Original Article

Coronary flow reserve measurement in the coronary sinus in pre and post CABG status

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

CFR measurement has many clinical applications including functional assessment of intermediate stenosis, detection of critical stenosis monitoring of coronary flow in the post angioplasty period, assessment of post infarct blood flow and assessment of coronary graft patency. The aim of this study was to measure CFR in the coronary sinus through the transthoracic echocardiographic approach, in patients who were candidate for coronary artery bypass graft surgery (CABG) before and one month after operation.

PATIENTS AND METHODS: The present study included 19 patients (mean age=56±9.1) including 15 males and 4 females, admitted for CABG. All patients had a sinus rhythm, normal wall thickness, normal RV systolic pressure, and tricuspid valvular regurgitation equal or less than grade 2. The antegrade phase of coronary flow in the coronary sinus moving into the right atrium was analyzed in two phases (systolic and diastolic). Each wave was determined considering the peak velocity and velocity time integral (VTI). The volumetric blood flow in the coronary sinus calculated at the baseline and then in hyperemic phase was used for determination of CFR both before and after CABG.

Results: There was a significant increase in the diameter of the coronary sinus after CABG (9.4±1.2mm) compared with that of before CABG values (8.6 ±1.05mm). Also there was a trend of increasing the diameter in the hyperemic phase before and after CABG. The absolute increase in mean coronary sinus diameter was 0.5 mm before and 1.5 mm after CABG. Coronary flow reserve (CFR) was significantly higher after surgery, despite a significant increase in systolic velocity ratio (hyperemic/baseline) after CABG. This is also true for systolic velocity time integral (VTI) and diastolic VTI ratios, but there was an insignificant increase in diastolic velocity ratio.

Conclusion: Our study in accordance with previous studies, denotes that transthoracic measurement of the coronary flow reserve can be used as a feasible and reproducible method to monitor the changes in cardiac perfusion after revascularization.

Key words: Coronary Flow Reserve, Coronary Artery Disease, Coronary Sinus.

Introduction:

Normally, blood flow in the coronary arteries can increase 4 to 6 fold to overcome myocardial oxygen demand. This effect is mediated by dilation of arteriolar bed, thereby reducing resistance and accelerating the flow.

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

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integrity of microvascular circulation. Even in the absence of stenosis in epicardial coronary arteries, the CFR is decreased in such compromised microcirculation as arterial hypertension, left ventricular hypertrophy, syndrome X, diabetes mellitus, hypercholesterolemia and hypertrophic cardiomyopathy[1].

CFR measurement has many clinical applications including functional assessment of intermediate stenosis, detection of critical stenosis monitoring of coronary flow in post PTCA period, evaluation of post infarct blood flow and assessment of coronary graft patency.

Several methods have been used for assessment of coronary flow reserve, including invasive intracoronary Doppler flow wire, PET scan with limited clinical use imposed by high cost, and new non-invasive echocardiographic technique[2].

There are several echocardiographic approaches including transthoracic Doppler of coronary arteries mostly LAD and LCX in decreasing degree of RCA, transesophagial Doppler of coronary arteries, transthoracic and transesophagial measurement of coronary sinus (CS) receiving blood flow from left coronary system.

The aim of this study was to measure CFR in coronary sinus from trans thoracic approach in patients scheduled for CABG before and one month after operation.

Patients and Methods:

Study group

The present study comprised 19 patients (mean age=56±9.1) including 15 males and 4 females, admitted for CABG. All patients had a sinus rhythm, normal wall thickness, normal RV systolic pressure, tricuspid valvular regurgitation equal or less than grade 2. Those with unstable angina including angina at rest, significant valvular disease and history of asthma were excluded from the study. The drugs were continued as prescribed.

Echocardiography

Echocardiography was done by vivid seven system GE machine. CS was visualized in long axis from modified RV inflow view while trying to reduce θ angel for accurate Doppler measurement of flow. Diameter of coronary sinus was measured at baseline status at 1 cm distance from the mouth in the end diastolic phase before the P wave on ECG. Sample volume was used and advanced about 1 cm from the mouth.

After baseline measurement of CS diameter and flow, dipyridamole (0.56 mg/Kg) was infused over a 4 min period. An additional infusion of 0.28 mg/Kg over 2 min was used if there was no increase in heart rate (10% from baseline status).

After termination of infusion, Doppler profile of CS was continuously recorded up to 10 min for detection of hyperemic flow. Diameter of CS was measured in 3 to 5 min after completion of infusion. Blood pressure and heart rate were measured automatically. Echocardiography was repeated one month after CABG using the same technique.

Analysis of coronary blood flow in CS

The antegrade phase of coronary flow in CS moving into the RA was analyzed in two phases of systolic and diastolic waves. Peak velocity and VTI of each wave were determined. The volumetric blood flow in the CS was calculated using the following formulas:

Table 1: Patients' age in relation to EF and CABG.

	Mean±SD
Age (year)	56.7±9.1
EF before CABG (%)	47.1±6.7
EF after CABG(%)	43.1±6.1

$$\text{Volume of blood /min} = \pi \times D^2/4 \times (S\ VTI + D\ VTI) \times HR$$

$$\text{Volume of blood /beat} = \pi \times D^2/4 \times (S\ VTI + D\ VTI)$$

Where D was the diameter of CS ,S the systolic velocity time interval, D VTI the diastolic velocity time interval and HR the heart rate.

This measurement was done in baseline and then in hyperemic phase for calculation of CFR both before and after CABG. CFR was calculated as the ratio of volumetric hyperemic blood flow to the volumetric baseline blood flow. The level of CFR < 2 was diagnostic of low CFR according to previous studies with sensitivity=89% and specificity =77%[3,4].

Statistical analysis

The statistical analysis was done by SPSS software package version 11.5. The data were analyzed by one way analysis of variance (ANOVA), paired T test and repeated measurement. The data were expressed as mean value ±SD. P vlaue less than 0.05 consider significance.

Results

Table 1 demonstrates the patients' age and ejection fraction before and after CABG. At baseline, the heart rate did not differ before and after CABG (Table 2). There was a significant increase in CS diameter in post CABG status (9.4±1.2 vs 8.6 ±1.05) compared with the pre CABG baseline. Also there was a trend towards increasing diameter of CS in hyperemic phase before CABG. This increment was higher in post operative status.

All patients exhibited an increase in the coronary blood flow before CABG during dipyridamole stress test (mean CFR/beat =1.38±0.2, mean CFR/min=1.54 ±0.18). CFR was significantly higher after surgery (mean CFR/beat=2.25±0.45, mean CFR/min=2.55 ±0.43). Also there was a significant increase (P =0.007) in mean systolic velocity ratio (hyperemic/baseline) before and after CABG (1.21 ±0.1 and 1.34 ±0.15 respectively). As shown in Table 2, this was also true about systolic and

Table 2: Echocardiographic data of the study population.

		Before CABG	After CABG	P value
HR	Baseline	66.8±5.2	68.8±4.2	0.117
	Dipyridamole	75.5±5.9	78.7±4.2	0.001
CS	Baseline	8.6±1.06	9.4±1.21	0.001
	Dipyridamole	9.1±1.04	10.97±0.92	<0.001
CFR/beat		1.38±0.2	2.25±0.43	<0.001
CFR/min		1.54±0.18	2.55±0.43	<0.001
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 VTI ratio		1.23±0.15	1.57±0.17	<0.001
D VTI ratio		1.27±0.15	1.68±0.33	<0.001

CFR: Coronary Flow Reserve, VTI: Velocity TimeIntegral.

diastolic VTI ratios, but increase in diastolic velocity ratio was not significant (P = 0.54).

Discussion

Coronary flow reserve is defined as a maximum to resting blood flow ratio. Normally, increase in the coronary blood flow is mediated by dilation of arteriolar bed.

CFR measurement is a very helpful clinical tool in several conditions including assessment of intermediate stenosis especially in patients with chest pain syndrome, detection of critical stenosis, and in-stent restenosis, as well as evaluation of graft patency after CABG.

There are two major vasodilators for measurement of CFR, adenosine and dipyridamole. In this study we used dipyridamole as a vasodilator and stressor test, mostly because of its prolonged action compared with adenosine[5,6]. Dipyridamole blocks the intracellular retransport of adenosine and inhibit adenosine deaminase responsible for intracellular breakdown of adenosine[7]. Thus dipyridamole acts as an indirect coronary arteriolar vasodilator.

Although assessment of CFR via intracoronary Doppler wire is accurate, but this method is invasive with radiation exposure; and makes the follow up study relatively impossible. PET scan is another method with radiation exposure and highly expensive. In the passed decade, there were several attempts for measurement of CFR by echocardiography as non-invasive and reproducible results, and mostly performed on coronary arteries by transthoracic or transesophageal approach. Although the coronary arteries (mostly leftanterior descending artery) was detected with Doppler and 2-D images, these lacked sufficient clarity for accurate measurement of vessel diameter, thus only the coronary blood velocity could be measured. The flow velocity variation is proportional to total blood flow if vessel lumen is kept constant. Thus, estimation of CFR can be accurate if the coronary artery functions only as a conduit[4].

CFR measurement of the coronary arteries by Doppler echocardiography is therefore limited to the coronary blood velocity. CFR and coronary flow velocity were closely correlated[1,8], because most of the vasodilation was located in microcirculation and arterioles, but in this study measurement of blood velocity and VTI was done on venous side of the coronary system. Similar to other veins, coronary sinus has a thin wall and highly extensible structure; so the coronary blood velocity is no longer closely related to CFR.

As a result, for measuring CFR in the coronary sinus, measurement of CS diameter at baseline and hyperemic phase is mandatory and ignoring this step may lead to significant error in estimation of CFR. In another study[9] with focus on CS diameter in baseline status before and after CABG, there was no significant increase in CS diameter after surgery.

Another difference in CFR estimation on arterial and venous side was based on different shape of flow in the cardiac cycle. Regarding the coronary arteries, there was predominantly diastolic flow with gradual diastolic slope and respective peak diastolic and systolic velocities of 28±9 cm/sec and 17±4 cm/sec[10]. However, in CS, the pattern of flow was also related to right atrial pressure with two distinct systolic and diastolic waves, considering that systolic wave was dominant in the healthy subjects[11].

Therefore, simple CFR assessment by diastolic velocity ratio in the coronary artery could be used with reasonable accuracy (6), but this is not true with respect to CS, as there was a significant difference between CFR and diastolic velocity ratio in our study.

Another variable of the coronary blood flow was heart rate. In our study measurement of CFR was done in two ways:

$$CFR/min=HR \times D^2 /4 \times (S+D)\ VTI$$

$$CFR/beat=D^2 /4 \times (S+D)\ VTI$$

In our study, a close relationship between above equations led to CFR/min to be higher than CFR/beat in all cases. Therefore, considering these technical points, coronary flow reserve measurement by transthoracic echocardiography can be used as a feasible and reproducible method to monitor the changes in cardiac perfusion after revascularization.

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