# COMPARISON OF CARDIAC OUTPUT CALCULATION BY 2D, X-PLANE, AND 3D ECHOCARDIOGRAPHIC IMAGING IN PATIENTS UNDERGOING CARDIAC SURGERY USING TRANSESOPHAGEAL ECHOCARDIOGRAPHY

**Thesis Submitted for the partial fulfilment for the requirement of Degree of DM (Cardiothoracic and Vascular Anaesthesia)**

**Of**

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# DECLARATION

I hereby declare that this thesis titled, "**Comparison of cardiac output calculation by 2D, X-plane, and 3D echocardiographic imaging in patients undergoing cardiac surgery using transesophageal echocardiography**" has been prepared by me under the capable supervision and guidance of Dr. Thomas Koshy, Professor, Dr. Suneel P.R, Additional Professor, Division of Cardiothoracic and Vascular Anaesthesia, Department of Anaesthesiology, at Sree Chitra Tirunal Institute for Medical Sciences &Technology, Thiruvananthapuram.

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# CERTIFICATE

This is to certify that this thesis titled, "**Comparison of cardiac output calculation by 2D, X-plane, and 3D echocardiographic imaging in patients undergoing cardiac surgery using transesophageal echocardiography**" has been prepared by Dr. Uvaraj. R, DM Cardiothoracic and Vascular Anesthesia Resident, Division of Cardiothoracic and Vascular Anesthesia, at Sree Chitra Tirunal Institute for Medical Sciences & Technology, Thiruvananthapuram. He has shown keen interest in preparing this project.

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***Dr. Uvaraj.R***

# CONTENTS

# INTRODUCTION

Measurement of Cardiac output (CO) is considered to be an essential monitor in the perioperative period especially during cardiac surgical procedures. Intra-operatively, monitoring CO has become routine for major surgeries and in high risk patients. Cardiac Output can be monitored by two methods, invasive and minimally invasive.

TEE (Transesophageal echocardiography) is commonly utilized to measure CO intra-operatively during cardiac surgery by cardiac anaesthesiologists trained in TEE. This is done by calculating the diameter of left ventricular outflow tract (LVOT) in the initial step. By multiplying the LVOT cross-sectional area (CSA) with the LVOT time velocity integral (TVI) stroke volume (SV) can be calculated. SV times the heart rate of the patient gives the cardiac output.

Perioperatively by utilizing 2D echocardiographic method, cross sectional area of the LVOT is calculated by calipering the LVOT diameter in the mid oesophageal Aortic valve long axis view (ME LAX) at approximately 120 degree angle. This measurement dependson assuming that LVOT shape is circular. But various recent studies showed that shape of the LVOT is elliptical instead of circular. It has a minor and major axis.[1-4] Based on which axis is measured, LVOT area calculation may yield a higher or lower range of values[2-5].

Orthogonal X-plane echocardiographic imaging is used to get the short axis of the LVOT from ME-AV LAX view, from which LVOT area is calculated by planimetry.

Three dimensional TEE is increasingly utilized during the intraoperative period to assess the left ventricular function. Cardiac 3D QLAB software in Phillips iE33 ultrasound machine gives accurate data on assessment of LV function and volumes, ejection fraction and SV.[5-7]

In this study we compared the LVOT area measured by 2D echocardiographic and X-plane imaging methods using intraoperative TEE (Philips iE33 echo machine). Cardiac outputs calculated with the above two methods were then compared with estimation of CO by 3D echo using QLAB software**.**

# REVIEW OF LITERATURE

## CARDIAC OUTPUT ESTIMATION

### History

In1870 AdolfFick first described cardiac output[8]. He calculated cardiac output in animals by measuring oxygen content ($O_2$) in arterial (CaO2) and venous (CvO2) samples.He described CO by the following formula.It is called as Fick's equation:

$$CO = \frac{VO_2}{(CaO_2 - CvO_2) \times 10}.$$

In 1886 Grehant and Quinquaud, first performed pulmonary artery catheterization in dogs but this technique did not become available to humans for another 50 years[9].

Indicator-dilution technique was first described by Stewart in 1897[10]. Stewart administered NaCl solution into animal circulation and calculated its concentration in the femoral artery at selected intervals.Later this method was modified by Hamilton, and he developed a curve relating concentration and time[11]. Cardiac output was found to be equal to the amount of indocyanine green dye administered, divided by the area under the curve calculated downstream.[11]This is called as the Stewart Hamilton equation:

$$\text{Flow} = \frac{C_0 V_0}{\int c(t)dt},$$

In this formula $C_0$ indicates initial concentration of injectate and $V_0$ indicates volume of injectate. Denominator is represented by concentration of the indicator in relation to time. By using the above principle, in 1954 Fegler introduced thermo dilution (TD) technique. He administered cold solution as an injectate and calculated the temperature variations of blood distally.[12]Swan et al, in 1970 introduced a balloon tipped flow directed catheter having several lumens. This catheter was named as pulmonary artery catheter (PA catheter).[13]This development helped clinicians to calculate CO by thermodilution method in the perioperative period. This method is still considered to be the reference method for CO calculation in various situations.

**INTERMITTENT PULMONARY ARTERY THERMODILUTION**

In this technique a measured volume of cold fluid is administered via the PA catheter into the RA (right atrium). This fluid is detected at distal site by a thermistor located at the distal part of PA catheter. The variation in temperature of blood is measured by the thermistor, allowing for the measurement of thermo dilution curve. Area under the curve is measured and CO is obtainedfrom a modified Stewart-Hamilton equation[14]:

$$\mathrm{CO} = \frac{\mathrm{VI} * (\mathrm{TB} - \mathrm{TI}) * K1 * K2}{\int \Delta \mathrm{TB}\,(t)\mathrm{d}t},$$

In this formula VI indicates amount of injectate, TB indicates blood temperature, TI indicates injectate temperature. Blood temperature variation in relation to time (denominator) reflects the area under the thermodilution curve.

***Reliability of Thermodilution***

Despite considered being the reference method of CO monitoring, thermo dilution method reproducibility is questioned. Stetz et al, [15] in 1982 did a study and described the reliability of thermodilution in comparison with other two methods, Fick's method and dye dilution technique. He revealed that values obtained by all the above methods of CO estimation were comparable. He analysed the reproducibility of values obtained using thermodilution technique and concluded that the variation should be less than 15 %.[15]

***Sources of Error in thermodilution***

Accurate measurement of CO can be done if many factors are correlated. The volume of cold solution should be same between the injection as well as detection sites. There should be adequate mixing of injectate and blood .There should be no changes in the basal temperature of blood. Causes of inaccuracy may occur in relation to some physiologic conditions or due to technical methods. Technical faults may occur due to loss of injectate, variation in temperature, amount of solution, and dysfunction of thermistor.

Initially it was thought that the accuracy of thermodilution was good with 10 mL of iced 5 per cent dextrose solution. But several studies found that there was no change in CO irrespective of whether room-temperature or iced solution was used[16]. If the amount of fluid administered is lower than the calculated volume it leads to higher CO. Ideal volumes of solution for adult is 10ml and 0.15mL/kg for paediatric patients. Injection time of indicator administration should be less than five seconds. It should be administered with constant pressure to avoid an error in upstroke of the thermodilution curve.

Both pathological and physiological conditions can lead to inaccurate estimation of CO. Rewarming during cardiopulmonary bypass results in variations in core temperature because of heat distribution to peripheral sites. Calculation performed during this period can lead to lower estimation of the CO. Rapid bolus volume administration can lead to change in the calculated CO. Another disadvantage of thermodilution is that it gives the right sided cardiac output. It does not measure the left sided CO. Cardiac shunt lesions, both tricuspid and pulmonary valve regurgitation can also produces variation in CO measurements. Indicator solution can recirculate through the regurgitant valves. Spontaneous as well as artificial ventilation, both produces major variations in right sided output in comparison to left sided output. Measurements taken at end-expiration are considered to have more reproducible capacity. However, accurate measurement of average CO is calculated by three repeated cardiac output calculations performed during different periods of the respiration.

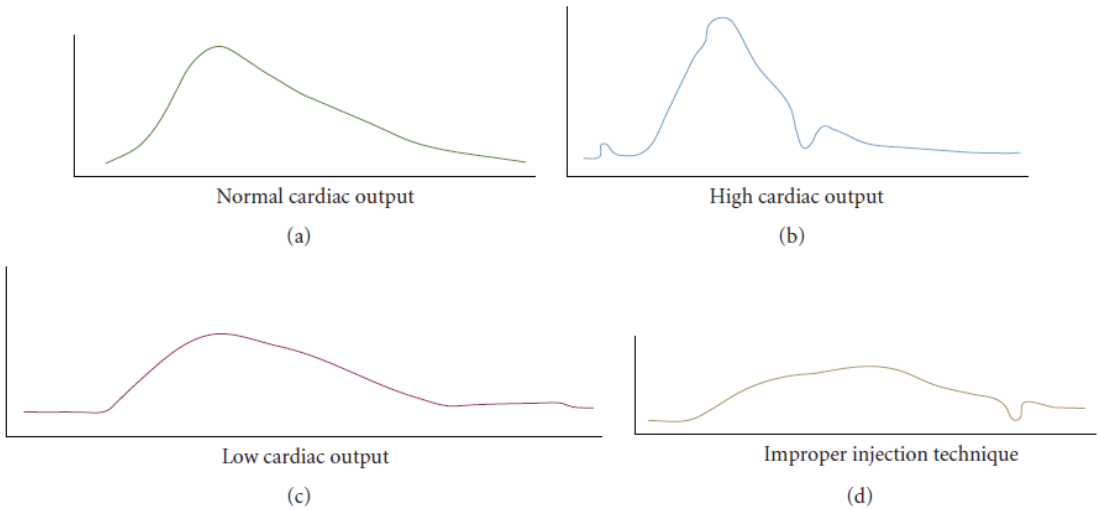



***Image 1:*** *Thermo dilution curve*

**Continuous Pulmonary Artery Thermodilution**

Newer technologies applied to PA catheterisbased on the same principle of thermodilution. Cardiac output can be measured continuously. In this method, an electric filament is incorporated inside the PA catheter in the RV portion. Blood is heated at selected interval, while passing via the RV about 15 to 25 centimetres from the distal end of PA catheter. The change in temperature is noted by a thermistor located at the distal end of the catheter. Advantages of this method (when compared to intermittent thermodilution) include monitoring the trend of cardiac output continually, reducing operator time, and lowering the risk of infection. Leibowitz and Oropello[17] studied the method in hemodynamically unstable patients. They found that this method leads to delayed response time of cardiac output measurement (approximately 8 to 12 minutes).[17] Because of this disadvantage it is called as continual instead of continuous.

***Controversies Related to PA catheter***

During the 1980's period, various articles revealed good results with use of PA catheter technique. In contrast to that, Gore et al.[18] in 1987 did a study and found that mortality was higher when PA catheter was used. However, the above study was case-control and retrospective study. Various researches utilizing the PA catheter to monitor cardiac output, systemic venous saturation (SvO2) and delivery of oxygen ($DO_2$) had not found any decrease in mortality and morbidity of intensive care unit patients. Another multicentre SUPPORT study, evaluated the relation between pulmonary artery catheterization and particular outcomes.[19]The study found higher one month mortality in PA catheter group. The food and drug administration (FDA) had given a consensus statement for randomized control trials using PA catheter.[20]

***Randomized studies related to PA catheter***

Canadian Critical Care study Group in 2003 published a randomized controlled trial. The trial compared the management with PA catheter and routine management with central venous catheter (CVC) in critically ill patients.[21]This study revealed that no change in mortality, duration of stay in hospital, or survival rate after 12 months. But there was a higher usage of inotropes, vasodilators, blood products administration and fluid therapy in patients with PA catheter. PA catheter group had more adverse events compared to usage of only CVC.

The PAC Man study in 2005 was a randomized trial performed in UK. This study revealed that there was no clear advantage with use of PA catheter.[22] Other parameters like length of stay in intensive care unit and duration of ventilator dependency needed were same in both groups. The study also showed higher rate of adverse events while using PA catheter. These events included hematoma formation, accidental puncture of artery, and rhythm disturbances. The above trial, similar to that of Sandham et al[21] refuted the occurrence of higher mortality as a result of using PA catheter. In 2006, study done in CABG patients without the use of CPB revealed no major change in short term mortality as well as long term outcomes with use of PA catheter.[23]

The ESCAPE trial evaluated the advantages of PA catheters for optimizing therapy particularly in heart failure patients admitted to intensive care unit.[24] The trial found no change in hospital mortality with PA catheter usage.

A RCT in 2006, The Acute Respiratory Distress Syndrome trial showed no clear advantages with usage of PA catheter when compared to CVC in patients with acute lung injury.[25] They reported no change in initial two month mortality or length of stay in hospital. But, the PA catheter patients had higher RBC and blood productusage. Adverse events,the more common being rhythm disturbanceswere more in PA catheter group.

## MINIMALLY AND NON-INVASIVE TECHNIQUES

Although thermodilutionis considered the reference technique for CO calculation, thermodilution usage is restricted by the adverse events of PA catheter (rhythm disturbances, valvular disease, risk of infection, pulmonary infarction, and rupture of PA). The ideal method should be non-invasive and continual, without the need for frequent calibration. It should also have higher accuracy, reproducibility, and reliability in different pathophysiologic conditions.

### Pulse Power Analysis

It is based on the principle that fluctuations of blood pressure about the mean are related directly to the stroke volume ejected into the arterial circulation. Accurate calculation was limited by many conditions like arterial compliance which is non-linear, compliance of the aorta, systemic vascular resistance (SVR) changes and transducer system damping.

#### *LiDCO method*

This method depends upon pulse power analysis. It is based on the fact that after correction for compliance and calibration, a linear relation occurs between net flow and net power. The LiDCO method can be combined with lithium dilution

system. This combined method is developed by Linton et al[26] in 1993.This system requires either peripheral or CVC placement along with an arterial access. The special arterial catheter has a sensor which is sensitive to lithium. The measured voltage undergoes amplification for measurement.

The LiDCO method needs repeat calibration at least every 8 hourly with lithium dilution. However, based on the recent evidence, it has been suggested, that frequent calibration is needed only when significant alteration in haemodynamics occur[27]. For good precision Cecconiet al[27]concluded that 3 lithium dilution measurements should be performed. From the dosage of lithium administered and the lithium time-concentration curve CO is derived.

LiDCO measurement reliability is affected by some of the conditions like aortic incompetence, aortic graft and prosthesis, Intra-aortic balloon counter pulsation, frequent dampening of transducer system, profound vasoconstriction while using more distal artery, error in the measurements of lithium and haemoglobin, rhythm disturbances, and cardiac shunt lesions. Every one gram change in Hb artifactually produces a difference in cardiac output calculation by 4%[28]. Use of LiDCO is contraindicated in patients with lithium therapy. It leads to higher measurement of CO, as a result of increased baseline concentrations.

**Pulse Contour Analysis**

It is based on the theory that the area under the systolic portion of the arterial pressure waveform is directly related to the stroke volume.

***The PiCCO method***

The PiCCO method is the first pulse contour analysis method utilized in the perioperative and intensive care units. Calibration is done externally and needs a central venous catheter. This is done with transpulmonary thermodilution 8 hourly. It can be done every one hour in case of unstable hemodynamic conditions. The arterial catheter contains a special thermistor which detects variations in temperature of blood. Calibration of this system is performed more than four times to derive a calibration factor for measurement of cardiac output, intra thoracic blood volume and extra vascular lung water.

***Limitations of PiCCO***

The accuracy of measurement is affected by compliance of vascular system, SVR and impedance of the aortic vasculature. Recent development and modification of the system overcomes the problems in regards to variations in the compliance of aorta.[29]Artefacts can occur due to the presence of air interface in the system, clot formation in the cannula, and insufficient amount of thermo indicator. Incorrect measurements also occur in rhythm disturbances, increased lung water, dilatation of aorta, high grade aortic and mitral regurgitation lesion, and frequent changes in temperature of blood. Cardiac shunt lesions also produce inaccurate measurements.

***Validation Studies of PiCCO***

The PiCCO technique is comparable with the PA thermodilution technique in multiple studies. However, since thermodilution is needed for measurement of CO, some error can occur. Some studies showed a major difference between these two methods. Halvorsen et al,[30] found unexpected major difference in comparison to PA

thermodilution in cardiac surgical patients. Notable variations occur during unstable hemodynamic periods because frequent calibration is required.

***FloTrac/Vigileo***

The FloTrac Vigileo is a pulse contour method developed in 2005. FloTrac provides continuous cardiac output calculation from an arterial cannula which is connected to the FloTrac sensor. The above system is attached to a special monitor called Vigileo. Unlike PiCCO, no manual calibration is needed. Another advantage is that CVC not needed.[31] Pulse pressures samplings are done over a period of twenty seconds to calculate the stroke volume. Recently, FloTrac underwent various modifications so that it can be utilized during periods of unstable hemodynamics. It can also be combined with CVC, so that SVR and systemic vascular resistance index (SVRI) can be calculated.

***Limitations of FloTrac:***

These measurements are highly based upon the characteristics of the arterial trace. Clear arterial waveform is essential to correct calculation of various parameters. Inaccuracy is noted when there is a severe rhythm disturbance and while using IABP counter pulsation.

***Validation Studies of FloTrac:***

Although FloTrac is considered an accurate monitor in various conditions, device inaccuracy has been noted in patients with hemodynamic instability. Manecke and Auger[32] found good correlation with PA thermo dilution in cardiac surgical groups. Another multicentre study by, Mc Gee et al.[33] reported that FloTrac was as reliable as PA thermo dilution in patients undergoing intensive care management.

Hamm et al[31], did a study on the device and found that the device was not as accurate when compared to PA thermodilution. Later Sakkaetal[34] found that transpulmonary thermodilution was considered as a reliable monitor in comparison with FloTrac in sepsis patients. More research is required to assess the FloTrac accuracy during various pathophysiologic conditions.

**Thoracic Electrical Bioimpedance-Bioreactance**

In 1959,Nyboer described the measurement of CO from the changes in electrical bio impedance. Low amplitude high frequency electrical stimulus is given after placing 4 electrodes at the chest level. Differences in thoracic bio impedance in relation to time is measured. The impedance is calculated during a particular time period. This period is usually between the opening and closing of the aortic valve. This method indirectly calculates the cardiac output. It is used to calculate the variations in thoracic blood volume, stroke volume, contractile function of the myocardium, and cardiac output at regular time intervals.

***Limitations of bio impedance***

Pacemakers including external pacemakers produce electrical artefacts to the bio reactance signal. Severe pulmonary artery hypertension leads to higher estimation of cardiac output. Presence of tricuspid and aortic incompetence leads to inaccurate calculations because that technique rejects regurgitate volumes. Pulsatile flow which is needed for cardiac output measurement by thoracic electrical bio impedanceis not present in continuous flow LVAD.

## DOPPLER TECHNOLOGY AND ECHOCARDIOGRAPHIC METHOD

The devices utilizing Doppler technique to calculate cardiac output underwent major developments in the previous decades. These techniques are minimal or non-invasive, in contrast to that of PA thermodilution. Echocardiography is an essential monitor in the perioperative period for hemodynamic monitoring and assessment of ventricular function.[35,36]

### *Physical principles*

Doppler law: Ultrasound is used in the frequency range of 2-10 MHz. It has the capacity to interact with various tissue components (example it is reflected by the moving RBC in the circulation). The Doppler law explains the relation between the changes in frequency of sound wave when the emitter and receptor are in a relative motion. This is explained as:

$$\Delta f = \frac{2 \times f_t \times v}{c} \times \cos \Theta$$

In this formula $\Delta f$ indicates the frequency change detected, $f_t$ indicates the initial frequency transmitted, v indicates the velocity of moving erythrocytes, c indicates velocity of sound wave (in human soft tissues this value is taken to be 1540 m/s approximately), and cos indicates the angle between ultrasound beam and the blood flow (angles of up to 30◦ are considered acceptable).

**Transoesophageal Doppler**

It contains a small probe, which is disposable. It's appearance is similar to that a nasogastric tube. This probe delivers ultrasound waves as well as receives the reflected waves in its distal part. It can be passed through the oral or nasal route. Probe is placed at the middle of the oesophagus. The probe delivers ultrasound waves into the bloodstream of descending thoracic aorta. Depending upon the manufacturers, it utilizes different method to calculate CO.

Complications are very minimal with this device. Major contraindications[37] include oesophageal stricture, acute esophagitis, oesophageal diverticuli, oesophageal tumours, oesophageal varices with bleeding risk, cervical spinal injuries, recent surgery in the oesophagus and severe coagulation abnormalities.

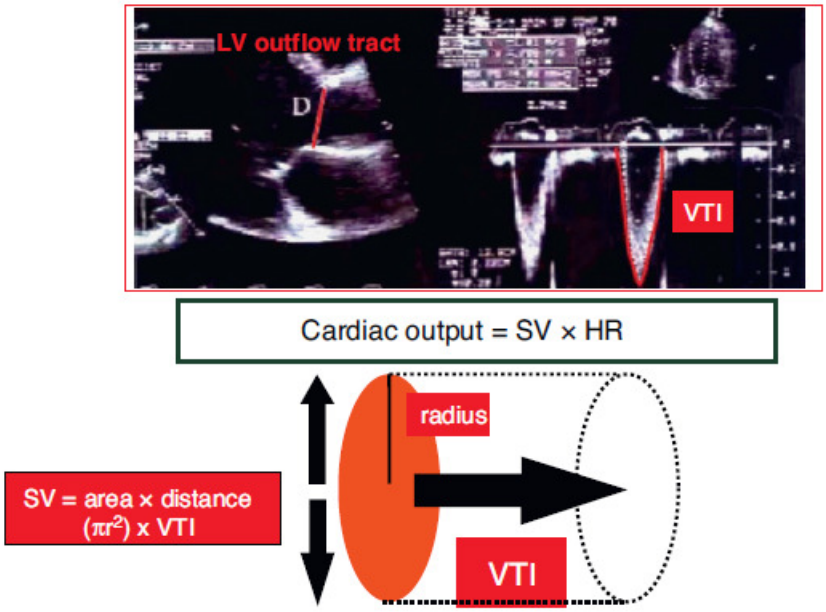
**Echocardiography**

Various methods are described to calculate CO using echocardiographic principle. It depends upon the Doppler technique and its various modalities (pulse wave, continuous wave and colour Doppler). Among these methods, more commonly used in the perioperative period and that gives good correlation with PA catheter is calculating CO by means of pulse wave Doppler.[38,39]Echocardiographic method measures two important parameters: (a) Diameter of the LVOT to derive its cross sectional area (b) LVOT velocity time integral (VTI).

TEE is commonly utilized to measure CO intra-operatively during cardiac surgery by cardiac anaesthesiologists. This is done by calculating the diameter of left ventricular outflow tract (LVOT) in the initial step. By multiplying the LVOT cross-

sectional area (CSA) with the LVOT time velocity integral (TVI) stroke volume (SV) can be calculated. SV times the heart rate of the patient gives the cardiac output.

***Image 2:*** *CO estimation by echocardiography*




Perioperatively by utilizing 2D echocardiographic method, cross sectional area of the LVOT is calculated by calipering the LVOT diameter in the mid oesophageal Aortic valve long axis view (ME LAX) at approximately 120 degree angle. This measurement depends on assuming the LVOT shape as circular. But various recent studies showed that shape of the LVOT is elliptical instead of circular. It has a minor and major axis.[1-4] Based on which axis is measured, LVOT area calculation may get a higher or lower range of values.[2-5]

Orthogonal X-plane echocardiographic imaging is used to get the short axis of the LVOT from ME-AV LAX view, from which LVOT area is calculated by planimetry.

## 3D TEE IMAGING

Three dimensional TEE is being increasingly used in the intra-operative period to assess cardiac anatomy and function. Ease of acquisition with rapid online display of detailed dynamic 3D images has overcome some of the early limitations associated with 3D echocardiography. In addition, exportation of 3D datasets to analytical software permits prompt off-line reconstruction of 3D models to accurately quantify cardiac anatomy and ventricular function.

### *3D technology:*

A fundamental difference between 2D and 3D echocardiographic imaging is how the image is acquired and displayed. Volume scanning is used in real time 3D echocardiography as compared with the standard sector planes in 2D[40]. This requires the use of special ultrasound probes to acquire raw data and integrated ultrasound machine software to process 3D datasets.

### *3D image acquisition:*

Creation of 3D ultrasound image of the heart involves four basic steps; data acquisition, data storage, data processing and image display.

The acquisition of 3D TEE images can occur instantaneously either in live or gated that is timed to the electrocardiogram (ECG) over multiple heart beats. Gated images are created as a loop by stitching together sub volumes acquired from consecutive heartbeats. Over a fixed number of cardiac cycles, the same portion of the ECG waves (usually the R wave) triggers the recording of each sub volume. It works best for regular sinus rhythm.

***3DQLAB:***

QLAB is available on the Phillips iE33 ultrasound machines for processing of 3D datasets. 3D QLAB Advanced waveform display gives accurate data for assessment of global function based on LV volume, ejection fraction and SV. QLAB uses multiplanar reconstruction to display the 3D volume in three colour coded orthogonal 2D planes. Green elevation plane, red lateral plane, blue depth plane. These planes can be adjusted independently.

Left ventricular volume can be accurately assessed using 3D echocardiography. It also provides dynamic assessment of left ventricle. In addition, this software provides assessment all regional segments.

# AIMS AND OBJECTIVES

**Primary objectives**

- Comparison of the LVOT area calculated by 2D echocardiographic method and X-plane planimetry method using intra-operative TEE.
- Comparison of the cardiac output calculated by 2D, X-plane, and 3D QLAB methods.

**Secondary objectives**

- Comparison of EF (ejection fraction) by 2D modified Simpson's and 3D QLAB method.

# MATERIALS AND METHODS

**Study Design**

Prospective, observational study.

**Setting**

Sree ChitraTirunal Institute for Medical Sciences and Technology.

**Study Group**

Number of patients – 40.

**Inclusion criteria**

Elective CABG surgery patients not having valvular lesion.

**Exclusion criteria**

Patient refusal

Patient who have contraindications for intra-operative TEE

Patient not in sinus rhythmwere excluded from the study.

**Approval from Technical Advisory Committee**: Approved

**Approval from Institutional Ethics Committee**: Approved (IEC/713)

**STUDY METHOD**

After taking written as well as informed consent, forty patients were enrolled in our study. After the induction of general anaesthesia according to the institutional protocol, TEE examination was done using Philips iE 33 echocardiographic machine with 3D probe in the pre CPB period. We performed a routine 2D examination. We calculated LVOT Cross sectional area (CSA) from 2D and orthogonal X-plane image in the ME AV LAX at an angle of approximately 120 degree. Then we measured SV by multiplying the LVOT area with LVOT velocity time integral (VTI). In the 2D technique, we calipered LVOT diameter at 0.5cm proximal to the aortic valve annulus. Measurements were done during the mid-systolic period. Most of the echo machines derive the LVOT area by using the formula $\pi r^2$.Then we obtained LVOT VTI from the long axis view in the deep trans gastric position at an angle of 0 degrees by using pulse wave Doppler. Doppler sample volumes were placed parallel to LVOT blood flow in the same place where we measured LVOT diameter. We calculated Stroke volume by multiplying the LVOT VTI with CSA of the LVOT. CO was obtained by multiplying SV with HR. The HR noted was same for the X-plane and 2D method calculation.

In the X-plane method, ME AV-LAX was obtained and the cursor was positioned 5 mm proximally in relation to the aortic valve annulus. The X-plane orthogonal window will show LVOT in short axis from which LVOT area is calculated by tracing the LVOT border. We also calculated left ventricular ejection fraction in 2D by biplane technique.

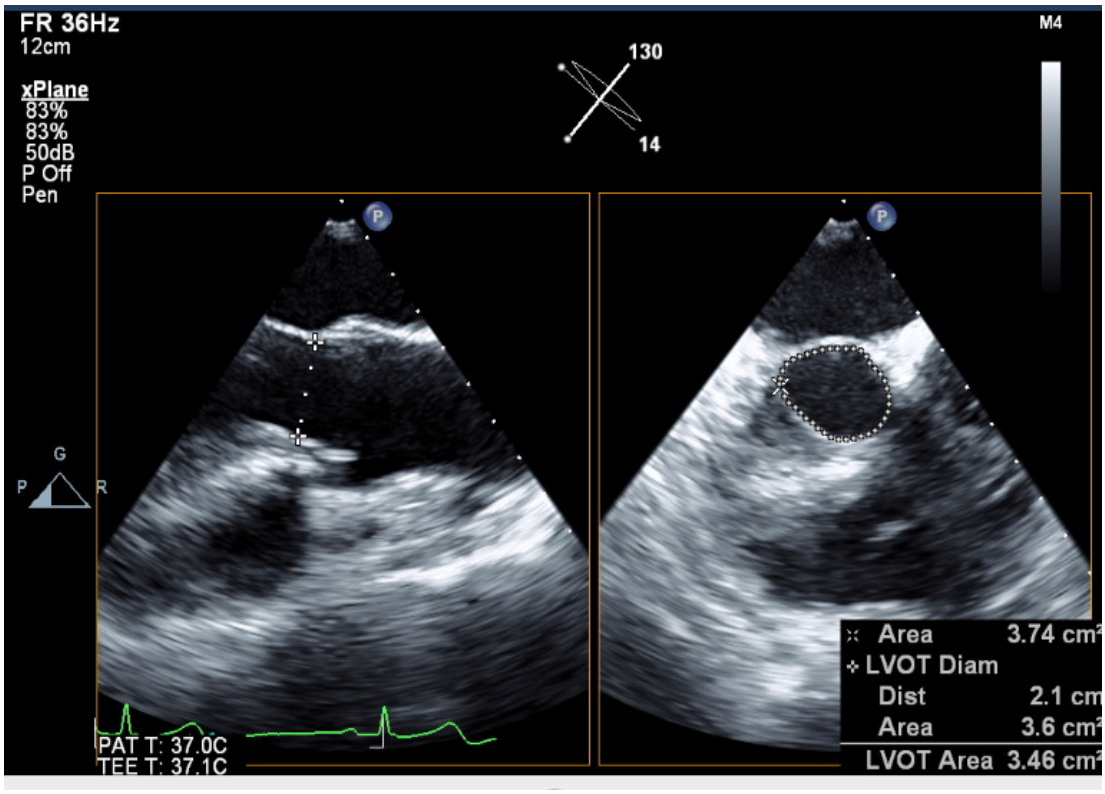



***Image 1**: LVOT area measurement by 2D and X-plane method.*

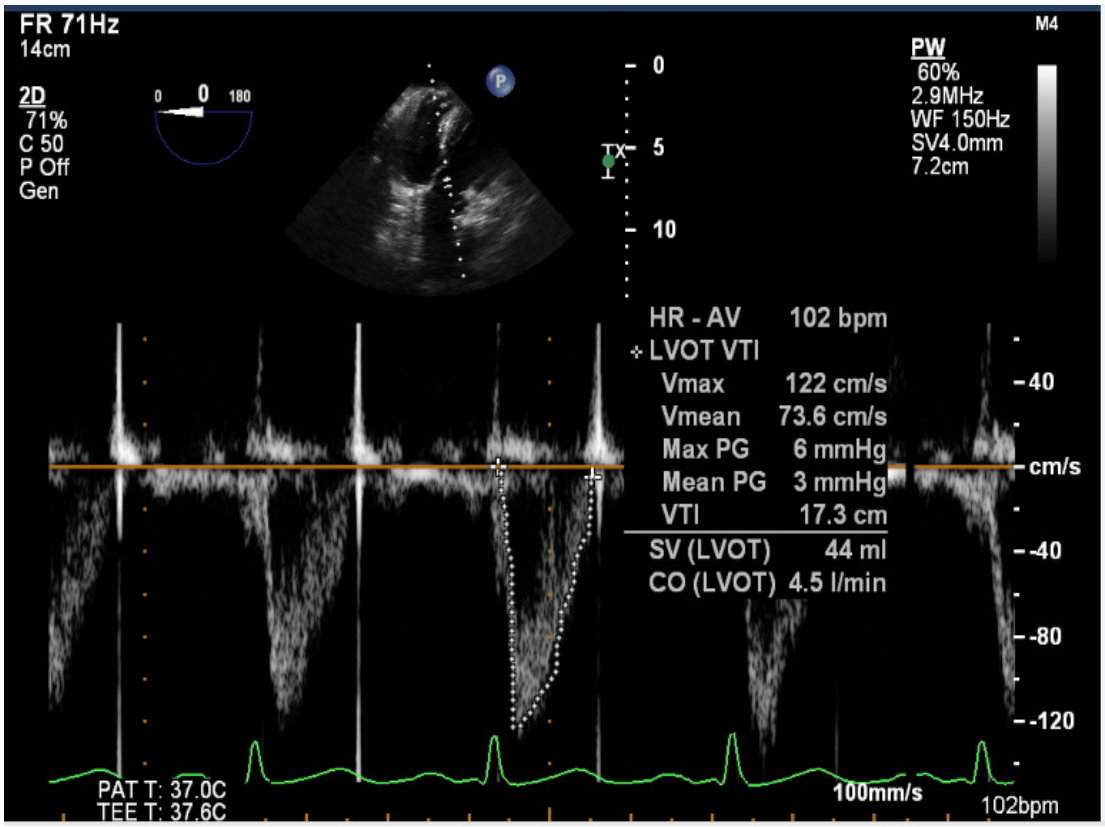



***Image 2:*** *LVOT VTI measurement.*

We used the 3D QLAB software to calculate the LV volumes in 3D method. Using the QLAB software, the full-volume data of the LV was organized into orthogonal four chamber, two chamber, and short-axis views. We selected the end systolic and end diastolic frames. Then we marked points at the septal and lateral annulus of mitral valve and LV apex. The software automatically detects LV endocardial border in three planes. The software then used sequence analysis to track the endocardium in all frames and then automatically calculate a true 3D ESV, EDV, and SV from the moving 3D endocardial shell. SV times the HR gives the cardiac output. We adjusted the borders of the endocardium manually, whenever endocardium border tracing seemed to be inadequate.

Cardiac output obtained from 2D method, X-plane method and 3D QLAB method were compared. All measurements were done 3 times in three different cardiac cycles and the average value was taken.

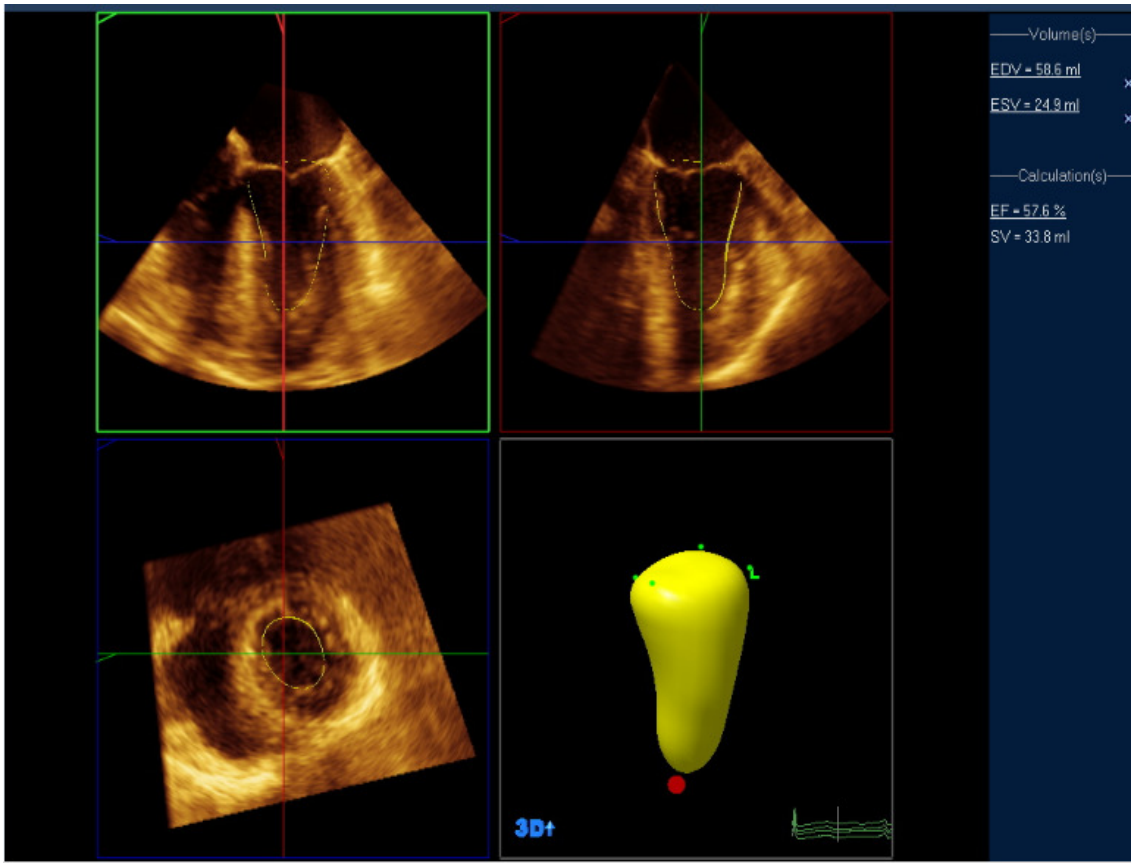



***Image3:*** *3D QLAB method measurement of CO.*

**Collection of Data**

Preoperative data like age, sex, left ventricular function, ejection fraction were noted. Variables measured by 2D echocardiography include LVOT diameter, LVOT area, LVOT VTI, Stroke volume and Cardiac output. Variables measured by X-plane method included, LVOT area and cardiac output. QLAB was used to measure cardiac output. Ejection fraction was measured by 2D and 3D echocardiographic methods.

**Statistical analysis**

As descriptive statistics, percentages for categorical variables and means (SD) for quantitative variables were presented. Associations between quantitative variables were assessed by Pearson's correlation coefficients. P values <.05 were considered to have statistical significance. MS Excel and IBM SPSS Statistics version 21 for Windows were used for data entry and analysis.

# OBSERVATION AND RESULTS

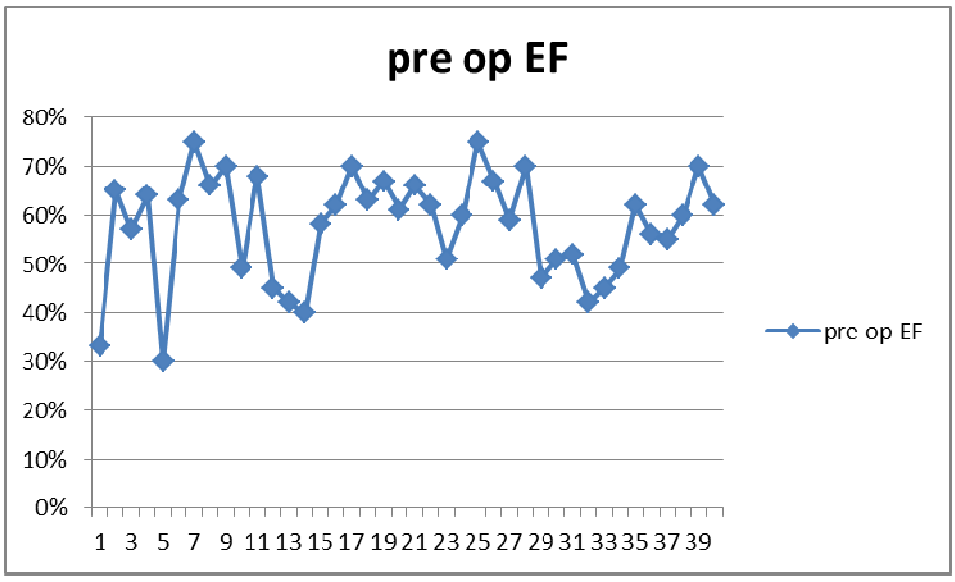
40 patients undergoing isolated coronary artery bypass graft surgery were studied. Twenty patients had preoperative regional wall motion abnormality, of these 10 patients had an ejection fraction (EF) of less than 50 %( graph 1). Age group of patients was between 42 to 82 years, average age was 57 years (table 1).

***Table 1**: Table showing the mean age and preoperative mean EF and their standard deviation*

| | N | Mean | Std. Deviation |
|---|---|---|---|
| AGE | 40 | 57 | 9.4 |
| Pre- op EF | 40 | 56 | 11.3 |

*EF - Ejection fraction*

***Graph 1**: Graph showing the pre op EF distribution*




*X axis – no of patients, Y axis- EF*

All patients were monitored with transesophageal echocardiography and cardiac output was calculated from 2D, X-plane and 3D QLAB method. LVOT area was compared with 2D and X-plane method. There was statistically significant difference between values obtained with the two methods (p value < 0.05). But the two methods showed a positive correlation in LVOT area measurement (table 2).

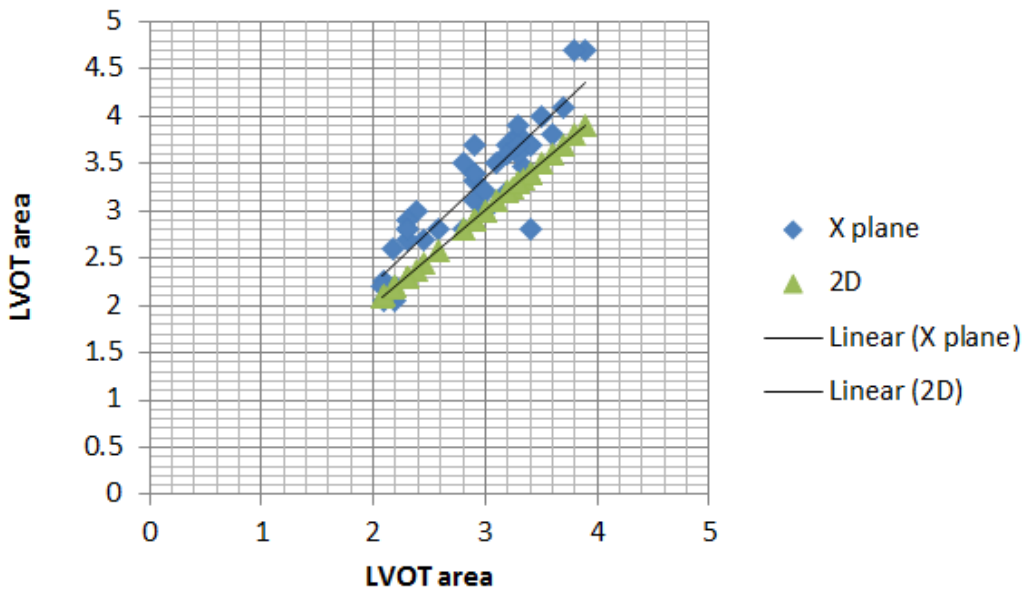
***Table 2:*** *Table showing the comparison of LVOT area between 2D and X-planemethods*

| Statistics of Paired Samples (T – Test) | | | | |
|---|---|---|---|---|
| | Mean | N | Standard Deviation | Std. Error Mean |
| LVOT area_2D | 2.9185 | 40 | .52608 | .08318 |
| LVOT area X-plane | 3.2543 | 40 | .65238 | .10315 |

*LVOT – left ventricular outflow tract.*

The above table showed that mean left ventricular outflow tract (LVOT) by 2D method was 2.9 $cm^2$ compared to 3.2 $cm^2$ by X-plane method. This difference was statistically significant (P<.001).

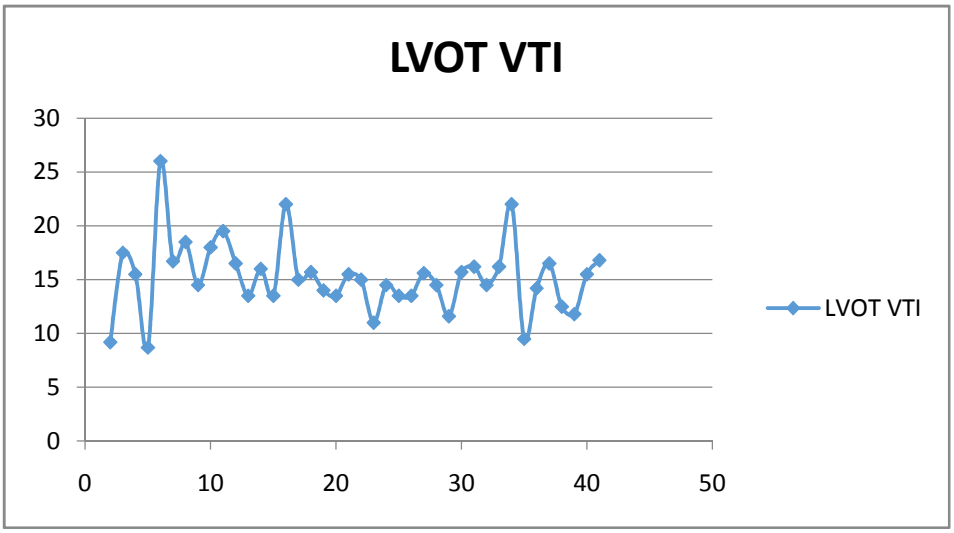
***Graph 2**: Graph showing the LVOT area correlation between 2D and X-plane*




The above graph showed LVOT area correlation between 2D and X-plane methods(graph 2). Pearson's correlation coefficient was r =.901, which shows strong positive correlation between the two methods.

LVOT VTI obtained from deep trans gastric LAX view was same for the 2D and X-plane groups. Below graphs shows the LVOT VTI distribution. (graph 3)

***Graph 3**: Graph showing LVOT VTI distribution among patients.*




*X axis – no of patients, Y axis- LVOT VTI*

Heart rate among the three methods was comparable and there was no statistically significant difference (table 3).

***Table 3****: Table showing heart rate comparison between 2D, 3D and X-plane methods*

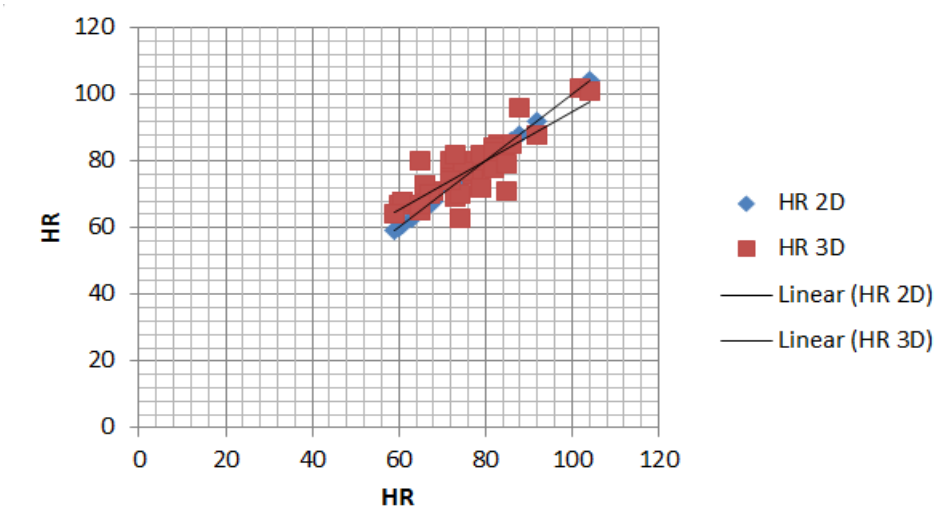
Paired Samples Statistics (T-Test )

| | **Mean** | **N** | **Std. Deviation** | **Std. Error Mean** | **P Value** |
|---|---|---|---|---|---|
| HR 2D | 75.48 | 40 | 10.607 | 1.677 | **0.323** |
| HR X-plane | 75.50 | 40 | 10.627 | 1.680 | |
| HR 2D | 75.48 | 40 | 10.607 | 1.677 | **0.130** |
| HR 3D | 76.85 | 40 | 9.225 | 1.459 | |
| HR X-plane | 75.50 | 40 | 10.627 | 1.680 | **0.139** |
| HR 3D | 76.85 | 40 | 9.225 | 1.459 | |

*HR- heart rate*

The above table showed that mean heart rate of 75 in 2D and X-plane method, 76 in 3D method. None of these differences were statistically significant.

***Graph 4**: Graph showing heart rate correlation between 2D and 3D methods*




*HR- heart rate*

The above graph showed that Pearson Correlationr =0.85, which shows strong positive correlation between 2D and 3D echocardiographic methods.(graph 4).

Cardiac output calculation by 2D, X-plane and 3D methods showed statistically significant difference between three methods, as X-plane method showed higher cardiac output than other two methods. (table 4).

***Table 4**: Table showing mean CO and their comparison between three methods*

Paired Samples Statistics (T-Test)

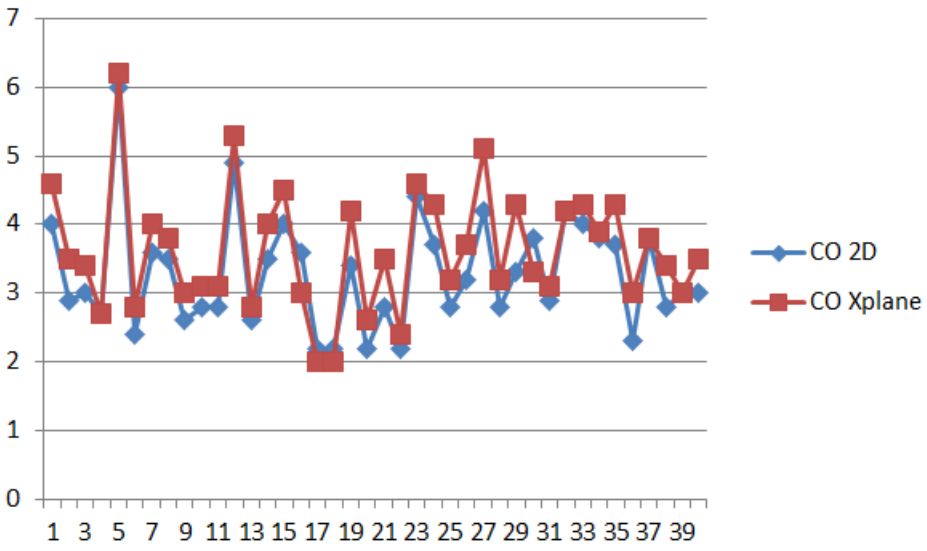
| | **Mean** | **N** | **Std. Deviation** | **Std. Error Mean** | **P Value** |
|---|---|---|---|---|---|
| CO-2D | 3.290 | 40 | .8098 | .1280 | **< 0.001** |
| CO X-plane | 3.618 | 40 | .8805 | .1392 | |
| CO-2D | 3.290 | 40 | .8098 | .1280 | **< 0.001** |
| CO_3D | 2.685 | 40 | .4154 | .0657 | |
| CO X-plane | 3.618 | 40 | .8805 | .1392 | **< 0.001** |
| CO-3D | 2.685 | 40 | .4154 | .0657 | |

The above table showed that mean CO by 2D, X-plane and 3D methods were 3.2, 3.6 and 2.6 L/min. This difference was statistically significant (P<0.05). Correlation of CO measurement between the three methods showed strong positive correlation between 2D and X-plane methods, but weak correlation between 3D and other two methods (table 5, graph 5,6,7).

***Table 5:*** *Table showing CO correlation between three methods*

| | | **CO X-plane** | **CO_3D** |
|---|---|---|---|
| CO-2D | Pearson Correlation | 0.923 | 0.602 |
| | P Value | <.001 | <.001 |
| CO X-plane | Pearson Correlation | | 0.573 |

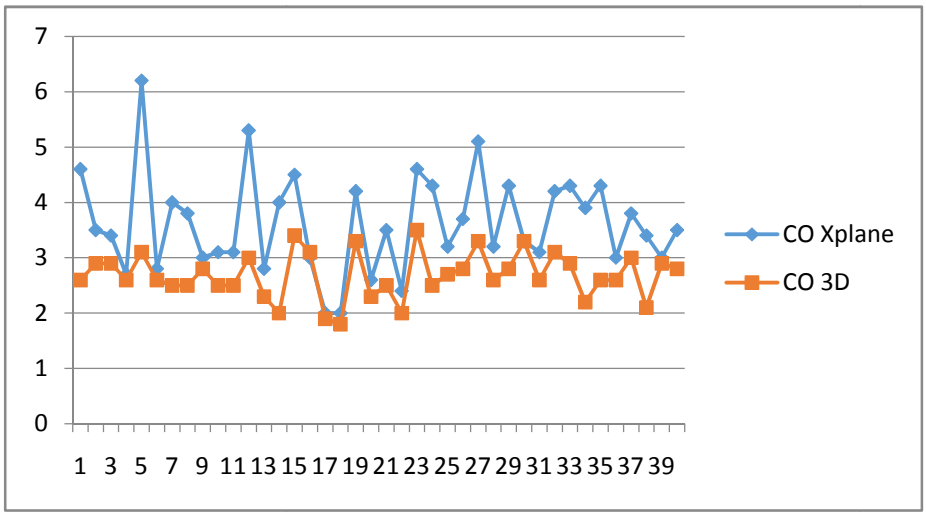
***Graph 5:****Cardiac output comparison between 2D and X-plane methods*




*X axis – no of patients,Y axis - cardiac output (L/m)*

The above graph showed correlation between 2D and X-plane CO measurement. Correlation was 0.93, which shows strong positive correlation.

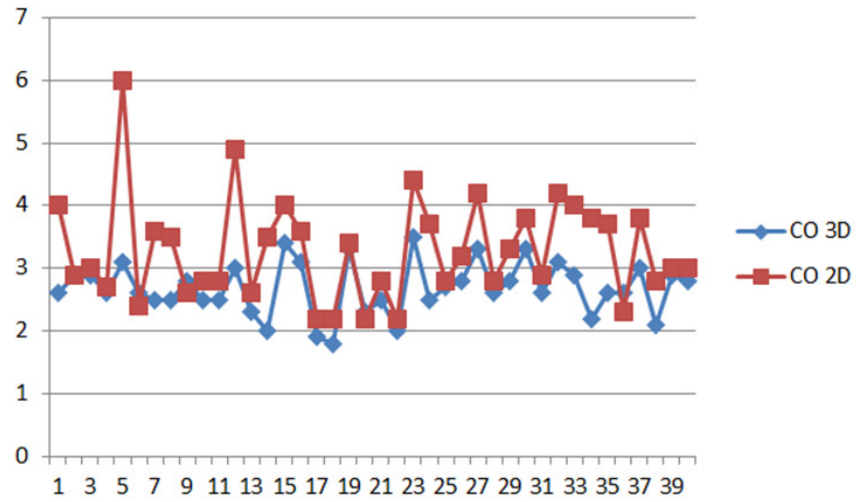
***Graph 6:****Cardiac output comparison between 3D and X-plane methods*




*X axis – no of patients,Y axis – cardiac output (L/min)*

The above graph showed correlation between 3D and X-plane CO measurement. Correlation was 0.57, which shows weak positive correlation.

***Graph 7:*** *Cardiac output comparison between 2D and 3D methods*




*X axis – no of patients, Y axis – cardiac output (L/min)*

The above graph showed correlation between 3D and 2D CO measurement. Correlation was 0.60, which shows weak positive correlation.

Ejection fraction comparison between 2D and 3D QLAB methods showed no statistical difference (P =.07) between the two methods (table 6, graph 8). There is strong correlation (Pearson's correlation r= 0.888) between the two methods in ejection fraction measurement.

***Table 6**: Table showing EF comparison between 2D and 3D methods*

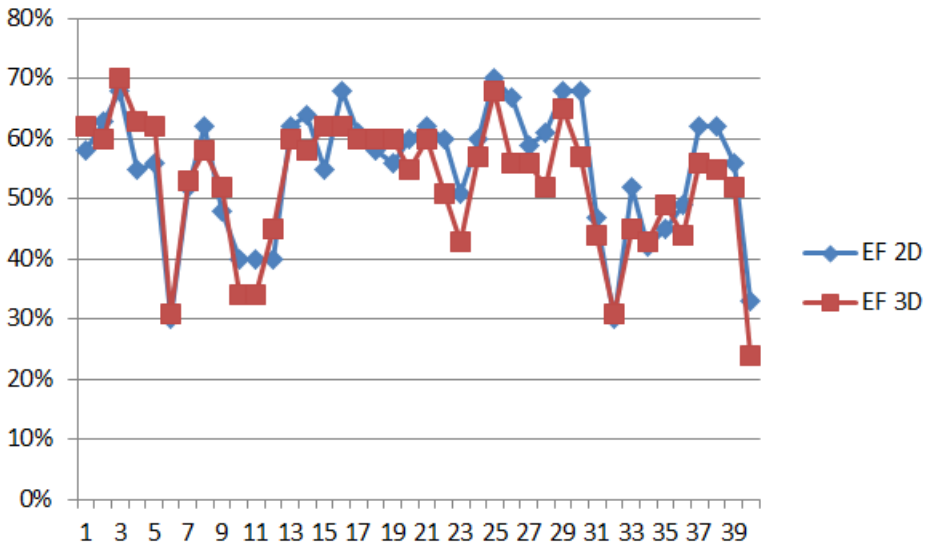
*Paired Samples Statistics (T-Test)*

| | **Mean** | **N** | **Std. Deviation** | **Std. Error Mean** |
|---|---|---|---|---|
| EF_2D | 55.00 | 40 | 10.718 | 1.695 |
| EF_3D | 52.73 | 40 | 10.782 | 1.705 |

EF - Ejection Fraction. P value =.07

The above table showed that mean EF by 2D, 3D method was 55%, 52.7% respectively. There was no statistical difference (P>0.05).

***Graph 8:** Ejection fraction comparison between 2D and 3D methods*




X axis – no of patients, Y axis – cardiac output (L/min)

The above graph showed correlation between 3D and 2D EF measurement. Correlation was 0.88, which shows strong positive correlation.

# DISCUSSION

The analysis of this study showed that left ventricular outflow tract (LVOT) area measured by 2D echocardiography method (measuring LVOT diameter in mid oesophageal aortic valve long axis view) was lesser than X-plane LVOT planimetry measurement. The average LVOT area measured by 2D and X-plane method was 2.9 and 3.2cm$^2$ respectively. This had resulted in 9 % lower cardiac output measurement by 2D echocardiography compared to X-plane method, although the difference in cardiac output might not be clinically significant. We used the same LVOT VTI in both methods obtained from deep trans gastric long axis view.

The reason for the lower estimation of CO by 2D method may be due to geometrically assuming that LVOT occurs in a circular orientation by conventional 2D method.This was similar to the study done by Utsunomiya H, Yamamoto H et al[3].They evaluated the ellipticity of LVOT with use of multi slice computed tomography and assessed the role of ellipticity in LVOT area calculation. This LVOT area was used in the continuity equation to estimate the aortic valve area in aortic stenosis group of patients. They concluded that ellipticity of the LVOT leads to lower estimation of aortic valve area calculation with the continuity equation (2D method). Montealegre-Gallegos M, Mahmood F, Owais Ket al[6], compared the calculation of CO and SV with the help of 2-D and 3-D transoesophageal echocardiography. They found that LVOT area was higher with the 3D technique. This variation leads to 10 % lesser cardiac output while using the 2 dimensional technique for calculation. They concluded that area of the LVOT was under-estimated when using the 2-D technique in comparison to that of 3-D method. In this study, the authors estimated the LVOT

area by 3D method and multiplied it with the VTI of the LVOT whereas in our study, the end-diastolic and end-systolic volumes were estimated with QLAB software.

Assuming that left ventricular outflow tract has a circular shape and accurate estimation of cross-sectional area of the LVOT are considered essential for estimation of CO. Other aspect is the aligning of the pulse wave Doppler parallel to LVOT as well as positioning of the sample volume. It is positioned in the same place where the diameter of LVOT is taken. LVOT area measurement is considered to be the common reason for error. This is due to the fact that LVOT diameter is halved to get the radius and then it is used in the formula. This results in inaccurate estimation of LVOT area. This also leads to error in cardiac output estimation.

This study also compared the cardiac output measured between 2D, X-plane and 3D QLAB method. The mean CO calculated by three methods was 3.3, 3.6 and 2.7 L/min respectively. These differences were statistically significant. Although the difference between 2D and X-plane was statistically significant, it is not clinically significant (300 ml difference between the two methods).

The reason for the lower CO measured by 3D method may be due to the following reasons. Measurement was taken in different cardiac cycle and use of a different principle to calculate the CO. 2D method uses time velocity integral of blood flow versus LV volumes by 3D QLAB method. Overestimation of CO with the X-plane method might be due to the difficulty in getting a correct orthogonal plane of LVOT in some patients. In our study comparison of correlation of CO measurement between the three methods showed positive correlation. However, the correlation was strong between the 2D and orthogonal plane method.

Stoddard MF, Prince CR et al[36] compared CO calculated from pulse wave Doppler TEE and thermodilution technique in post-operative patients. They concluded that thermo dilution CO showed good correlation with the CO estimated by TEE. To date no clinical study had compared the 3D and X-plane methods with thermodilution technique.

Comparing the practicability of 2D versus 3D QLAB full volume cardiac output measurement, the latter method has more sources of error. This is because 3D imaging is affected more by ECG artefacts, arrhythmias and electro cautery compared to 2D method.

Hare JL, Jenkins C et al,[5]assessed the feasibility and potential impact of routine 3D echocardiography in the measurement of LV ejection fraction and volume. They concluded that calculation of LVEF and volumes by 3D echocardiography was clinically feasible although it was lower than 2D echocardiographic method. This is similar to the findings of our study. We also found difficulty in getting good 3D images in certain patients due to poor imaging quality.

Also the 3D method had taken more time compared to other two techniques. We excluded those patients who had poor imaging quality from our study (7 out of total 47 patients). Vidar Ruddox, Thor Edvardsen et al[41], examined the feasibility of 3D Echocardiography and agreement between 2D Echocardiography and 3D Echocardiography with transthoracic imaging. They found that 3D echo was considered unfeasible in the presence of arrhythmia and poor imaging quality. They concluded that significant overestimation of LV volumes was noted in terms of 2D echocardiography versus 3D echocardiography, whereas no difference was found for LVEF.

Our study also compared the ejection fraction by 2D modified Simpson's method and 3D QLAB full volume method. The mean EF calculated by the two methods was 55% and 52.7% respectively. This difference was not statistically significant. There was strong correlation between values obtained using the two methods (Pearson correlation was r= 0.88). This finding was similar to a previous study by B. Cowie, R. Klugeret al[7], who measured LVEF and volumes in 2D biplane method, 3D QLAB method and X-plane method. They concluded that using 3-D TEE to calculate LVEF and volumes lead to minimal errors in comparison to 2-D method. They also found that there is no extra benefit of 3-D TEE for LVEF assessment in comparison to conventional two dimensional method.

# LIMITATIONS

- Cardiac outputs measured by all three methods were not compared with the gold standard, the thermo dilution technique.
- 2D & 3D echocardiographic measurements were taken in different cardiac cycles.
- This study was conducted only in patients with sinus rhythm, because sinus rhythm is needed for full-volume 3D acquisition over a number of cycles.
- Patients with valvular lesions were excluded from the study.
- 3D echocardiographic measurements are more prone to artefacts caused by electro cautery, abnormal rhythms and respiration.

# CONCLUSIONS

- LVOT area measurement was lower with conventional 2D echocardiography method compared to X-plane method. Correlation between the two methods was good.
- Cardiac output measurement was highest with X- plane method, lowest with 3D QLAB method. Both the methods were not compared with thermodilution technique; therefore, the ideal method cannot be commented.
- There was good correlation between CO measurements obtained using 2D, X-plane and 3D methods. Strong correlation was observed between values obtained with 2D and X-plane methods
- LV EF values obtained using 2D and 3D methods were comparable. Excellent correlation was found between values obtained using the two methods.

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**Patient information sheet**

**Title of study:**comparison of cardiac output calculation by 2D, X-plane and 3D echocardiographic imaging in patients undergoing cardiac surgery using transesophageal echocardiography.

**1) A statement that consent is for a study/research/experiment.** .

We are planning to conduct a research on echocardiographic calculation of cardiac output in the intraoperative period. We are requesting you to voluntarily participate in our research project. And we request you to provide a written consent that you are voluntarily willing to participate in our research project.

**2) An explanation of the purpose of research and nature of procedure.**

Transesophageal echocardiography (TEE) is a routine monitoring tool which is used during cardiac surgery. After making you unconscious during anesthesia induction, the Anaesthesiologist will introduce a flexible tube (TEE probe) inside your esophagus. This will be done when you will be under anesthesia and hence will not cause any discomfort to you. This approach allows your doctor to get more detailed pictures of your heart because the esophagus is directly behind the heart.

**3) What is the purpose of our research project?**

As the use of TEE has become a routine during cardiac surgery. Our study observations are the integral part of examination of cardiac output, which is routinely performed in the intraoperative period. Our study neither involves performance of any added invasive procedure nor does it add to the risk of routine intraoperative monitoring. Results obtained from the study are helpful in defining the intraoperative hemodynamic performance and which will be of great help for the future analysis and comparison of similar patients undergoing cardiac surgery.

**4) What are the foreseeable risks/discomforts to participants due to research?**

We will neither perform any extra invasive procedure nor will be using any extra drug. TEE examination will be done when you will be under anaesthesia and hence will not cause any discomfort to you.

**5) Safety of TEE (Transesophageal echocardiography)?**

TEE is a low risk procedure that yields an enormous amount of clinically relevant information when used appropriately. Although it is semi invasive, TEE is generally very safe. TEE has been performed for many years and thousands of studies have been done, virtually, all of them without significant complications.

Complication due to use of TEE is very minimal .TEE is used routinely for all cardiac surgical procedures in our institute. If any injury occurs that will be addressed and managed as per institute protocols.

**6) What are the benefits to be expected due to research?**

Results obtained from the study are helpful in defining the intraoperative hemodynamic performance and echocardiographic characteristics of cardiac output calculation which will be of great help for the future analysis and comparison of similar patients undergoing cardiac surgery.

**7) Can you withdraw from the study after it starts?**

Your participation in this study is entirely voluntary and you are also free to decide to withdraw permission to participate in this study. If you do so, this will not affect your usual treatment at this hospital in any way.

**8) Will your personal details be kept confidential?**

Your personal details and study data will not be revealed to anyone except the investigators. All steps will be taken to maintain confidentiality regarding your study data. Your personal details will be deleted from the echo images before making scientific presentations or publications. Your details will not be revealed to the publisher if the proposed study would be published in future.

**9)Explanation on provision of compensation for injury caused to participant during the study.**

We do not expect that our study will cause any injury to you because our study protocol is a part of routine intraoperative TEE examination. We will not perform any extra invasive procedure or administer any drug for the sake of our study.

**10) Will you have to pay for the study?**

No.

**11) Whom to contact to know more about the study and participant's rights.**

**Dr. Uvaraj. R**., Senior Resident, Department of Anaesthesia (Tel: 9633513218 or mail me: uvaraj@sctimst.ac.in)

**Dr. Thomas Koshy**, Professor, Department of Anaesthesia.

**Dr. Suneel P.R**, Additional Professor, Department of Anaesthesia.

# CONSENT

I, _____ (Please tick boxes)

Declare that I have read the above information provided to me regarding the study:**Comparison of cardiac output calculation by 2D, X-plane and 3D echocardiographic imaging in patients undergoing cardiac surgery using transesophageal echocardiography.**

- And have clarified any doubts that I had. [ ]
- I also understand that my participation in this study is entirely voluntary and that I am free to withdraw permission to continue to participate at any time without affecting my usual treatment or my legal rights [ ]
- I understand that the study staff and institutional ethics committee members will not need my permission to look at my health records even if I withdraw from the trial. I agree to this access [ ]
- I understand that my identity will not be revealed in any information released to third parties or published [ ]
- I voluntarily agree to take part in this study [ ]
- I received a copy of this signed consent form [ ]

Name:

Signature:

Date:

Name of witness:

Relation to participant:

Date:

(Person Obtaining Consent)

I attest that the requirements for informed consent for the medical research project described in this form have been satisfied. I have discussed the research project with the participant and explained to him or her in nontechnical terms all of the information contained in this informed consent form, including any risks and adverse reactions that may reasonably be expected to occur. I further certify that I encouraged the participant to ask questions and that all questions asked were answered.

_____ _____

Name and Signature of Person Obtaining Consent

# Case record form / Proforma

**Patient characteristics**

Age (yr):
Gender: Male/female
Height: cm
Weight: kg

**Preoperative TTE (Trans Thoracic Echocardiogram):**

Ejection Fraction:

RWMA:

LV function:

**Intraoperative TEE (Transesophageal echocardiography)**

**2D method**

| Parameters | Measurement 1 | 2 | 3 |
|---|---|---|---|
| LVOT diameter (cm) | | | |
| LVOT area (cm2) | | | |
| LVOT VTI | | | |
| Stroke volume (ml) | | | |
| Heart rate | | | |
| Cardiac output (L/min) | | | |
| Ejection fraction | | | |

**X- plane method**

| Parameters | Measurement 1 | 2 | 3 |
|---|---|---|---|
| LVOT area (cm2) | | | |
| Stroke volume (ml) | | | |
| Heart rate | | | |
| Cardiac output (L/min) | | | |

**3D method:**

| Parameters | Measurement 1 | 2 | 3 |
|---|---|---|---|
| Stroke volume (ml) | | | |
| Heart rate | | | |
| Cardiac output (L/min) | | | |
| Ejection fraction | | | |

## LIST OF ABBREVIATIONS

| | | |
|---|---|---|
| CO | - | Cardiac Output |
| HR | - | Heart Rate |
| SV | - | Stroke Volume |
| LVOT | - | Left ventricular Outflow tact |
| PA | - | Pulmonary Artery |
| CSA | - | Cross sectional area |
| X-plane | - | Orthogonal plane |
| TVI | - | Time Velocity integral |
| AV | - | Aortic Valve |
| $Vo_2$ | - | Volume of oxygen consumption |
| $Do_2$ | - | Delivery of oxygen |
| SVR | - | Systemic vascular resistance |
| CVC | - | Central Venous Catheter |
| TEE | - | Transoesophageal Echocardiography |
| EF | - | Ejection fraction |
| ME | - | Midoesophageal |
| SAX | - | Short axis view |
| LAX | - | Long axis view |

| patient no | age | pre op EF | LVOTarea | LVOTarea | HR | HR | HR | LVOT VTI |
|---|---|---|---|---|---|---|---|---|
| | | | 2D | X plane | 2D | X plane | 3D | |
| 1 | 71 | 58% | 2.9 | 3.32 | 77 | 77 | 76 | 18 |
| 2 | 55 | 63% | 2.9 | 3.7 | 68 | 68 | 71 | 14.6 |
| 3 | 82 | 68% | 2.1 | 2.26 | 76 | 76 | 80 | 18.2 |
| 4 | 50 | 55% | 2.2 | 2.2 | 73 | 73 | 69 | 16.5 |
| 5 | 67 | 56% | 3.34 | 3.47 | 68 | 68 | 71 | 26.5 |
| 6 | 69 | 30% | 3.3 | 3.8 | 83 | 83 | 85 | 8.7 |
| 7 | 41 | 70% | 3.24 | 3.72 | 65 | 65 | 65 | 14.5 |
| 8 | 49 | 49% | 2.45 | 2.7 | 74 | 74 | 70 | 16.5 |
| 9 | 59 | 45% | 2.58 | 2.8 | 63 | 63 | 67 | 16 |
| 10 | 67 | 42% | 3.4 | 3.7 | 66 | 66 | 73 | 12.5 |
| 11 | 46 | 60% | 3.4 | 3.7 | 66 | 66 | 73 | 11.5 |
| 12 | 55 | 40% | 3.6 | 3.8 | 102 | 102 | 102 | 13.7 |
| 13 | 45 | 62% | 2.08 | 2.2 | 82 | 82 | 81 | 15 |
| 14 | 63 | 65% | 3.29 | 3.9 | 60 | 60 | 67 | 16.5 |
| 15 | 66 | 57% | 3.5 | 4 | 72 | 72 | 80 | 15.5 |
| 16 | 53 | 59% | 3.4 | 2.8 | 74 | 74 | 63 | 17.8 |
| 17 | 58 | 58% | 2.2 | 2.05 | 61 | 61 | 68 | 18.2 |
| 18 | 55 | 55% | 2.1 | 2.05 | 61 | 61 | 68 | 13.5 |
| 19 | 62 | 67% | 2.38 | 3 | 86 | 86 | 85 | 15.6 |
| 20 | 63 | 61% | 2.18 | 2.6 | 75 | 75 | 78 | 13.6 |
| 21 | 65 | 66% | 2.3 | 2.9 | 82 | 82 | 84 | 15 |
| 22 | 45 | 62% | 2.3 | 2.7 | 78 | 78 | 80 | 11 |
| 23 | 69 | 51% | 3.7 | 4.1 | 79 | 79 | 82 | 14.8 |
| 24 | 74 | 60% | 3.2 | 3.7 | 83 | 84 | 79 | 13.5 |
| 25 | 55 | 66% | 2.9 | 3.4 | 72 | 72 | 75 | 19.5 |
| 26 | 48 | 67% | 2.3 | 2.8 | 82 | 82 | 78 | 15.7 |
| 27 | 56 | 59% | 3.9 | 4.7 | 75 | 75 | 77 | 14.5 |
| 28 | 45 | 56% | 3.3 | 3.6 | 73 | 73 | 82 | 13.5 |
| 29 | 47 | 70% | 2.8 | 3.5 | 92 | 92 | 88 | 12 |
| 30 | 48 | 70% | 3.2 | 3.2 | 67 | 67 | 70 | 16.5 |
| 31 | 61 | 47% | 3.2 | 3.6 | 72 | 72 | 74 | 12 |
| 32 | 62 | 38% | 2.9 | 3.1 | 88 | 88 | 96 | 9.5 |
| 33 | 62 | 52% | 2.9 | 3.4 | 82 | 82 | 83 | 16 |
| 34 | 69 | 42% | 3 | 3.2 | 79 | 79 | 72 | 16 |
| 35 | 56 | 45% | 3.1 | 3.5 | 85 | 85 | 71 | 14.5 |
| 36 | 60 | 49% | 3.8 | 4.7 | 65 | 65 | 80 | 9.5 |
| 37 | 67 | 62% | 3 | 3 | 59 | 59 | 64 | 22 |
| 38 | 52 | 55% | 2.3 | 2.8 | 85 | 85 | 79 | 14.5 |
| 39 | 69 | 56% | 2.8 | 2.8 | 65 | 65 | 67 | 16.5 |
| 40 | 51 | 33% | 3.3 | 3.7 | 104 | 104 | 101 | 9.2 |

| SV | SV | SV | CO | CO | CO | EF | EF |
|---|---|---|---|---|---|---|---|
| 2D | X plane | 3d | 2D | Xplane | 3D | 2D | 3D |
| 51 | 59 | 34 | 4 | 4.6 | 2.6 | 58% | 62% |
| 42 | 53 | 40 | 2.9 | 3.5 | 2.9 | 63% | 60% |
| 38 | 44 | 36 | 3 | 3.4 | 2.9 | 68% | 70% |
| 38 | 37 | 37 | 2.7 | 2.7 | 2.6 | 55% | 63% |
| 88 | 91 | 42 | 6 | 6.2 | 3.1 | 56% | 62% |
| 29 | 33 | 31 | 2.4 | 2.8 | 2.6 | 30% | 31% |
| 54 | 62 | 36 | 3.6 | 4 | 2.5 | 52% | 53% |
| 46 | 54 | 36 | 3.5 | 3.8 | 2.5 | 62% | 58% |
| 42 | 46 | 42 | 2.6 | 3 | 2.8 | 48% | 52% |
| 42 | 47 | 34 | 2.8 | 3.1 | 2.5 | 40% | 34% |
| 42 | 46 | 35 | 2.8 | 3.1 | 2.5 | 40% | 34% |
| 48 | 52 | 30 | 4.9 | 5.3 | 3 | 40% | 45% |
| 32 | 33 | 29 | 2.6 | 2.8 | 2.3 | 62% | 60% |
| 56 | 65 | 30 | 3.5 | 4 | 2 | 64% | 58% |
| 55 | 62 | 41 | 4 | 4.5 | 3.4 | 55% | 62% |
| 47 | 41 | 43 | 3.6 | 3 | 3.1 | 68% | 62% |
| 35 | 32 | 27 | 2.2 | 2 | 1.9 | 61% | 60% |
| 34 | 32 | 27 | 2.2 | 2 | 1.8 | 58% | 60% |
| 37 | 47 | 38 | 3.4 | 4.2 | 3.3 | 56% | 60% |
| 30 | 36 | 31 | 2.2 | 2.6 | 2.3 | 60% | 55% |
| 34 | 43 | 30 | 2.8 | 3.5 | 2.5 | 62% | 60% |
| 27 | 31 | 23 | 2.2 | 2.4 | 2 | 60% | 51% |
| 56 | 60 | 43 | 4.4 | 4.6 | 3.5 | 51% | 43% |
| 44 | 51 | 31 | 3.7 | 4.3 | 2.5 | 60% | 57% |
| 40 | 45 | 36 | 2.8 | 3.2 | 2.7 | 70% | 68% |
| 37 | 44 | 37 | 3.2 | 3.7 | 2.8 | 67% | 56% |
| 55 | 75 | 42 | 4.2 | 5.1 | 3.3 | 59% | 56% |
| 39 | 44 | 32 | 2.8 | 3.2 | 2.6 | 61% | 52% |
| 37 | 45 | 32 | 3.3 | 4.3 | 2.8 | 68% | 65% |
| 55 | 51 | 47 | 3.8 | 3.3 | 3.3 | 68% | 57% |
| 38 | 42 | 36 | 2.9 | 3.1 | 2.6 | 47% | 44% |
| 47 | 49 | 32 | 4.2 | 4.2 | 3.1 | 30% | 31% |
| 48 | 55 | 34 | 4 | 4.3 | 2.9 | 52% | 45% |
| 47 | 50 | 31 | 3.8 | 3.9 | 2.2 | 42% | 43% |
| 44 | 50 | 35 | 3.7 | 4.3 | 2.6 | 45% | 49% |
| 35 | 46 | 33 | 2.3 | 3 | 2.6 | 49% | 44% |
| 63 | 63 | 43 | 3.8 | 3.8 | 3 | 62% | 56% |
| 33 | 40 | 26 | 2.8 | 3.4 | 2.1 | 62% | 55% |
| 47 | 47 | 44 | 3 | 3 | 2.9 | 56% | 52% |
| 30 | 33 | 27 | 3 | 3.5 | 2.8 | 33% | 24% |

# PROJECT 2

**COMPARATIVE STUDY OF C-MAC VIDEOLARYNGOSCOPE AND MACINTOSH LARYNGOSCOPE FOR DOUBLE LUMEN ENDO BRONCHIAL TUBE INTUBATION IN PATIENTS UNDERGOING THORACOTOMY**

**Comparative study of C-MAC Videolaryngoscope and Macintosh laryngoscope for Double Lumen Endo bronchial Tube Intubation in patients undergoing thoracotomy.**

## INTRODUCTION

The Double-Lumen Endobronchial Tube (DLT) has been widely used for one-lung anaesthesia. Recently, many video laryngoscopes that are primarily meant for single-lumen tracheal tube insertion have been presented as promising alternatives to the Macintosh laryngoscope.[1-3] In contrast, there is less experience with the placement of DLTs using video laryngoscope. We evaluated DLT intubation using the C-MAC® videolaryngoscope, in comparison with Macintosh laryngoscope.

## AIMS AND OBJECTIVES:

### Primary Objectives

Time taken for trachea-bronchial intubation

Number of intubation attempts

First intubation success

Use of additional manoeuvres

### Secondary Objectives

Hemodynamic response

Complication like bronchospasm, bleeding, and arrhythmia.

## MATERIALS AND METHODS:

### Study Design

Prospective randomised observational study.

### Setting

Sree Chitra Tirunal Institute of Medical Sciences and Technology

### Inclusion criteria

Thirty adult Patients requiring DLT insertion for thoracic surgery.

### Exclusion criteria

Patient refusal

Patients with increased risk of pulmonary aspiration

Emergency surgery.

### Study Method

Thirty adult patients who required DLT for thoracic surgery were enrolled in the study. Patients were allocated into either a Macintosh group or C-MAC group. A preoperative airway examination of modified Mallampati class, thyromental distance, inter-incisor distance, presence of loose teeth, and limitation of neck motion were performed. After standard anaesthesia induction, DLT insertion was performed. Time taken for of intubation, number of attempts, first intubation success, use of additional manoeuvre, hemodynamic response, and complication like bronchospasm, bleeding and arrhythmia were noted.

## OBSERVATION AND RESULTS:

Among the 30 patients DLT insertion was successful with C-MAC Videolaryngoscope in 9 out of 15 patients (60%). First attempt was successful in 5 (33%) patients, 3 (20%) on the second and 1 (11%) on the third.

By using Macintosh laryngoscope intubation was successful in 14 out of 15 patients, first attempt in 10 (70%) patients, second attempt (14%) in two patients and third attempt in (14%) 3 patients. Median time to successful intubation was 55 [25-130] seconds with the C- MAC compared with 52 [30-155] seconds using the Macintosh.

***Table 1**: Patient Characteristics*

| | **Macintosh laryngoscope (n= 15)** | **C MAC videolaryngoscope (n= 15** |
|---|---|---|
| Age(yr) | 44 (20 -62) | 52 (37- 62) |
| Sex(male/female) | 11/4 | 12/3 |
| Weight (kg) | 63 (50- 78) | 60 (45- 78) |
| Height(cm) | 164( 158 – 173 ) | 165 (156 – 174 ) |
| BMI kg/m2 | 23.5 | 22 |

The above table showing the patient characteristics in the two groups. There was no statistically significant differences between the groups. (Table 1)

***Table 2**: Airway Assessment*

| | Macintosh Laryngoscope(n =15) | C-mac video laryngoscope (n=15) |
|---|---|---|
| Mallampati class (1/2/3/4) | 2/12/1/0 | 3/12/0/0 |
| Inter-incisor distance (cm) | 4.6 | 4.8 |
| Thyromental distance (cm) | 7 | 7.5 |
| Limited neck motion( +/-) | 15/0 | 15/0 |
| C and L grade (I/II/III/IV) | 7/6/2/0 | 5/8/2/0 |
| Left/right-sided DLT | 14/1 | 13/2 |

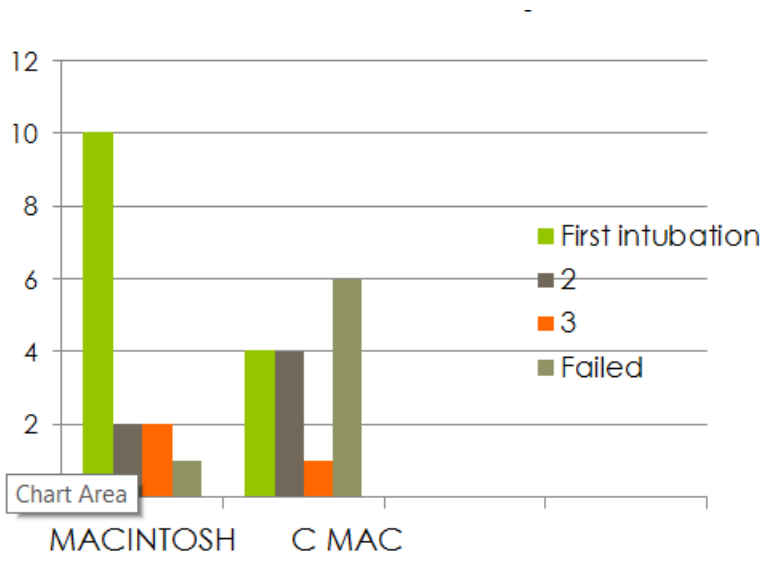
The above table shows the airway assessment parameters in the two groups. The differences were not statistically significant. (P > 0.05)

***Table 3:** Tracheobronchial intubations*

| | C mac video laryngoscope | Macintosh laryngoscope | P-value |
|---|---|---|---|
| Success/total (n) | 9 / 15 | 14 / 15 | < 0.05 |
| Number of attempts (n) - 1 | 4 | 10 | |
| 2 | 4 | 2 | |
| 3 | 1 | 2 | |
| Failed | 6 | 1 | |
| Time to success (s) | 55 (25-130) | 52(30 -155) | 0.010 |

The table shows that success rate for intubation was higher with Macintosh group compared to C-MAC group. The time to successful intubation was not significantly difference in the two groups. (table 3)

***Graph 1:*** *tracheal intubation comparison*




The above graph showing intubations success rate in the two groups. Macintosh group had higher success rate compared to C-MAC Group (Graph 1).

***Table 4:*** *complications*

| | Macintosh laryngoscope | C mac video laryngoscope | |
|---|---|---|---|
| Blood on the device | 1 | 2 | ns |
| Oral bleeding | 3 | 1 | ns |
| Bronchospasm | 0 | 0 | ns |
| Arrythmia | 0 | 0 | ns |

*ns- not significant*

The above table shows the incidence of complications in the two groups. It shows no statistically significant difference. (Table 4).

## DISCUSSION

- Although glottis view was improved by use of C-MAC video laryngoscope compared to Macintosh, DLT insertion was less successful in that group.
- Success rate was improved by increasing the anterior curvature of DLT.
- There was also higher incidence of tracheal cuff damage with C- MAC video laryngoscope.
- The higher failure rate in the C-MAC group may be because the pre-formed anterior curvature of DLT is not sufficient enough.
- With conventional laryngoscope there is more mouth opening (than with C-MAC) and there is no need for additional bending of the DLT.

## CONCLUSION

We concluded that although C-Mac video laryngoscope is useful in difficult airways in placing regular endotracheal tubes[4-5], but it is less useful in placing DLT unless preformed curvature is altered.

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**Case record form / Proforma**

Name – patient sticker-

Age& sex –

Weight-

Height –

BMI-

Disease/Lesion –

Airway assesment:

Mallampati class: 1/2/3/4
Inter-incisor distance: cm
Thyromental distance:cm
Neck movement: normal/restricted
Cormack Lehane Grade: 1/2/3/4
Size of DLT:Rt side/Lt side

Details of intubation using the Macintosh laryngoscope or C-MAC Video laryngoscope:

First intubation attempt successful :yes/no
Number of intubation attempts:
Duration of intubation(s):
BURP (backwards upwards rightwards) manoeuver used:

Complications:

Blood on the device: yes/no

Oral bleeding: yes/no

Bronchospasm: yes/no

Arrhythmia: yes/no

# Consent form

**Title of study:** Comparative study of C-MAC Video laryngoscope and Macintosh laryngoscope for Double Lumen Endobronchial Tube (DLT) Intubation in patients undergoing thoracotomy. A PROSPECTIVE RANDOMIZED OBSERVATIONAL STUDY

**Study numbers:** We request you to participate in the study where we are planning to compare the C-MAC video laryngoscope and Macintosh laryngoscope for double lumen tube intubation in 30 patients undergoing thoracic surgery.

**What is General Anaesthesia?**

General anesthesia is the common anaesthetic technique used for all thoracic surgeriesrequiring one lung ventilation. In this technique anesthetic drug is injected in the blood and we will make you sleep in a deep plane, where you will not have awareness during surgery. In this procedure an appropriate size Double lumen endobronchial tube is placed into the windpipe through mouth, with the help of a device called laryngoscope. This technique is called endobronchial intubation.

**What is one lung ventilation?**

Normally one lung on each side, connected to the windpipe through right and left main bronchus. During lung surgery lung in the operating side collapsed and kept immobile. During this period ventilation and oxygenation is maintained through other lung. This is called one lung ventilation. This is achieved with the help of special endotracheal tube called Double lumen tube.

**How Double lumen Tube is inserted?**

The technique used for Double Lumen Tube insertion is Direct laryngoscopy using a device called laryngoscope. There are different kinds of laryngoscope based on the blade used in it, commonly used laryngoscope with curved blade is Macintosh laryngoscope.

**What is C-MAC videolaryngoscope ?**

It is a videolaryngoscope which makes endotracheal intubation easier. It features standard D shaped blade designs with a complementary metal oxide semiconductor

video chip at the tip of the blade that extends a 60° optical axis in the vertical plane to a video display monitor.

**What are the risks and side-effects of laryngoscopy?**

During direct laryngoscopy there is chance of mucosal injury, bleeding, dental injury. But it is very rare with experienced persons. Using videolaryngoscope the incidence of trauma is less compared to direct laryngoscopy.

**Why are we doing the study?**

We are doing this study to compare this videolaryngoscope with Macintosh laryngoscope in double lumen tube insertion.

**Can you withdraw from this study after it starts?**

Your participation in this study is entirely voluntary and you are also free to decide to withdraw permission to participate in this study. If you do so, this will not affect your usual treatment at this hospital in any way.

**What will happen if you develop any study related injury?**

We do not expect any injury to happen to you but if you do develop any side effects or problems due to the study, these will be treated at no cost to you. We are unable to provide any monetary compensation, however.

**Will you have to pay for the study?**

No.

**Will your personal details be kept confidential?**

The result of this study will be published in a medical journal but you will not be identified by name in any publication or presentation of results. However the medical notes will be reviewed by people associated with the study, without your permission, should you decide to participate in this study.

***If you have any further questions, please ask:***

***Dr. Uvaraj.R, Senior Resident, Dept. of Cardiac Anaesthesia. Tel: (9633513218)***

***Dr. Thomas Koshy, professor, Dept. of Anaesthesiology***

***Dr.Suneel P.R, Additional Professor, Dept. of Anaesthesiology.***

## ***DECLARATION***

I, _____ (Please tick boxes)

•Participant's name: Date of Birth / Age (in years)

Declare that I have read the above information provided to me regarding the study:

"Comparative study of C-MAC Video laryngoscope and Macintosh laryngoscope for Double Lumen EndobronchialTube (DLT) Intubation in patients undergoing thoracotomy". A PROSPECTIVE RANDOMIZED STUDY

And have clarified any doubts that I had. [ ]

• I also understand that my participation in this study is entirely voluntary and that I am free to withdraw permission to continue to participate at any time without affecting my usual treatment or my legal rights [ ]

• I understand that the study staff and institutional ethics committee members will not need my permission to look at my health records even if I withdraw from the trial. I agree to this access [ ]

• I understand that my identity will not be revealed in any information released to third parties or published [ ]

• I voluntarily agree to take part in this study [ ]

• I received a copy of this signed consent form [ ]

Name:

Signature:

Date:

Name of witness:

Relation to participant:

Date:

(Person Obtaining Consent)

I have discussed the research project with the participant and explained to him or her in nontechnical terms all of the information contained in this informed consent form, including any risks and adverse reactions that may reasonably be expected to occur.

_____ _____

Name and Signature of Person Obtaining Consent