Transthoracic echocardiographic assessment of global left ventricular perfusion before and after percutaneous coronary intervention in patients with chronic stable angina

Evaluación ecocardiográfica transtorácica de la perfusión ventricular izquierda global antes y después de la intervención coronaria percutánea en pacientes con angina crónica estable

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Abstract

Background: percutaneous coronary intervention for symptomatic patients with chronic stable angina improves coronary artery blood flow and hence the left ventricular perfusion. Transthoracic echocardiography that is simple, non-invasive and cost effective technique, can provide an efficient procedure for measuring coronary sinus blood flow. **Objectives:** to assess coronary sinus blood flow (CSBF) and global LV perfusion in the coronary sinus using 2 D and Doppler transthoracic echocardiography in patients with chronic stable angina before and after Percutaneous Coronary Intervention. **Patients and methods:** Ninety-two (92) patients with stable chronic coronary artery disease chosen after admission for diagnostic (and/or therapeutic) catheterization have been enrolled in the current study at the Department of Catheterization and Echocardiography in Baghdad teaching hospital. After admission for coronary angiography, 63 patients had positive coronary lesions and proceeded to percutaneous coronary intervention (PCI). Fifty 50 normal healthy adults with no coronary artery disease CAD or CAD risk factors served as the control group. Standard 2D and Doppler echocardiography was performed and CSBF, CSVTI, CSPG LV mass and LV perfusion were registered. **Results:** Basic parameters were the same between the two groups (P>0.05). Controls had significantly higher CSBF, global LV perfusion and lower LV mass than the cases group (3.04±0.7 mL/min/gm, 501.64±63.8 mL/min and 99.97±9.4gm/m^2 in controls vs 2.11±1mL/min/gm, 223.15±55.7 mL/min and 195.74±68.6 gm/m^2 in the cases group). The positive group also showed significant increase in CSBF 438.09±89.9 ml/min (p value less than 0.05) after successful PCI. The same applied for the global LV perfusion which increased to 2.537±1.06 mL/min/gm. **Conclusion:** This study revealed that the transthoracic echocardiographic measurement of the coronary sinus blood flow is a valuable tool to assess the results obtained by angiography and it can be used as a practical and reproducible method for observing the changes in cardiac perfusion before and after percutaneous coronary intervention in patients with chronic stable angina.

Keywords: coronary sinus blood flow, PCI, echocardiography, coronary artery disease

Resumen

Antecedentes: la intervención coronaria percutánea en pacientes sintomáticos con angina estable crónica mejora el flujo sanguíneo de la arteria coronaria y, por tanto, la perfusión del ventrículo izquierdo. La ecocardiografía transtorácica, que es una técnica simple, no invasiva y rentable, puede proporcionar un procedimiento eficaz para medir el flujo sanguíneo del seno coronario. **Objetivos:** evaluar el flujo sanguíneo del seno coronario (CSBF) y la perfusión global del VI en el seno coronario mediante ecocardiografía transtorácica 2 D y Doppler en pacientes con angina estable crónica antes y después de la intervención coronaria percutánea. **Pacientes y métodos:** Noventa y dos (92) pacientes con enfermedad arterial coronaria crónica estable elegidos después del ingreso para un cateterismo diagnóstico (y / o terapéutico) se inscribieron en el estudio actual en el Departamento de Cateterismo y Ecocardiografía del hospital universitario de Bagdad. Tras el ingreso para coronariografía, 63 pacientes presentaron lesiones coronarias positivas y procedieron a intervención coronaria percutánea (ICP). Cincuenta 50 adultos sanos normales sin enfermedad de las arterias coronarias CAD o factores de riesgo de CAD sirvieron como grupo de control. Se realizó ecocardiografía estándar 2D y Doppler y se registraron CSBF, CSVTI, CSPG LV masa y perfusión LV. **Resultados:** Los parámetros básicos fueron los mismos entre los dos grupos (P>0.05). Los controles tuvieron CSBF significativamente mayor, perfusión global del

VI y masa del VI más baja que el grupo de casos (3,04±0,7 ml / min / gm, 501,64±63,8 ml / min y 99,97±9,4 g / m2 en los controles frente a 2,11±1 ml / min / gm, 223,15±55,7 mL / min y 195,74±68,6 gm / m2 en el grupo de casos). El grupo positivo también mostró un aumento significativo en CSBF 438,09±89,9 ml / min (valor de p menor que 0,05) después de una ICP satisfactoria. Lo mismo se aplicó para la perfusión global del VI que aumentó a 2.537±1.06 mL / min / gm. **Conclusión:** Este estudio reveló que la medición ecocardiográfica transtorácica del flujo sanguíneo del seno coronario es una herramienta valiosa para evaluar los resultados obtenidos por angiografía y puede ser utilizada como un método práctico y reproducible para observar los cambios en la perfusión cardíaca antes y después de la coronaria percutánea. Intervención en pacientes con angina estable crónica.

Palabras clave: flujo sanguíneo del seno coronario, ICP, ecocardiografía, enfermedad arterial coronaria.

Introduction

Naturally, blood flow in the coronary arteries can increase four to six times to meet the cardiac demand for myocardial oxygen. This response is mediated by the dilation of the arteriolar bed, which decreases resistance and accelerates the flow. After myocardial infarction, there can be large differences in the degree of left ventricular systolic dysfunction (LVSD) and increased left ventricular (LV) mass in individual patients. Any of these conditions result in failure of the adaptive mechanism and diminished coronary blood flow[1].

Quantitative evaluations of myocardial blood flow have a significant clinical promise in many fields. This involves the detection of functional rather than structural abnormalities that may indicate adverse effects of coronary risk factors on endothelial function or early stages of coronary artery disease that may contribute to increased risk of heart disease [2].

A further important feature of flow measurement is the ability to classify the degree and severity of coronary artery disease. Eventually, those measurements provide a way of determining the overall ischemic burden of the myocardium due to macrovascular and microvascular disease, and an estimation of the ischemic damage. Finally as many studies have shown, it can provide valuable prognostic information[3].

Coronary blood flow would decrease even in the absence of stenosis in epicardial coronary arteries, compromised microcirculations found in arterial hypertension, left ventricular hypertrophy, diabetes mellitus, hypercholesterolemia and hypertrophic cardiomyopathy play a major role in this flow reduction[4].

Coronary sinus blood flow (CSBF) has been used as an indicator of cardiac perfusion. Unfortunately, standard procedures for cardiac perfusion measurement are invasive and include cardiac catheterization (for example, intravascular Doppler flow wire, thermodilution catheter, or digital coronary angiography) or the use of radioisotope dyes (argon technique or xenon scintigraphy)[5].

Two-dimensional and Doppler echocardiography, a quick, simple, inexpensive, reliable and non-invasive tool, have clinical implications for the measurement of coronary sinus blood flow for the assessment of severe coronary artery stenosis[6].

Aims of study

The objective of this study was to assess coronary sinus blood flow (CSBF) and global LV perfusion in the coronary sinus using 2 D and Doppler transthoracic echocardiography in patients with chronic stable angina before and after Percutaneous Coronary Intervention (PCI).

Patients and Methods

This cross-section study was conducted at Baghdad Teaching Hospital between October 2019 and October 2020. All participants have given informed consent. A total of 140 patients were included, 92 patients with chronic stable coronary artery disease enrolled in the present research and were listed as the **cases group**.

Patients admission for angiography and/or PCI was based on the criteria published in the latest update of the European Society of Cardiology in 2017 7.

A total of 63 patients were found to have coronary artery lesions by angiography and were treated with percutaneous coronary intervention (PCI)and named the **positive group**. 29 patients had a negative coronary angiography result and continued medical attention, listed as the **negative group**.

The **control group** consisted of 50 patients (normal healthy adults with no coronary artery disease CAD or CAD risk factors either from patients' family or staff).

Inclusion criteria: symptomatic CAD with a previous myocardial infarction (MI) (with positive laboratory results and ECG abnormalities) who were admitted for diagnostic coronary angiography (CAG) or percutaneous transluminal coronary angioplasty. They all had sinus rhythm, normal right ventricular systolic activity. They had normal right atrial pressure, normal pulmonary artery pressure, and mitral and tricuspid valve regurgitation of below grade two.

Exclusion criteria

Patients with congenital heart disease, valve disease, cardiomyopathy, diabetes mellitus, pulmonary hypertension, intracoronary shunts.

Four patients were dismissed from the study; they required coronary artery bypass grafting (CABG) and four others due to lack of good image quality.

Each patient was submitted to a complete medical history with focus on cardiovascular symptoms and risk factors by specialist cardiologist.

Blood pressure was measured after 15 minutes of rest in the sitting position with mercury sphygmomanometer (an adult size MDF mercury sphygmomanometer and stethoscope).

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Twelve lead ECG was recorded using a GE MAC 1200 ECG machine (Germany) with automated analysis software.

According to the Fourth universal definition of myocardial Infarction by the European Society of Cardiology (ESC) in 2018, ischemic changes (ST segment changes and pathological Q wave) were analyzed and categorized[8]. Localization of myocardial infarction and ischemia was defined depending on Braunwald's classification[9].

Tansthoracic echocardiography (TTE) was performed for all patients using (CX50 diagnostic ultrasound system, Philips Ultrasound, Bothell, WA 98021 USA). Equipped with S5-1 2.5 MHz transducer. All patients were examined in the left lateral decubitus position, to bring the heart forward to the chest wall and lateral to the sternum, as recommended by the American society of echocardiography with dimmed light room[10].

The regional LV systolic function was tested using a 17-segment LV model. Each segment was evaluated individually and graded on the basis of motion and systolic thickening[11].

The coronary sinus CS was evaluated with a 5 MHz transducer. The transducer positioned in the second intercostal space on the left side of the sternum, with the index aiming to the right shoulder; the transducer was angulated posteriorly to visualize the coronary sinus in longitudinal section. Transducer position and direction were adjusted to make the Doppler beam as parallel as possible to CS flow, and an angle correction was performed. Observers blinded to patient information analyzed the echocardiographic study data, which included the following pulsed wave Doppler parameters of CS antegrade phase of flow moving into the right atrium flow:

- The peak and mean velocity.
- The peak and mean pressure gradient.

The above parameters were measured with pulse-wave sample volume kept within 1 cm of the CS opening in the right ventricular inflow view, with optimised zoom. Based on the Doppler principle that moving objects change the characteristic of sound waves. By sending short and quick pulses of sound, it becomes possible to accurately measure the velocity of blood precisely at the coronary sinus.

• The CSBF was calculated from the formula:

CSBF= [(CSVTI) × (cross-sectional area of the CS) × (heart rate)).

Given that the cross-section of the CS is an ellipse and that the larger diameter is twice the length of the smaller diameter, the cross-sectional area of the CS was calculated as:

CS area= (0.39 × (the major diameter)^2

• Left Ventricular mass was calculated from the formula:

LVM = {0.8 X [1.04 X ((LVIDd + LVPWd + IVSd)^3 – (LVIDd)^3]}+ 0.6[10]

• The global LV perfusion was estimated by dividing the CSBF over the LV mass.

Coronary Angiography:
Coronary angiography was successfully completed in all patients through a femoral approach within 24 hours of the Doppler transthoracic echocardiography according to the Judkins standard procedure[12]. using the COROSKOP Plus angiographic complex (Siemens AG, Berlin, Germany) and standard catheters and conventional views. The number of coronary arteries with severe stenosis, location of stenosis, and maximal percent stenosis were determined[13] and[14].

Statistical analysis
In this cross sectional study, Comparisons of quantitative data were handled by means of ANOVA tests. Statistical analysis was performed using the statistical package SPSS for windows (version 13, SPSS Inc., Chicago, IL, USA). A *P* value of less than 0.05 was adopted to indicate statistical significance for each test.

Results

The mean age for the cases group was 54.0± 8.17 years; 37.5% of them had age between 55 years to 64 years, while, controls group had a mean age of 51.98± 9.0 years; 36% of them were between 45 to 64 years of age, with **no significant** difference in age between the two groups. Most patients in both groups were males, as 77.5% of cases and 64% of controls were males, with no significant association between gender and the study groups.

Baseline characteristics and risk factors of the selected patients were demonstrated by table (1).

Table 1. Baseline characteristics of the study cases

Variables	Number	%	Number	%	*P-value*
Age group	**Cases**		Controls		
35-44	12	15.0	11	22.0	0.500
45-54	28	35.0	18	36.0	
55-64	30	37.5	13	26.0	
65 and more	10	12.5	8	16.0	
Gender					
Male	62	77.5	32	64.0	0.094
Female	18	22.5	18	36.0	

Pulsed wave Doppler echocardiography measurements were illustrated by table (2), which revealed the following:

VTI was significantly lower in cases, as it was **13.71± 3.1 cm** compared to **18.63±1.5 cm** in controls; the same applied for the **peak velocity** that was significantly lower in cases (**41.71±8.5 m/s**, compared to **49.32±4.2 m/s** in controls). Similarly, the **mean velocity** was significantly lower in cases (**22.32±8.5** m/s in cases vs **28.92±4.1 m/s** in controls).

As a result, the **CSBF** showed a similar picture by being significantly lower in cases (**223.15±55.7 ml/min** in cases and **501.64±63.8 ml/min** in controls, p value $<$0.05). Other variables, namely the coronary sinus diameter, peak gradient, and mean gradient showed **no statistically** significant difference between cases and controls.

Variables	Cases (n=80)	Controls (n=50)	*P-value*
Diameter (cm)	0.69±13.7	0.7±18.6	0.293
VTI (cm)	13.71±3.1	18.63±1.5	<0.001*
Peak Velocity (m/s)	41.71±16	49.32±4.2	<0.001*
Mean Velocity (m/s)	22.32±8.5	28.92±4.1	<0.001*
Peak Gradient (mmHg)	2.17±7.8	2.53±0.5	0.680
Mean Gradient (mmHg)	0.71±3.4	0.93±0.2	0.654
CSBF (ml/min)	223.15±55.7	501.64±63.8	<0.001*
***Highly significant difference tested by Independent sample T-test**			

Table 2. Comparison between cases and controls regarding coronary sinus parameters

Data are presented as mean± standard deviation

Significant difference (P≤0.05) between groups

VTI= velocity time integral

CSBF= coronary sinus blood flow cm=centimeter m/s= meter per second mmHg= millimeter mercury Ml/min= milliliter per minute

Table (3) regarding 2D Echocardiography, showed that cases had significantly higher LV mass compared to controls. Cases had **195.74±68.6 g/m²** in comparison to **99.97±9.4 g/m² in controls.** The opposite was found for global LV perfusion; where the cases had significantly lower CSBF **2.11±1 ml/min/g** in comparison to **3.04±0.7 ml/min/g** in the control group.

Table 3. Comparison between cases and controls selected variables

Variables	Cases (n=80)	Controls (n=50)	*P-value*
LV mass g/m²	195.74±68.6	99.97±9.4	<0.001*
Global LV perfusion ml/min/g	2.11±1	3.04±0.7	<0.001*
Data are presented as mean± standard deviation *Significant difference (P≤0.05) between groups			

Among the patients group CSBF was significantly higher in patients with negative results (529.01±71.5 ml/min) than patients with positive results (223.15±55.7ml/min). The same applies for LV perfusion which was also significantly higher in the negative PCI (3.47±1.06 mL/minute) compared to (68±0.56 mL/minute) in the positive PCI group. This study also revealed significantly higher LV mass in the positive PCI group 205.19±69.1g/m² than the negative PCI group 165.37±58.6 g/m². As explained in table no. 4.

Table 4. Comparison of coronary sinus and left ventricular parameters between the positive and negative group before PCI

Variables	Negative PCI (n=29)	Positive PCI (n=63)	*P-value*
CSBF ml/min	529.01±71.5	223.15±55.7	<0.001*
LV mass g/m²	165.37±58.6	205.19±69.1	<0.001*
Global LV perfusion ml/min/g	3.47±1.06	1.68± 0.56	<0.001*

Data are presented as mean± standard deviation

*Significant difference (P≤0.05) between groups

CSBF= coronary sinus blood flow cm= centimeter m/s= meter per second mmHg= millimeter mercury Ml/min= milliliter per minute

Coronary sinus parameters were explained in table 5. The cases that had successful PCI showed significant changes in CS parameters, including diameter (increased to 0.69±16.9 cm), VTI (increased to 16.94±2.1 cm), peak velocity (increased to 56.06±9.2 m/s), mean velocity (increased to 34.32±6.1 m/s) and CSBF (increased from 223.15±55.7 to 438.09±89.9 ml/min) and global LV perfusion (from 1.68± 0.56 mL/min/g to 2.537±1.06 mL/min/g), though peak and mean gradients did not show statistically significant variations following the successful PCI.

Table 5. CS parameters before and after PCI

Variables	Before	After	*P-value*
Diameter (cm)	0.68±12.3	0.69±16.9	<0.001*
VTI (cm)	12.28±1.9	16.94±2.1	<0.001*
Peak Velocity (m/s)	43.61±7.9	56.06±9.2	<0.001*
Mean Velocity (m/s)	23.91±4.8	34.32±6.1	<0.001*
Peak Gradient (mmHg)	2.13±8.8	2.75±9.5	0.875
Mean Gradient (mmHg)	0.83±3.9	0.79±2	0.247
CSBF (ml/min)	223.15±55.7	438.09±89.9	<0.001*
Global LV perfusion mL/min/g	1.68± 0.56	2.537±1.06	<0.001*
***Highly significant difference tested by Paired-samples T-test**			

Data are presented as mean± standard deviation

Different letters: Significant difference (P≤0.05) between groups

CSBF= coronary sinus blood flow cm= centimeter m/s= meter per second mmHg= millimeter mercury Ml/min= milliliter per minute mL.min/g= millilitre per minute per gramm

Discussion

Several studies have shown that coronary artery disease causes a substantial decrease in CSBF[15] and[6].

The assessment of coronary artery stenosis by traditional echocardiography remains challenging due to inadequate visualization of the coronary arteries, especially in the middle and distal sections[16].

In the current study, the average flow of the CS was estimated to be 501.64±63.8 mL/min in normal subjects (the control group) which is significantly higher than the CSBF of 223.15±55.7 mL/min in patients with CAD (the cases group). This was slightly higher than the results concluded by Zheng and his coworkers[6] who found an average CS flow of 181.38±108.72 mL/min in patients with CAD and 306.78±120.81 mL/min in their control group. It also came

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in range with what has been found in previous echocardiographic studies conducted by Liu et al. where values from 150 mL/min to 250 mL/min in patients with CAD and from 250 mL/min to 450 mL/min in normal subjects have been reported[17]. And Meenakshi et. al who found values less than 300 mL/min in patients with anterior MI[18]. This insignificant variation in the CSBF between the current study and the previous ones might be due to the different echocardiographic machines used in examining the patients, or the fact that each study has different sample of patients. For example, 89% of patients in the latter study had anterior MI compared to 79.2% of overall cases in the current study.

The significantly low values of CSBF in CAD perhaps is clarified by the fact that the coronary sinus receives 95% of the left ventricular circulation and the ideal cardiac performance is dependent on coronary blood flow, which is seriously diminished in CAD, and can be estimated by measuring the coronary sinus blood flow (CSBF), that provides a good estimation on global LV perfusion.

The cases group had significantly higher LV mass 195.74±68.6 g in comparison to controls with value of 99.97±9.4 g. The opposite was found for global LV perfusion; where the cases had significantly lower global LV perfusion 2.11±1 ml/min/g in comparison to 3.04±0.7 ml/min/g in the control group. This came in agreement with Xiao Zhi Zheng et. al[6], with values of (LV mass 132.43±22.61b g in normal subjects and 163.67±37.79 g in patients with CAD, global LV perfusion was 2.51±1.43 ml/min/g in normal subjects and 1.97±1.14 ml/min/g in patients with CAD) but the result where non-significantly higher in the current study group. The higher LV mass in the current study might be attributed to the large number of hypertensive patients included. The high value of LV mass and the low levels of CSBF in CAD together has led to decrease in the global LV perfusion that is directly proportional to CSBF and inversely to LV mass. The following factors may contribute for the discrepancies in outcome compared to other studies. First of all, the LVM was calculated by M-mode and two-dimensional echocardiography. This method is inherent to defects as it presumes the left ventricle as prolate ellipsoid shape [19]. Second reason, some restrictions are encountered during measurement of LV mass, such as non-standard left ventricular view of long or short axis, undefined epicardial or endocardial borders and sometimes the poor acoustic windows, all of which influence the precision of measurements.

Following myocardial infarction, there can be large differences in the degree of left ventricular systolic dysfunction (LVSD) and elevated left ventricular (LV) mass in individual patients[1].

Kishi and co-workers illustrates a parallel independent relationship of coronary artery atherosclerosis, myocardial infarction and left ventricular mass[20]. Previous publications with different groups of patients, recorded similar results and agreed with the potential role of higher LVM as an independent indicator of negative impacts besides coronary atherosclerosis and myocardial ischaemia[10].

This study concluded significant increase in CSBF after successful PCI in all the cases with positive results from 217. 56 ±58 ml/min to 484.83±130 ($P<0.05$), which comes in agreement with Meenakshi and colleagues[18] and Toyota and Amaki who evaluated coronary sinus flow rate with pulsed wave Doppler TEE during coronary artery bypass graft surgery. The peak velocity and CS flow in the post-CABG duration increased significantly compared to the pre-CABG duration[21].

Bogatyrev et. al, agreed in agreement with this study, and found significant increase in CSBF in anterior MI[22] despite using thermodilution technique in assessing acute myocardial infarction.

Conclusion

This study revealed that the transthoracic echocardiographic measurement of the coronary sinus blood flow is a valuable tool to assess the results obtained by angiography and it can be used as a practical and reproducible tool for observing the changes in cardiac perfusion before and after percutaneous coronary intervention in patients with chronic stable angina.

References

1. Reinier K, et al. *Increased left ventricular mass and decreased left ventricular systolic function have independent pathways to ventricular arrhythmogenesis in coronary artery disease.* Heart rhythm. 2011;**8**(8):1177-1182.
2. Cecchi F, et al. *Coronary microvascular dysfunction and prognosis in hypertrophic cardiomyopathy.* New England Journal of Medicine.2003;**349**(11):1027-1035.
3. Tio RA, et al. *Comparison between the prognostic value of left ventricular function and myocardial perfusion reserve in patients with ischemic heart disease.* Journal of Nuclear Medicine.2009;**50**(2):214-219.
4. Petkow-Dimitrow P. *Coronary flow reserve-measurement and application: Focus on transthoracic Doppler echocardiography: Focus on Transthoracic Doppler Echocardiography.* 2002;13: Springer Science & Business Media.
5. Toufan M. et al. *The Journal of the Pakistan Medical Association.* Measurement. 2007;**32**(2).
6. Zheng XZ, Yang B, Wu J. *Comparison of the efficacy of conventional echocardiographic parameters in the diagnosis of significant coronary artery stenosis.* Iranian Journal of Radiology, 2015;**12**(1).
7. Ibanez B, et al., *2017 ESC Guidelines for the management of acute myocardial infarction in patients presenting with ST-segment elevation: The Task Force for the management of acute myocardial infarction in patients presenting with ST-segment elevation of the European Society of Cardiology (ESC).* European Heart Journal, 2017;**39**(2):119-177.
8. Thygesen K, et al. *Fourth universal definition of myocardial infarction (2018).* European Heart Journal.2018;**40**(3):237-269.
9. Lilly LS, *Braunwald's Heart Disease Review and Assessment E-Book.* 2018: Elsevier Health Sciences.
10. Lang RM, et al. *Recommendations for cardiac chamber quantification by echocardiography in adults: an update from the American Society of Echocardiography and the European Association of Car-*

diovascular Imaging. European Heart Journal-Cardiovascular Imaging.2015;**16**(3):233-271.

11. Ehrman RR, et al. *Pathophysiology, echocardiographic evaluation, biomarker findings, and prognostic implications of septic cardiomyopathy: a review of the literature.* Critical Care.2018;**22**(1):1-14.

12. Judkins MP. *Selective coronary arteriography: part I: a percutaneous transfemoral technic.* Radiology.1967;**89**(5): p. 815-824.

13. Jose M, et al. *Prospective application of pre-defined intravascular ultrasound criteria for assessment of intermediate left main coronary artery lesions: results from the multicenter LITRO study.* Journal of the American College of Cardiology.2011;**58**(4):351-358.

14. Park S.-J., et al. *Intravascular ultrasound-derived minimal lumen area criteria for functionally significant left main coronary artery stenosis.* JACC: Cardiovascular Interventions.2014;**7**(8):868-874.

15. Nagaraja P, et al. *Transesophageal echocardiography estimation of coronary sinus blood flow for the adequacy of revascularization in patients undergoing off-pump coronary artery bypass graft.* Annals of cardiac anaesthesia. 2015;**18**(3):p. 380.

16. Ramos Filho J, et al. *Study of coronary sinus flow reserve through transesophageal Doppler echocardiography in normal subjects.* Arquivos brasileiros de cardiologia.2002;**79**(2):102-106.

17. Liu Z, et al. *Detection and reproducibility of coronary sinus with transthoracic Doppler echocardiography.* Chin J Med Imaging Technol.2005;**21**:1888-90.

18. Meenakshi K, Swaminathan S, Manickam R. *Role of transthoracic echocardiography in the estimation of coronary sinus blood flow in coronary artery disease.* Heart Asia.2013;**5**(1):168-171.

19. Wasilewski J, et al. *Predominant location of coronary artery atherosclerosis in the left anterior descending artery. The impact of septal perforators and the myocardial bridging effect.* Kardiochirurgia i torakochirurgia polska=Polish journal of cardio-thoracic surgery.2015;**12**(4):p. 379.

20. Kishi S, et al. *Relationship of left ventricular mass to coronary atherosclerosis and myocardial ischaemia: the CORE320 multicenter study.* European Heart Journal-Cardiovascular Imaging.2015;**16**(2):166-176.

21. Toyota S, Amaki Y. *Measurement of coronary sinus flow using transesophageal echocardiography in patients undergoing coronary artery bypass grafting.* Journal of clinical anesthesia.2000;**12**(4):270-272.

22. Bogatyrev I, et al. *Coronary venous blood flow in patients with acute myocardial infarction.* Kardiologiia.1991;**31**(6):31-34.

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