

# Transesophageal echocardiography estimation of coronary sinus blood flow for the adequacy of revascularization in patients undergoing off-pump coronary artery bypass graft

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## ABSTRACT

**Aims and Objectives:** Physiologically coronary sinus (CS) drains the left coronary artery (LCA) territory. Stenosis of the branches of LCA may decrease the coronary sinus blood flow (CSBF). Any intervention that aims at restoring the flow of the stenosed vessel increases coronary artery flow that should consequently increase the CSBF. Hence, this study was undertaken to assess the CSBF before and after each branch of LCA to determine the adequacy of surgical revascularization in patients undergoing elective off pump coronary artery bypass grafting (OPCAB) using transesophageal echocardiography (TEE). **Materials and Methods:** Thirty consecutive patients scheduled for elective OPCAB were enrolled. CSBF was assessed before and after each branch of LCA revascularization using TEE. Left internal mammary artery (LIMA) Doppler was also obtained post LIMA to left anterior descending (LAD) grafting. **Results:** Hemodynamic and echocardiographic variables were compared by means of Student's *t*-test for paired data before and after revascularization. The CSBF per beat ( $1.28 \pm 0.71$ ), CSBF per minute ( $92.59 \pm 59.32$ ) and total velocity time integral (VTI) ( $8.93 \pm 4.29$ ) before LAD grafting showed statistically significant increase to CSBF per beat ( $1.70 \pm 0.89$ ), CSBF per minute ( $130.72 \pm 74.22$ ) and total VTI ( $11.96 \pm 5.68$ ) after LAD revascularization. The CSBF per beat ( $1.67 \pm 1.03$ ), CSBF per minute ( $131.91 \pm 86.59$ ) and total VTI ( $11.00 \pm 5.53$ ) before obtuse marginal (OM) grafting showed statistically significant increase to CSBF per beat ( $1.91 \pm 1.03$ ), CSBF per min ( $155.20 \pm 88.70$ ) and total VTI ( $12.09 \pm 5.43$ ) after OM revascularization. In 9 patients, color flow Doppler of LIMA could be demonstrated which showed diastolic predominant blood flow after LIMA to LAD grafting. **Conclusion:** Demonstration of CSBF was simple and monitoring the trend of CSBF values before and after each graft of LCA territory will guide to determine the adequacy of surgical revascularization.

Received: 30-12-14  
Accepted: 26-05-15

Access this article online

Website: [www.annals.in](http://www.annals.in)

DOI:  
10.4103/0971-9784.159809

Quick Response Code:



**Key words:** Coronary artery bypass grafting; Coronary sinus blood flow; Left internal mammary artery; Transesophageal echocardiography; Velocity time integral

## INTRODUCTION

Cardiac perfusion can be assessed by coronary sinus blood flow (CSBF).<sup>[1]</sup> In patients with coronary artery disease, there is reduced CSBF. Any intervention that increases coronary perfusion may also increase CSBF.

Measurement of CSBF is by various invasive techniques that require cardiac catheterization using intravascular Doppler flow wire, thermodilution catheter,<sup>[2]</sup> or digital coronary angiography. It can also be measured by the use of radioisotope dyes such as argon technique or xenon scintigraphy.<sup>[1]</sup> Feasibility and

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reproducibility of transesophageal echocardiography (TEE) in measuring CSBF have been previously demonstrated.<sup>[3]</sup>

However, coronary artery blood flow (CABF) can also be assessed by coronary angiography and Doppler flow measurement in surgically revascularized patients. Unlike CSBF which is simple to demonstrate, obtaining CABF is quite challenging using TEE.

There has been limited literature available on CSBF for assessment of Coronary artery perfusion after surgical revascularization using TEE. Hence, this study was undertaken to assess the CSBF before and after each branch of left coronary artery (LCA) to determine the adequacy of surgical revascularization in patients undergoing elective off pump coronary artery bypass grafting (OPCAB) using TEE.

## MATERIALS AND METHODS

After obtaining Institutional Ethics Committee clearance and informed consent from each patient, 30 adult patients scheduled for elective OPCAB were enrolled in the study. Patients with coronary artery bypass grafting (CABG) with valvular heart disease, emergency CABG, patients with dilated coronary sinus (CS) (diameter > 1 cm), left ventricular ejection fraction < 45%, and contraindication to insert TEE probe were excluded from the study.

All patients were premedicated with injection midazolam 0.05 mg/kg intravenously. General anesthesia was induced with injection fentanyl 5 mcg/kg, titrated doses of injection propofol and injection vecuronium 0.1 mg/kg to facilitate muscle relaxation. Following endotracheal intubation, patients were mechanically ventilated and maintained with injection fentanyl, midazolam and vecuronium. A 5 MHz Biplane TEE probe (Philips En Visor CHD, Bothell, Washington, USA 98041) was inserted after induction of anesthesia. B mode echocardiography was used to obtain midesophageal modified four chamber (ME 4C) [Figure 1a] and/or modified bicaval view for the demonstration of CS. After the CS had been demonstrated, care was taken to align the CS within an angle correction < 20°. To attain this, we withdrew and retroflexed the probe rotating slightly towards the right for the best possible image with the least angle correction. Pulse wave Doppler measurement was performed 1 cm before the CS inflow into the right atrium. Average of 3 velocity time integral (VTI) of CS

was noted. Diameter of CS was measured in M Mode [Figure 1b]. Diameter of CS was taken at 3 equally spaced segments in the cardiac cycle, over 3 cardiac cycles were averaged and used as major diameter of the CS. Assuming that the cross section of CS is elliptical and that the major diameter is double the length of the minor diameter, the cross section area of CS was calculated as  $0.39 \times (\text{major diameter})^2$ . CSBF per beat was then calculated as CS VTI  $\times$  cross-sectional area of CS.<sup>[4]</sup> We have excluded those patients in whom angle of CSBF to ultrasound beam was more than 20°.

Coronary sinus blood flow was measured before initiation of grafting (T0) [Figure 2a] and after left internal mammary artery (LIMA) to left anterior descending (LAD) grafting (T1) [Figure 2b]. Origin of LIMA was visualized as previously reported.<sup>[5]</sup> Ratio of LIMA diastolic peak velocity (Dp), mean velocity (Dm) and VTI (Dvti) to systolic peak velocity (Sp), mean velocity (Sm) and VTI (Svti) was calculated after LIMA to LAD grafting respectively [Figure 3a]. Ratio of Dp/Sp and/or Dm/Sm < 0.6 is considered as critical stenosis, 0.6–1 as restrictive graft flow and > 1.0 as normal graft flow.<sup>[6]</sup> These ratios were measured to know if LIMA flow after grafting with LAD is diastolic or systolic predominant flow. Normal functioning LIMA conduit after anastomosis with LAD shows diastolic predominant flow. After grafting saphenous vein to obtuse marginal (OM), CSBF was again measured (T2). Heart rate, mean arterial pressure (MAP), central venous pressures (CVP) regional wall motion abnormality (RWMA), and inotrope score were measured at T0, T1 and T2 intervals. EF was measured at T0 and T2 intervals. Patients were followed up for 48 h and any adverse events were noted.

## Statistical analysis

Hemodynamic and echocardiographic variables were compared by means of Student's *t*-test for paired data before and after revascularization. A two-tailed probability level of < 0.05 was considered as statistically significant. All results were expressed as mean  $\pm$  standard deviation. Statistical analysis was performed using MedCalc software version 12.2.1.

## RESULTS

The CSBF was obtained in all 30 patients. LIMA blood flow was demonstrated in 9 (30%) of 30 patients. OM grafting was performed in 20 (66.67%) of 30 patients in addition to LAD graft.

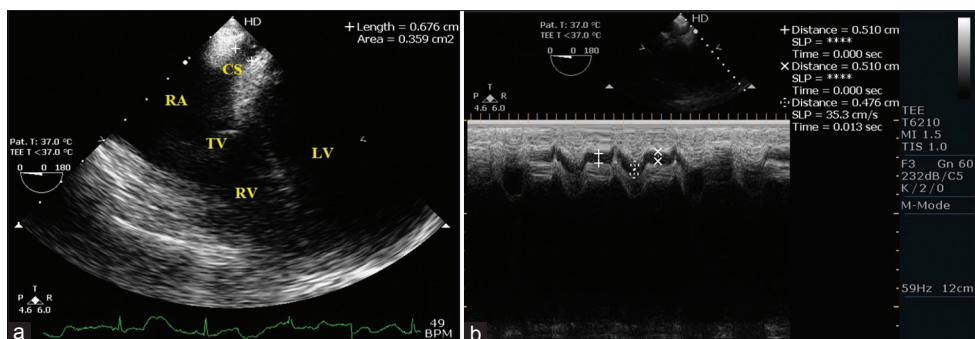


Figure 1: (a) Coronary sinus by modified ME 4 chamber view. (b) M: Mode measurement for coronary sinus diameter

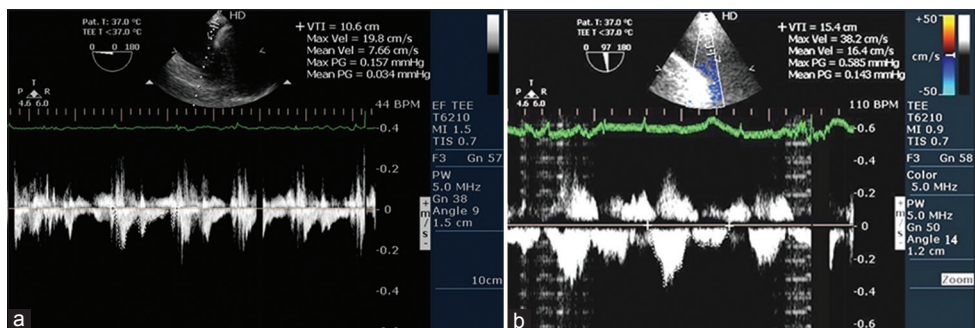


Figure 2: (a) Coronary sinus velocity time integral (VTI) before revascularization. (b) Coronary sinus VTI after revascularization

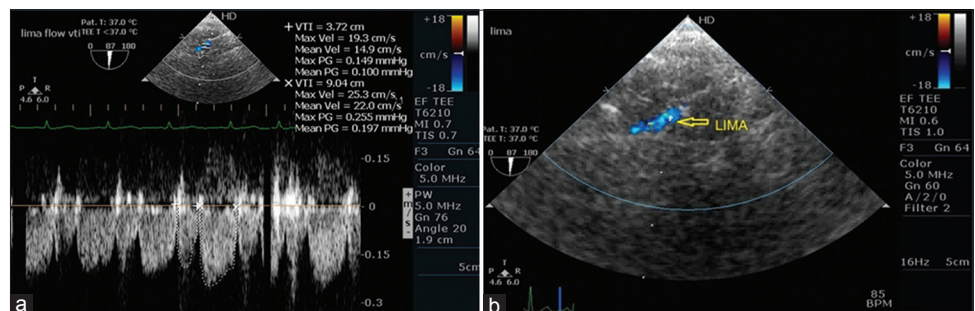


Figure 3: (a) Left internal mammary artery blood flow measured with transesophageal echocardiography (TEE) showing diastolic predominance after grafting with left anterior descending artery. (b) TEE view of left internal mammary artery after left anterior revascularization

The CSBF per beat, CSBF per min, total VTI and heart rate has shown statistically significant increase in patients after LAD revascularization. However, there was no statistically significant change in the CS diameter [Table 1a]. In the similar manner, CSBF per beat and per min, total VTI and heart rate increased statistically in patients after OM revascularization with no statistically significant change in the CS diameter [Table 1b].

Among 30 patients, 9 patients had LIMA blood flow demonstrated after LAD revascularization [Figure 3a and b]. The CSBF per beat, CSBF per min and total VTI have shown statistically significant increase in patients after LAD revascularization. However, there was no statistically significant change in heart rate and CS diameter [Table 2].

LIMA flow showed diastolic predominance after LIMA to LAD grafting that is ratio of  $Dp/Sp = 1.25 \pm 0.12$ ,  $Dm/Sm = 1.35 \pm 0.13$  and  $Dvti/Svti = 2.66 \pm 1.15$ .

There was no statistically significant change in EF ( $P = 0.44$ ) before ( $52.26 \pm 4.32$ ) and after ( $51.66 \pm 4.42$ ) LCA revascularization. The MAP ( $T_0 = 75.50 \pm 10.25$  vs.  $T_1 = 75.80 \pm 10.38$ ,  $P = 0.457$ ) and ( $T_1 = 75.80 \pm 10.47$  vs.  $T_2 = 76.25 \pm 11.45$ ,  $P = 0.41$ ) CVP ( $T_0 = 7.00 \pm 2.33$  vs.  $T_1 = 7.46 \pm 2.19$ ,  $P = 0.09$ ) and ( $T_1 = 7.3000 \pm 2.17$  vs.  $T_2 = 7.85 \pm 2.66$ ,  $P = 0.10$ ) were comparable before and after revascularization. Inotrope score was:  $T_0 = 0.0 \pm 0.0$  vs  $T_1 = 0.53 \pm 1.43$ ,  $P = 0.051$  and  $T_1 = 0.80 \pm 1.70$  vs.  $T_2 = 2.35 \pm 3.79$ ,  $P = 0.007$ . There was no new RWMA observed after revascularization.

## DISCUSSION

The CS drains the LCA territory. The CS is located 1 cm above and parallel to the left atrioventricular junction. Normally it is 1 cm in diameter.<sup>[1]</sup>

Meenakshi *et al.*<sup>[7]</sup> have estimated CSBF in PTCA patients using TTE and shown an increase of 76 ml in CSBF ( $P = 0.04$ ) post PTCA that was comparable with the present study. The increase in the CSBF was 38 ml post LAD grafting ( $P < 0.0001$ ) [Table 1a] and 24 ml after OM grafting ( $P = 0.0002$ ) [Table 1b]. So, total increase in CSBF was 62 ml after LCA revascularization in the present study.

Ng DW *et al.*<sup>[1]</sup> have studied the usefulness of TTE in demonstrating the CSBF before and after CABG and showed that there was a significant increase in CS VTI from  $10.6 \pm 1.93$  to  $13.4 \pm 2.3$  ( $P = 0.01$ ) with no significant change in CS diameter. In the present study, VTI after LAD revascularization increased from  $8.93 \pm 4.29$  to  $11.96 \pm 5.68$  ( $P \leq 0.0001$ ) [Table 1a] and after OM revascularization, it increased from  $11 \pm 5.53$  to  $12.09 \pm 5.43$  ( $P = 0.002$ ) [Table 1b] with no statistically significant change in CS diameter. The total change in the VTI and the change in CS diameter were comparable in both the studies. The advantage of the present study is that CSBF was estimated before and after each branch of LCA unlike Ng DW *et al.*<sup>[1]</sup> who estimated the CSBF before and after complete revascularization. The present study could also demonstrate the correlation between CSBF and adequacy of LIMA to LAD grafting.

Nanda *et al.*<sup>[8]</sup> have demonstrated left subclavian artery branches using TEE with 53% success rate in identifying LIMA. In the present study, LIMA was demonstrated in 30% of patients post-LAD grafting [Figure 3a and b]. Even in the experienced hands, the success rate being only 53%, LIMA flow demonstration is definitely difficult to obtain on a regular basis. Whereas CSBF demonstration was feasible and reproducible (100%) with minimal experience.

Kuroda *et al.*,<sup>[9]</sup> Orihashi *et al.*,<sup>[10]</sup> Calafiore *et al.*<sup>[6]</sup> have successfully demonstrated LIMA to LAD flow. They have opined that the normal functioning LIMA to LAD graft should have  $Dp/Sp$  and/or  $Dm/Sm > 1$  and/or  $Dvti/Svti > 1.10$ . In the present study, LIMA Doppler showed diastolic predominance with  $Dp/Sp$  and/or  $Dm/Sm > 1$  and/or  $Dvti/Svti > 1.10$  after LIMA to LAD revascularization. All patients who had normal

**Table 1a: Comparison of CSBF before and after LAD revascularization (n=30)**

	T0	T1	P
HR (beats/min)	71.4±15.01	78.13±13.73	0.0014
Total VTI (cm)	8.93±4.29	11.96±5.68	<0.0001
CS diameter (cm)	0.60±0.09	0.60±0.10	0.8103
CSBF/beat (ml)	1.28±0.71	1.70±0.89	<0.0001
Total CSBF/min (ml/min)	92.59±59.32	130.72±74.22	<0.0001

CSBF: Coronary sinus blood flow, HR: Heart rate, VTI: Velocity time integral, CS: Coronary sinus, LAD: Left anterior descending

**Table 1b: Comparison of CSBF before and after OM revascularization (n=20)**

	T1	T2	P
HR (beats/min)	79.70±13.57	81.80±13.19	0.004
Total VTI (cm)	11.00±5.53	12.09±5.43	0.002
CS diameter (cm)	0.61±0.11	0.63±0.09	0.0524
CSBF/beat (ml)	1.67±1.03	1.91±1.03	0.0014
Total CSBF/min (ml/min)	131.91±86.59	155.20±88.70	0.0002

CSBF: Coronary sinus blood flow, HR: Heart rate, VTI: Velocity time integral, CS: Coronary sinus, OM: Obtuse marginal

**Table 2: Comparison of CSBF before and after LAD revascularization (n=9) in whom LIMA flow was demonstrated post-LAD revascularization**

	T0	T1	P
HR (beats/min)	82.88±4.91	85.55±3.94	0.0554
Total VTI (cm)	7.71±5.59	10.54±6.74	0.0015
CS diameter (cm)	0.62±0.06	0.63±0.07	0.4436
CSBF/beat (ml)	1.25±0.96	1.81±1.29	0.0055
Total CSBF/min (ml/min)	106.47±80.96	155.59±111.44	0.0067

CSBF: Coronary sinus blood flow, HR: Heart rate, VTI: Velocity time integral, CS: Coronary sinus, LAD: Left anterior descending, LIMA: Left internal mammary artery

functioning LIMA to LAD graft showed a statistical significant increase in the CSBF post grafting without any statistical change in heart rate and CS diameter.

Ng DW *et al.*<sup>[1]</sup> and Meenakshi *et al.*<sup>[7]</sup> had no statistically significant change in the heart rate before and after surgical revascularization and PTCA respectively. In the present study, there was no statistical significant increase in the heart rate in those 9 patients in whom LIMA flow was demonstrated but when all 30 patients were analyzed, the change in heart rate was statistically significant. The mean heart rate before grafting was  $71.4 \pm 15.01$  and had increased to  $81.80 \pm 13.19$  after complete revascularization. However, the heart rate in only 4 patients had an increase of more than 20% from the baseline values. The increase in the heart rate may be possibly due to the inotropes in these patients.

There was also decrease in the ejection fraction in these patients from the preoperative value.

The limitation of the present study is that we were not able to compare CSBF with those of any invasive methods. The adequacy of LIMA to LAD flow also could not be compared with coronary angiography.

## CONCLUSION

Demonstration of CSBF was simple and monitoring the trend of CSBF values before and after each graft of LCA will guide to determine the adequacy of surgical revascularization. Demonstration of LIMA flow is challenging post LIMA to LAD grafting but if obtained will make it easy for correlating CSBF with the adequacy of grafting.

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**Cite this article as:** Nagaraja PS, Singh NG, Patil TA, Manjunath V, Prasad SR, Jagadeesh AM, *et al.* Transesophageal echocardiography estimation of coronary sinus blood flow for the adequacy of revascularization in patients undergoing off-pump coronary artery bypass graft. *Ann Card Anaesth* 2015;18:380-4.

**Source of Support:** Nil, **Conflict of Interest:** None declared.