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Correlation of Transesophageal Echocardiography and Common Carotid Artery Doppler Derived Cardiac Output in Patients Undergoing on-Pump Coronary Artery Bypass Graft Surgery: An Observational Study

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ABSTRACT

Background and aims: The CO estimation with commoncarotidartery (CCA)doppler has good correlation with transthoracic echocardiography (TTE) in coronary artery bypass graft surgery (CABG), but TTE is not possible in patients undergoing cardiac surgery. The perioperative use oftransesophageal echocardiography (TEE) is standard of care in most of the cardiac theatre. The common carotidarterydoppler derived cardiac output is never compared with TEE derived CO. hence this study aimed to derived correlation between two techniques.
Methods: This prospective observational study enrolled 100 patientsscheduled foron-pump CABG. The anaesthesia technique was as per institutional protocol. The measurements were taken during stable hemodynamics. Two different trained anaesthesiologists were measured CO by TEE and carotid doppler at four pre-defined time intervals: 10 min after the induction of anaesthesia (T1), before going on cardiopulmonary bypass (CPB) (T2), 20 min after termination of cardiopulmonary bypass (T3) and after sternal closure (T4). The statistical analysis was performed with the SPSS, version 22.
Results: There was no statistically significant difference in cardiac output measured by TEE and CCA doppler at T1 and T2, where as statistically signifi cant difference was observed at T3 and T4 time points. However, there was good correlation between two techniques at alltime intervals with correlation coefficients of 0.567, 0.617. 0.628 and 0.685.
Conclusion: There was moderate correlation between CO measured with TEE and CCA doppler at all four-time intervals, hence it can be considered as an alternative technique in cardiac surgery.

Keywords: *Cardiac output, carotid doppler, transesophageal echocardiography.*

INTRODUCTION

Cardiac surgery is a complex procedure and requires cardiac output (CO)monitoring for safe and successful outcome in selected patients.The pulmonary artery catheter (PAC), also known as the Swan-Ganz catheter is placed in pulmonary artery with the help of flow directed ballon, is the 'gold standard' technique for cardiac output (CO) measurement, but due to invasiveness and complications rarely used nowadays.[1]The CO can be measurement non-invasively by specialized monitors but still not preferred due to reliability issues. The CO can be measured by minimally technique that has less complications but cost of disposable equipment is a major concern.

The echocardiography (ECHO) used to assess regional wall motion abnormalities, fluid status, andcardiac output during cardiac surgery. The ECHO is very effective, risk-free, and economical modality. The CO measured accurately with transthoracic echocardiography(TTE), but itcould not possible in intraoperative period.[2]In the recent days, intraoperative use of transesophageal echocardiography (TEE) is standard of care. The TEE is a semi-invasive procedure in which the echoprobe is inserted into the esophagus in order to assess the cardiac function without thehindrance by chest wall and ribs. It fairly correlateswith the transpulmonary thermodilution technique. Studies proved that TTE/TEE are the equally effective modality for CO determination inthe perioperativeperiod.[3]The dressing of surgical wound and presence of chest drains are the contributing factors for the poor window for TTE.

Few researches, has favored the carotid doppler as a reliable alternative to quantifyingcardiac output. Thecarotidflowtime (CFT) and carotid blood flow (CBF), which are simple to measure, seem to match withintravascularvolume and discovered a tenuous correlation betweenCBFand CO, EF, CI, and SV. [4,5]The cardiac output is calculated with carotid doppler ultrasound. Itisnon-invasive,safe,andmoreaffordable method. [6]Sidor et al. demonstrated carotid flow as a substitute forcardiac output assessment in hemodynamic stable patients.[7]They asserted that additional research is required to confirm theirfindingsandmakeuseofthesefactorstodirectfluidmanagementandforecastfluidresponse.Since the doppler wave is biphasic, it is simple to measure blood flow.

Although some studies showed poor correlation of CCA flowmetry and PAC thermodilution cardiac output in cardiac surgery.[8]

To the best of our knowledge, studies are lacking that compared TEE with common carotid artery dopplerderived CO in on-pump CABG patients. Hence this study was conducted to compare the cardiacoutputmeasured by transesophageal echocardiography and commoncarotidarterydopplerinpatientsundergoingon-pump CABG.

MATERIALS AND METHODS:

The study was carried out afterethical approval from the Institutional Ethics Committee and registration under Clinical Trial Registry-India.Informed written consent was obtained from all the patients. The patients aged between 18-70 years, of either gender, ASA physical II-IIIscheduled for on-pump CABGwere included. Patients in atrial fibrillation and significant carotid artery disease (>50%) were excluded.

Thorough preoperative check-up was done one day before the surgical procedure. The nilper oral (NPO) and premedication was advised as per institutional policy. The anaesthesia was induced as per standard protocol. Rightinternaljugularcatheterwas insertedunderultrasoundguidance after induction of anaesthesia and lubricated3-DmultiplaneTEEprobewas inserted in all patients.

The TEE and carotid artery doppler were carried out independently by two investigatorswho are blind to one another's measurement. TEE measurements wereperformed by a trained echocardiographer by using PhilipsEPIQ 7ultrasoundmachineandcarotidartery dopplerwasdonebyanothertrainedinvestigatorby the sameUS machine withthe high frequencylinearprobe.The CO was estimated by both modality two times and average of twomeasurements was taken.Measurementsweretakenat four pre-defined time intervals with both techniques: The CO was measured by TEE and carotid doppler at four pre-defined time intervals: 10 min after the induction of anaesthesia (T1), before going on cardiopulmonary bypass (CPB) (T2), 20 min after termination of cardiopulmonary bypass (T3) and after sternal closure (T4).

In TEE group,stroke volume (SV) was calculated by LVOT diameter in mid-oesophageal long axis view, and aortic valve velocity-time integral (VTI)in deep trans-gastricview. The cardiac output was obtained by multiplying SV with HR.

In CCA doppler group, the CO was measured with the help of high frequency linear ultrasound probe (6-13 MHz). The CCAwas visualised in the transverse plane before being rotated 90 degrees in the sagittalplane.Thebifurcationandcarotidbulbwererecognised and CO was estimated 1 to 1.5 cm from the bifurcation. Vesseldiameter (measured intimal to intimal edgein sagittal plane),VTI-total(VTI of systolicanddiastolic phase), VTIof systole(VTI-systolic),thesystolictime(Ts),thediastolictime(Td), the cycle time (Tc).The heart rate was also recorded. The sample volume was positioned in the centre of the artery lumen, and a 60° angleadjustment was used to match the pulsed wave doppler evaluation with the direction ofbloodflow. Aftercompletionofthesurgicalprocedure, patientswereshiftedtotheintensivecareunitfor electiveventilation.

The CO by CCA doppler was calculated byfollowing formula:

- Volumeflow[cm3/secor(ml/s)]=Cross-sectionalarea (CSA)xVelocity time integral
- The volume flow obtained in cm3/s (ml/s) is converted to ml/min by multiplying theobtainedvalue by 60.
- Approximately 20% of CO is going to the brain, out of which 50% wastraversed through each carotid artery.
- CO= CarotidDoppler flow volumex 10.

In both techniques CI was obtained by CO divided by body surface area (BSA) in both groups. The SV in CCA doppler group obtained by division of CO with heart rate.

The primary objective was comparison of cardiac output measured by transesophageal echocardiography (TEE) andcommoncarotidartery (CCA)doppler, while secondary objectives were comparison of stroke volume, and cardiac indexin both groups and to findany possiblecorrelation ofvalues ofCOmeasured inboth thegroups.

This study was time-bound. The data of 100 CABG patients were obtained during study period.Statistical analysis was performed with the SPSS, version 22 for Windows statistical softwarepackage (SPSS inc., Chicago, IL, USA). The Categorical data was presented as numbers(percent) and were compared among groups with using Chi-square test. The quantitative data waspresented as mean and standard deviation and were compared by students t-test. Probabilitywas considered to be significant if less than 0.05. Correlations between the cardiac outputmeasured by common carotid artery doppler and transesophageal echocardiography wereevaluatedusing Pearsoncorrelation coefficient analysis.

RESULTS:

The demographic variables and clinical parameters were shown in table 1.The measurements were taken in100 patients,by both techniques at four pre-defined time intervals. There was no statistically significant difference in cardiac output measured by TEE and CCA doppler at T1 (after induction of anaesthesia) and T2 (pre CPB period) time point, while statisticallysignificantdifferenceat T3 (20 minute after termination of CPB) and T4 (at sternal closure) time point. Although hasbeendemonstratedinvaluesaftercardiopulmonarybypass and at sternal closure. However, there was good correlationbetween two techniques at alltime intervals with correlation coefficients of 0.567, 0.617. 0.628 and 0.685.

Table1: Demographic characteristics

Characteristics	Value
Age in years (Mean ± SD)	51.23±13.09
Sex (M:F) in numbers	60:40
ASA grade (II/III/IV)	34:66:0
Weight (Mean ± SD)	59.05 ± 13.09
Height (Mean ± SD)	163.00 ± 9.12
Baseline SBP	74.78 ± 10.17
Baseline DBP	70.35 ± 9.81
Baseline HR	74.78 ± 10.91
Baseline SPO2	99.12 ± 0.98

Table 2: Distribution of cardiac output, cardiac index, and stroke volume according to groups in different time periods

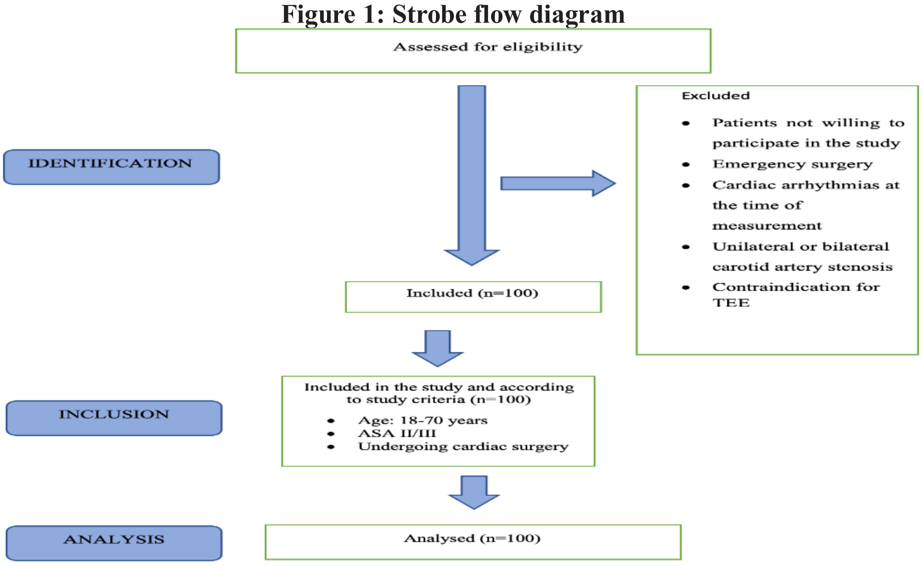
Group Statistics						
CARDIAC OUTPUT MESURED	Group	N	Mean	Std. Deviation	T value	P value
10 MINS AFTER INDUCTION OF ANAESTHESIA	Carotid Flow Doppler	100	4135.38	786.14		
	TEE	100	4101.77	717.95	0.316	0.753
BEFORE CPB	Carotid Flow Doppler	100	4234.07	826.66		
	TEE	100	4333.28	795.22	-0.819	0.414
AFTER TERMINATION OF CPB	Carotid Flow Doppler	100	4427.93	802.92		
	TEE	100	4705.90	787.80	-2.471	0.014
AT STERNAL CLOSURE	Carotid Flow Doppler	100	4503.50	789.96		
	TEE	100	4972.77	802.00	-4.169	p<0.001
CAROTID FLOW DOPPLERAT 10 MINS AFTER INDUCTION OF ANAESTHESIA	Carotid Flow Doppler	100	58.87	14.89	0.689	0.492
	TEE	100	57.63	9.93		

STROKE VOLUME AT 10 MINS AFTER INDUCTION OF ANAESTHESIA TEE		100 100	57.36 58.29	12.50 10.06	-0.582	0.561
STROKE VOLUME 20 MINS AFTER TERMINATION OF CARDIOPULMONARY BYPASS OR REMOVAL OF CROSS CLAMP	Carotid Flow Doppler TEE	100 100	55.37 58.74	11.06 9.77	-2.285	0.023
STROKE VOLUME DURING CLOSURE OF INCISION	Carotid Flow Doppler TEE	100 100	53.62 58.83	10.67 10.30	-3.514	p<0.001
CARDIAC INDEX (L/MIN/M^2) 10 MINS AFTER INDUCTION	Carotid Flow Doppler TEE	100 100	2.58 2.57	0.58 0.59	0.157	0.875
CARDIAC INDEX (L/MIN/M^2) 10 MINS BEFORE PERICARDIECTOMY OR AORTIC CROSS CLAMPING	Carotid Flow Doppler TEE	100 100	2.64 2.70	0.60 0.60	-0.761	0.448
CARDIAC INDEX (L/MIN/M^2) 20 MINS AFTER TERMINATION OF CARDIOPULMONARY BYPASS OR REMOVAL OF CROSS CLAMP	Carotid Flow Doppler TEE	100 100	2.76 2.94	0.61 0.64	-1.994	0.048
CARDIAC INDEX (L/MIN/M^2) DURING CLOSURE OF INCISION	Carotid Flow Doppler TEE	100 100	2.81 3.10	0.60 0.64	-3.348	p<0.001

Table 3: Pearson correlation of cardiac output between TEE and CCA doppler

Time interval	Pearson correlation coefficient (r) (95% confidence interval)
Cardiac output after induction of anaesthesia	0.567 (-176.3 to 243.6)
Cardiac output in pre-CPB time	0.617 (-325.4 to 127)
Cardiac output after termination of cardiopulmonary bypass	0.628 (-499.8 to -56.14)
Cardiac output duringsternal closure	0.685 (-691.3 to -247.3)

Figure 1: Strobe flow diagram



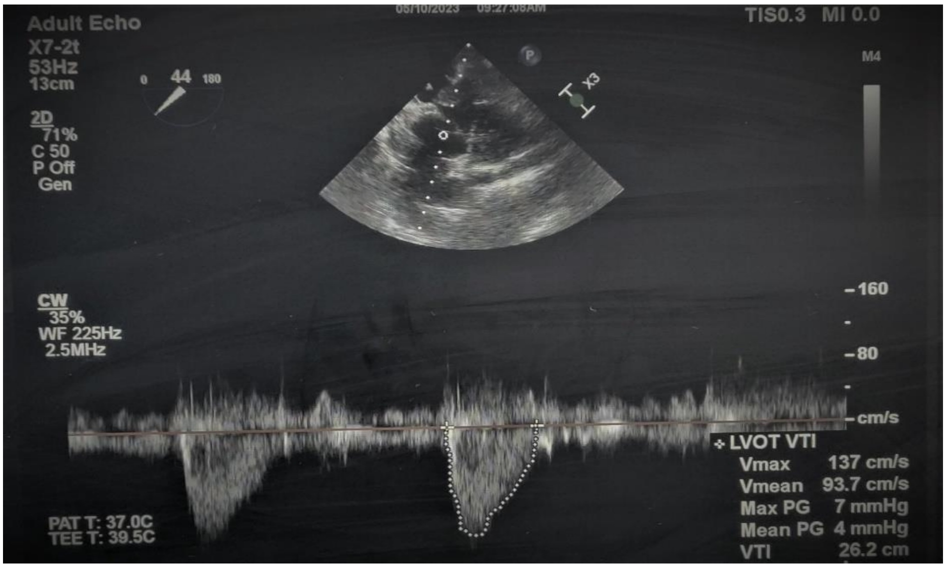


Figure 2: Image of pulse wave doppler in the LVOT and measurement of VTI tracing

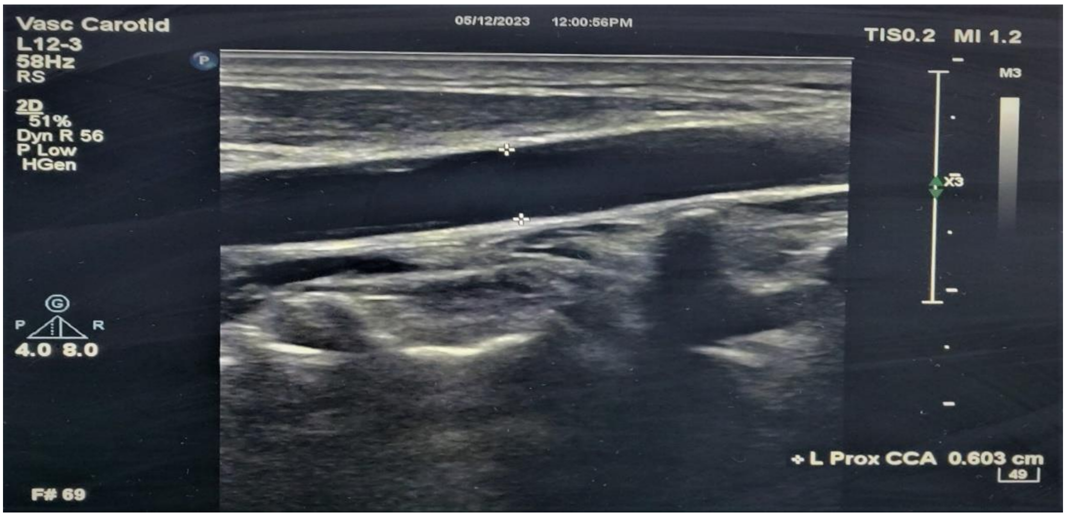


Figure 3: Longitudinal view of common carotid artery representing the lumen diameter

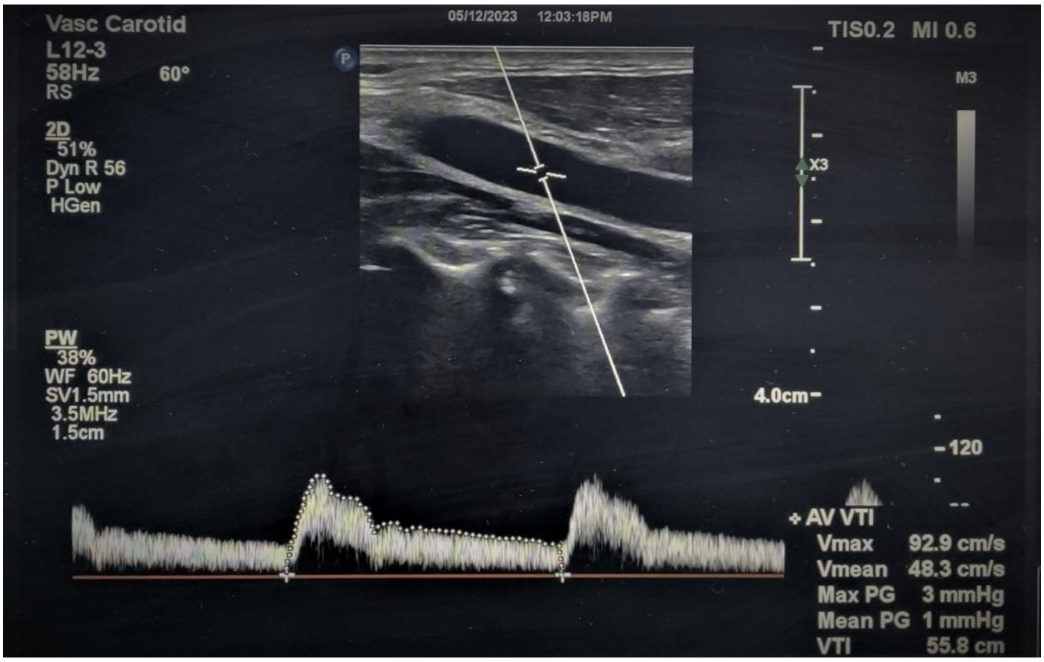


Figure 4: Spectral doppler of the common carotid artery (CCA), obtained with pulsed-wave doppler. sample volume encompasses the whole vessel diameter.

The results show that there isno statistically significant difference in cardiac index and stroke volume measured by Carotid Flow Doppler andTEEbeforecardiopulmonarybypass period,whereas there is a significant difference in cardiac index and stroke volume measured by the Carotid Flow Doppler and TEE groups in 20 mins after termination of cardiopulmonary bypass or removal of cross clamp and during closure of incision.There is good correlation of cardiac output measured by the two techniques at alltime intervals with correlation coefficients of 0.567, 0.617. 0.628 and 0.685.

DISCUSSION:

This study demonstrated no statistically significant difference between cardiac output at the first two time points (after induction of anaesthesia and in pre-CPB time, whereas statistically significant difference was present after termination of CPB and at sternal closure. Both modality has moderate corelation hence these can be used interchangeably.

CO monitoring is dynamic index of cardiac functionand plays a critical role in the management of cardiac surgical patients. Pulmonary artery (PA) catheter is the gold standard method, but due to its associated complications, it is infrequently used nowadays. Recently, monitoring is shifting from invasive to partially or non-invasive modalities. The availability TEE equipment and expertise almost vanish the use of PA catheter in cardiac OR The literature support that CO values derived by TEE and PAC has good agreement. Beside this, other advantages are non-invasive, inexpensive modality.

The TEE equipment and expertise is not available in noncardiac OR, hence CO estimation in these cases are done by minimally invasive or non-invasive monitors. The reliability issues of non-invasive monitors, lack of equipment's and cost of consumables of minimally invasive monitors are the main factors for infrequently used in perioperative period.

CO estimation or hemodynamic monitoring by carotid artery doppler being a topic of recent interest. The carotids are easily accessible in most of the surgeries and good quality image can be obtained by simple high frequency transducer byanaesthesiologists not having experience of TTE or TEE. The CCA derived CO is accurate and feasibility technique and showed perfect correlation (0.8152) between measurements of CO via CCA ultrasound vs. invasive modalities(PA catheter or pulse contour method).They concluded that common carotid artery POCUS offers a non-invasive method of measuring the CO in the critically ill population. [9]

Similar study was conducted by Van Houte J et aland they

While another author showed poor trending ability of carotid artery blood flow and invasive CO with only moderate correlation (0.67) and carotid artery-derived CO tends not to be interchangeable with invasive CO. [10]

Peng QY et alemphasized that CCA doppler derived CO can be considered as alternative in emergencies and when TTE cardiac out is unobtainable, but it cannot be used to recommend in patients with septic shock, multiple trauma, respiratory failure. [11]Sidor et alconcluded that carotid flow can be used as a surrogate marker for cardiac output measurement in hemodynamically stable patients. [6] We found moderate correlationbetween CBF and CO by TEE and CCA doppler at all four time points with coefficients of:0.567, 0.617. 0.628 and 0.685.This highlighted that both modality can be used interchangeably. More precisely CCA dicrotic notch velocities has some relation with left ventricular ejection fraction estimated by biplane modified Simpson method and concluded that it might offer some clinical value in selected cases. [12]

Sato K et aldescribed that anywhere from 9 to 13 % of the CO would traverse from each carotid artery depending on the degree of patient stress[13]and later Gassner M et algeneralised that to 10% and CO calculated by multiplying carotid blood volume (CBV) with 10. [9]Blanco P et al. used mean velocity time integral (VTI) velocity for CO calculation in CCA blood flow due to parabolic flow of blood where highest velocities in the center and lowest along the vessel walls, so there are chances of underestimation of volume flow with mean velocities. Blood flow velocity is also dependent on angle of insonation of ultrasound beam with respect to vessel. For standardization purpose most ultrasound machines are having feature of angle correction. [14,15] We used this feature in our study.

In contrast to above studies and our study Weber U et al demonstrated weak correlation in cardiac index measured with PAC with doppler-estimated carotid and brachial arterial blood flows and these cannot be used in patients after cardiac surgery.[16]Eicke BM et alalsofoundno correlation between ejection fraction, stroke volume, or heart minute volume and absolute volume flow in the carotid arteries and TTE.[17]

According to our findings, common carotid artery doppler offers a non-invasive and safe alternative for measurement of cardiac output. But in cardiac surgery patients there is statistically significant difference between cardiac output measured by TEE and carotid doppler after termination of cardiopulmonary bypass, this may be attributed to the hemodynamic changes that occurs in a patient post-bypass. Although there is good corelation between two modality, hence CCA doppler can be used as alternative technique. The CCA doppler may be the emerging technique in noncardiac surgical procedure due to non-availability of TEE as well as expertise.

Our study limitations has following limitations like study was time bound in nature, CO measured by both modality were in different cardiac cycles. and CO measured by CCA doppler was not compared with gold standard method that is thermodilution technique.

CONCLUSION:

Common Carotid Artery (CCA) doppler demonstrated a moderate correlation with transesophageal Echocardiography (TEE) in measurement of cardiac output in patients undergoing elective cardiac surgery and thus this can be considered as an alternative for measurement of cardiac output when other modalities are not available. However, there is statistically significant difference between the values of cardiac output measured by both the techniques after termination of cardiopulmonary bypass, this may be attributed to the haemodynamic alterations that occur in the patient post-bypass.

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