after surgery, which excluded from the study. The mean age of the patients was 60 ± 18 years. The male-to-female ratio was 3 to 1. The baseline clinical characteristics of the study patients are presented in Table 1. The echocardiographic findings of the patients are shown in Table 2. The resting heart rate and the LVEF did not differ significantly before and after CABG. The diameters of the middle (6.68 ± 0.52 vs 7.42 ± 0.62; $P < 0.0001$) and terminal (7.20 ± 0.52 vs 7.93 ± 0.68; $P < 0.0001$) segments of the coronary sinus were significantly increased after CABG.

Table 1. Baseline clinical characteristics of the study patients (N = 104)

Characteristic	number(104), mean[a],percent
Age (y)	59.93± 10.09
Male sex female sex	75 (73%) 28(27%)
Weight (kg)	72.69± 11.69
BSA (kg/m^2)	1.83± 0.18
Diabetes mellitus no diabetes	33 (32%) 70(68%)
Systemic hypertension	58 (58%)
History of MI	37 (37%)
LM disease	20(19%)
Double-vessel CAD	21 (21%)
Triple-vessel CAD	62(60%)

All plus-minus values are mean ± SD.
BSA, Body surface area; MI, Myocardial infarction; CAD, Coronary artery disease; LM, Left main

Table 2. Echocardiographic characteristics of the CSD and the LVEF before and after CABG

Characteristic	One Day Before CABG[a]	Seven Days After CABG[a]	Percent of Difference	*P* value
EF (%)	55.0 ± 10.4	52.3 ± 7.3	-4.9%	NS
Heart rate (beat/min)	72 ± 12	75 ± 13	4.2%	NS
Middle segment of the CS (mm)	6.68 ± 0.52	7.42 ± 0.62	11.8%	< 0.0001*
Terminal segment of the CS (mm)	7.20 ± 0.52	7.93 ± 0.68	10.1%	< 0.0001*
Mean CSD (mm)	6.89 ± 0.69	7.67 ± 0.65	11.3%	< 0.005*

All plus-minus values are mean ± SD.
CABG, Coronary artery bypass graft surgery; CS, Coronary sinus; CSD, Coronary sinus diameter; LVEF, Left ventricular ejection fraction; NS, Nonsignificant *$P < 0.05$ is significant.

Similarly, a significant increase was observed in the mean CSD after CABG (6.89 ± 0.69 vs 7.67 ± 0.65; $P < 0.005$). In different groups before and after CABG, a history of diabetes, hypertension, or myocardial infarction had no statistically significant effects on the results (Table 4). The CSD in the patients with triple-vessel disease was increased even higher than that in the patients with double-vessel and left main diseases.

Table 3. Echocardiographic characteristics of the mean CSD before and after CABG

Characteristic	Mean Diameter 1 Day Before CABG[a]	Mean Diameter 7 Days After CABG[a]	*P* value
Diabetes	6.97 ± 0.58	7.78 ± 0.76	< 0. 003*
Hypertension	6.96 ± 0.53	7.76 ± 0.68	< 0. 007*
Pervious MI	6.77 ± 0.51	7.61 ± 0.72	< 0. 006*
Double-vessel CAD	7.25± 0.58	8.06 ± 0.76	< 0. 005*
Triple-vessel CAD	6.76 ± 0.48	7.53 ± 0.54	< 0. 007*
Left main CAD	6.56 ± 0.49	7.44 ± 0.61	< 0. 005*

All plus-minus values are mean ± SD.
CABG, Coronary artery bypass graft surgery; CSD, coronary sinus diameter; MI, Myocardial infarction; CAD, Coronary artery diseases * $P < 0.05$ is significant.

Table 4. Comparisons of the CSD before and after CABG between the different groups

Characteristic		Groups Mean Diameter 1 Day Before CABG[a]	*P* value	Mean Diameter 7 Days After CABG[a]	*P* value
Gender	male	6.89 ± 0.72	0.87	7.70 ± 0.63	0.45
	female	6.87 ± 0.59		7.58 ± 0.71	
Diabetes	yes	6.97 ± 0.58	0.42	7.78 ± 0.76	0.22
	no	6.85 ± 0.58		7.61 ± 0.58	
Hypertension	yes	6.96 ± 0.53	0.23	7.76 ± 0.68	0.09
	no	6.79 ± 0.86		7.54 ± 0.58	
Pervious MI	yes	6.77 ± 0.51	0.18	7.61 ± 0.72	0.48
	no	6.96 ± 0.77		7.70 ± 0.60	
CAD	double-vessel	7.25± 0.58	0.002*	8.06 ± 0.76	<0.001*
	triple-vessel	6.76 ± 0.48	0.007	7.53 ± 0.54	
Left main CAD		6.56 ± 0.49	0.007*	7.44 ± 0.61	0.04*

All plus-minus values are mean ± SD.
CABG, Coronary artery bypass graft surgery; CSD, Coronary sinus diameter; MI, Myocardial infarction; CAD, Coronary artery diseases
*$P < 0.05$ is significant.

DISCUSSION

In our study, we observed a significant increase in the CSD in each individual compared with the diameter before surgery.

The coronary sinus is a tubular structure, about 3 cm in length and 1 cm in caliber, located in the groove between the left atrium and the left ventricle posteriorly. It begins as a continuation of the great cardiac vein and empties the entire blood of the cardiac veins into the right atrium through the ostium of the coronary sinus. [10] In 1983, Ishimitsu and colleagues [10] described the detection of the coronary sinus by parasternal 2D echocardiography. A severe dilatation of the coronary sinus compared to normal values is a clue to the presence of a persistent left superior vena cava or more rarely, other congenital anomalies such as coronary arteriovenous fistulae or anomalous pulmonary venous drainage into the coronary sinus. [12] Recently, the dilatation of the coronary sinus has also created much interest among echocardiographers as a surrogate echocardiography marker for various conditions such as pulmonary hypertension and tricuspid regurgitation. [12,13,14] This is probably related to an elevated pressure in the right atrium, where the coronary sinus is emptied, due to a transfer of the right atrial pressure to the coronary sinus causing dilatation of this vein. Our results revealed an increase in the CSD compared with pre-CABG status in the patients with significant stenosis in 2 or 3 major coronary arteries and without right atrial hypertension, which may have been in consequence of a decrease in venous drainage secondary to a decrease in the coronary artery flow distal to stenosis in per CABG status. Based on such evidence, there may be a positive association between the CSD and the intra-coronary flow. In fact, our evaluation of the CSD in the patients before surgery showed that those with severe stenosis in 2 or 3 arteries had a decrease in the CSD compared with post CABG.

The CSBF is often used as a measure of cardiac perfusion and it has been shown to increase after CABG in response to a decreased flow by stenosis before surgery. [2,6] The main finding of our study was that the CSD significantly increased after CABG in comparison with the diminished size due to coronary stenosis before surgery; this finding corresponds with the results of other perfusion studies. We think that it might be due to the exposure of the vein to an increased intravascular flow and the coronary sinus pressure after CABG, which subsequently distends the coronary sinus. The aforementioned phenomenon has also been previously reported in the case of the overdistention of the venous graft after exposure to arterial blood pressure following CABG. [14] In 2004, Winging et al [15] showed that the CSBF improved significantly after CABG in comparison with before CABG via a rise in the flow velocity of the coronary sinus in 15 patients. In that study, however, the CSD did not change appreciably (0.92 ± 0.22 vs 1.3 ± 0.15; P = 0.09). In another study, Xia et al [15] assessed the CSD and the blood velocity of the coronary sinus post CABG in 78 patients and reported that the difference was more prominent in those with triple-vessel disease than in the ones with double-vessel disease. In our study on 100 patients, we found significant changes in the CSD itself, with 95% confidence intervals (6.89 ± 0.69 vs 7.67 ± 0.65; P = 0.0001); additionally, we observed that the increase in the diameter was more significant in our patients with triple-vessel disease in comparison with those with double-vessel disease after CABG (7.24 ± 5.83 vs 8.06 ± 7.63; P < 0.005; in double-vessel disease and 6.76 ± 4.83 vs 7.53 ± 5.43 in triple-vessel disease). Our finding is in line with that reported by Xia and coworkers. The difference can be explained by the fact that both the flow and the diameter of the coronary sinus are reduced more in triple-vessel disease than in double-vessel disease; therefore, before and after complete revascularization, we can expect more flow and diameter increments in triple-vessel disease in comparison with double-vessel disease. Our study aimed to test whether the CSD increases after CABG and whether TTE can be used as a suitable noninvasive method for the detection of diameter changes in the recovery period or afterward. Based on previous studies, there is an assumption that the coronary flow and perfusion improves after CABG.

In conclusion, our results suggest that the TTE-determined CSD can be a potential surrogate marker for myocardial perfusion clopediogerl after CABG. Further studies are warranted to assess the predictive value of the CSD for the patency of grafts after CABG.

Acknowledgments

This study was extracted from the postgraduate thesis of Dr. Leilizadeh. We acknowledge the contribution of Ahvaz Jundishapur University of Medical Sciences for financial support. Our special thanks go to the members of the Atherosclerosis Research Center and the Golestan Hospital Clinical Development Research Unit for their contributions.

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