Coronary Flow Reserve Before and After Coronary Artery Bypass Surgery

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Abstract

Background- The coronary sinus (CS) blood flow can be used as a non-invasive measure of cardiac perfusion. Besides transesophageal echocardiography, transthoracic echocardiography with Doppler flow measurement has been introduced as a feasible and reproducible method to determine the CS blood flow. The purpose of this study was to assess the coronary flow reserve (CFR) by transthoracic imaging of the CS flow in patients with coronary artery disease before and after coronary artery bypass graft surgery (CABG).

Methods- Twenty-nine patients with coronary artery disease who were candidates for CABG were evaluated in this study. CFR was measured using the CS flow profile. Twenty-one patients, comprised of 15 men and 6 women at a mean age of 56.7 ± 9.1 years, were evaluated. All the patients had a pre-operative increase in their coronary blood flow during the dipyridamole stress test (mean CFR/beat=1.38±0.2, mean CFR/min=1.54±0.18).

Results- CFR was significantly higher in post-operative status (mean CFR/beat=2.25±0.45, mean CFR/min=2.55±0.43, p <0.001).

Conclusion- Our study, in accordance with previous studies, denotes that a transthoracic measurement of CFR can be used as a feasible and reproducible method to monitor the changes in cardiac perfusion after revascularization ***(Iranian Heart Journal 2009; 10 (1):21-26).***

Key words: coronary flow reserve ■ coronary artery disease ■ coronary sinus ■ coronary artery bypass graft

Coronary flow reserve (CFR) is defined as the maximal (hyperemic) to resting ratio of the coronary blood flow. CFR is an important physiologic parameter of coronary circulation and depends on the patency of the epicardial coronary arteries and the integrity of the microvascular circulation.

CFR measurement has such various clinical applications as functional assessment of the intermediate stenosis, detection of the critical stenosis, monitoring of the coronary flow in the post-angioplasty period, and assessment of the post-infarct blood flow.

It has been proposed that the coronary sinus (CS) blood flow can be used as a feasible and reproducible measure of cardiac perfusion. However, the standard methods for CFR measurement are expensive, invasive, and require cardiac catheterization (intravascular Doppler flow wire, thermodilution wire, or digital coronary angiography) or the use of radioisotope dyes (argon technique or xenon scintigraphy). New methods in the field of echocardiography that have been recently introduced to determine CFR include direct visualization of the coronary arteries (mostly

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left anterior descending artery) by transesophageal echocardiography.[1,2,3] Nevertheless, the images do not have sufficient clarity for an accurate measurement of the vessel diameter; as a result, only coronary blood velocity can be measured.[5-14]
Recently, Alexander and colleagues described reduced coronary flow reserve in the CS as a predictor of hemodynamically significant stenosis of the left coronary artery territory.[14]
More recently, transthoracic imaging of the CS to measure CFR has been presented and its validity and reproducibility has been confirmed compared with standard invasive techniques.[15,16]
In this study, we used transthoracic echocardiography to determine CFR in the CS in patients who were candidates for coronary artery bypass graft surgery (CABG) before and one month after surgery.

Methods

Obtaining an acceptable imaging of the CS was possible for 21 of the 29 selected patients (age=56±9.1; 15 male, 6 female). The baseline characteristics of the patients are summarized in Table I.

Table I. Baseline characteristics of the study group

No.	**21**
Age	**56.7±9.1**
Male/Female	**15/6**
HTN	**9**
DM	**5**
HLP	**7**
Smoking	**8**
LVEF	**47.1±6.1**
Single vessel	**2**
Two vessel	**5**
Three vessel	**14**
Left main disease	**1**

All of the 29 patients had sinus rhythm without a significant valvular disease. Patients with unstable angina (i.e., angina at rest), significant valvular disease, and history of asthma were excluded from the study. All drugs were continued to prevent acute symptoms. Eight patients were excluded due to poor image quality,[5] occurrence of chest pain during the test,[2] and poor follow-up.[1]
Dipyridamole was used as the vasodilator agent mostly because of its prolonged action compared with adenosine.[17-19]
Echocardiography was done with a GE Vivid 7 system with a 2.5-MHz transducer. The CS was visualized in the long axis view from modified RV inflow view, and efforts were made to reduce the θ angle for an accurate Doppler measurement of the flow. Color Doppler was carried out to confirm the flow within the CS. The CS blood flow velocity was identified via pulse-wave Doppler recordings as systolic and diastolic waves. The sample was placed at the CS ostium. The peak velocity and time–velocity integral (TVI) of the CS were measured by outlining the antegrade phase of the flow velocity signal in the CS moving into the right atrium. The CS was then imaged in the apical 4-chamber view with the posterior tilting of the transducer (Fig. 1).

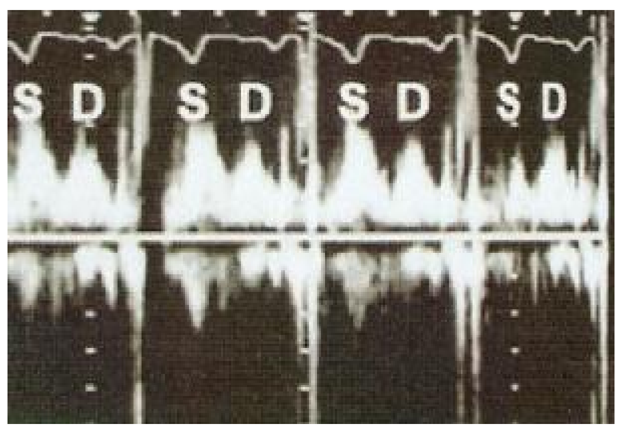

Fig. 1. Systolic and diastolic waves in the transthoracic imaging of the coronary sinus

M-mode echocardiography of the CS at its entry point to the right atrium was used to obtain its diameter. The average of the measurements over 3 cardiac cycles was used as the major diameter of the CS.[23]
Assuming that the cross-sectional area (CSA) of the CS is an ellipse and that the major diameter is double the length of the minor diameter, the CSA of the CS was calculated as: 0.39 (the major diameter)

The CS blood flow was then calculated as:

$$(\text{CS TVI}) \times (\text{CS CSA}) \times (\text{HR})$$

TVI: Time Velocity Integral, CSA: Cross-Sectional Area, HR: Heart Rate

To determine the flow/beat, HR was omitted. After the baseline measurement of the CS diameter and flow, dipyridamole (0.56 mg/Kg) was infused over a 4-minute period to obtain an increase in the heart rate (10% from baseline status).
After the termination of the infusion, a Doppler profile of the CS was continuously recorded up to 10 minutes for the detection of the hyperemic flow. The CS diameter was measured 3 - 5 minutes after the termination of the infusion. Blood pressure and heart rate were automatically measured.
Echocardiography was repeated nearly one month after surgery (28 to 36 days). This measurement was done in the baseline and then in the hyperemic phase for the calculation of CFR both before and after CABGs.
CFR was calculated as the ratio of the volumetric hyperemic blood flow to the volumetric baseline blood flow. The level of CFR <2 was used for the diagnosis of low CFR according to the previous studies (sensitivity=89%, specificity =77%).[14]

Results

All the parameters were expressed as mean and standard deviation (SD). Comparisons between the parameters recorded before and after revascularization were made with the paired Student's *t*-test (Table II).
Statistical significance was accepted when confidence intervals were >95% (p <0.05).
The baseline heart rate did not differ before and after CABGs.

Table II. Echocardiographic data before and after surgery

Variable		*Preop*	*Postop*	*P value*
HR	Resting	66.8±5.2	68.8±4.2	0.117
	Stress	75.5±5.9	78.7±4.2	0.117
CS diam	Resting	8.6±1.06	9.4±1.21	0.001
	Stress	9.1±1.04	10.97±0.92	<0.001
CFR/beat		1.38±0.2	2.25±0.43	<0.0001
CFR/min		1.54±0.18	2.55±0.43	<0.0001
S velocity ratio		1.21±0.1	1.34±0.15	<0.007
D velocity ratio		1.21±0.19	1.36±0.28	<0.054
S TVI ratio		1.23±0.15	1.57±0.17	<0.001
D TVI ratio		1.27±0.15	1.68±0.33	<0.001

There was a significant increase in the CS diameter in the post-CABG status (9.4±1.2 vs. 8.6±1.05) compared to the baseline status. Also, there was a trend for increase in the CS diameter in the hyperemic phase before CABGs; this increase was higher in the post-operative status (mean value of increase CS diameter: 0.5 mm before and 1.5 mm after surgery).
Before surgery, there was an increase in the coronary blood flow during the stress test (mean CFR/beat=1.38±0.2, mean CFR/min =1.54±0.18). CFR was significantly higher in the post-operative status (mean CFR/beat =2.25±0.45, mean CFR/min=2.55±0.43).
Comparing the similar values before and after surgery showed meaningful differences in the values before and after revascularization (p<0.0001).There was a significant increase in the systolic velocity ratio (hyperemic/baseline) after surgery (mean systolic velocity ratio before surgery=1.21±0.1, mean systolic velocity ratio after surgery=1.34±0.15, p=0.007). This was also true about the systolic TVI ratio (mean systolic TVI ratio before surgery=1.23±0.15, mean systolic TVI ratio after surgery=1.57±0.17, p<0.001).Similarly, there was a significant increase in the diastolic TVI ratio (mean diastolic TVI ratio before surgery=1.27±0.15, mean diastolic TVI ratio after surgery=1.68±0.33, p<0.001).

In contrast to the previous values, there was an insignificant increase in the diastolic velocity ratio (mean diastolic velocity ratio before surgery=1.21±0.19, mean systolic velocity ratio after surgery=1.36±0.28, *p*=0.054).

Conclusion

Several studies have demonstrated that revascularization in patients with coronary artery disease produces remarkable improvement in the cardiac function, symptoms, and exercise tolerance. However, an objective measurement of the expectable CS blood flow has traditionally required invasive studies.

By using this noninvasive method of measuring the CS blood flow by TTE, we were able to show a statistically significant increase in the coronary artery flow after revascularization procedures, a finding previously established by invasive studies. One limitation of this study is that we did not compare our data with those of an invasive technique.[2,3]

In the coronary arteries, CFR measurement by Doppler echocardiography is limited to the coronary blood velocity. The flow velocity variation is proportional to the total blood flow if the vessel lumen is kept constant. So an estimation of CFR can be accurate if the coronary artery functions only as a conduit.[4,5]

CFR and CF velocity are closely correlated, because most of vasodilatation is located in the microcirculation and the arterioles. Nonetheless, in this study a measurement of blood velocity and TVI was done on the venous side of the coronary system. Similar to other veins, the CS has a thin wall and highly extensible structure; and in this point, the coronary blood velocity is no longer closely related to CFR.[15]

As a result, for the measurement of CFR from the CS, a measurement of the CS diameter at baseline and hyperemic phases is mandatory; and ignoring this step may lead to significant errors in the estimation of CFR. In another study with a focus on the CS diameter before and after CABGs, there was an insignificant increase in the CS diameter in the post-surgery status.[23]

Another difference in the CFR estimation on the arterial and the venous side is based on the different shape of the flow in the cardiac cycle. In the coronary arteries, there is a predominantly diastolic flow (peak diastolic velocity: 28±9 cm/sec and peak systolic velocity 17±4 cm/sec) with a gradual diastolic slope in the CS. However, the pattern of the flow is also related to the right atrial pressure wave, and there are two distinct systolic and diastolic waves. In the healthy subjects, the systolic wave is dominant.[16]

A simple CFR assessment via the diastolic velocity ratio in the coronary arteries is, therefore, used with reasonable accuracy. [5-8] This is not, however, true in the CS; and there is a significant difference between CFR and the diastolic velocity ratio in our study.

Another variable of the coronary blood flow is heart rate. As was mentioned, we calculated CFR using 2 formulas to obtain CFR/beat and CFR/min. There is a close relation between these two parameters leading to CFR/min higher than CFR/beat in all cases.[23]

In summary, our study demonstrated that TTE could be used to measure the CS blood flow in patients after CABG. This statistically significant finding, in accordance with previous invasive studies, suggests that TTE may be used as a noninvasive modality to monitor the changes in the CS blood flow and to determine coronary perfusion in patients after revascularization, especially when it is added to the findings of regional wall motion abnormalities in the stress echo lab. [20-22]

Conflict of Interest

No conflicts of interest have been claimed by the authors.

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