# Assessment of LV systolic function

A knowledge of the LV systolic function is crucial in the undertanding of and management of unstable hemodynamics or a failing heart in the ICU. As with fluid status assessment, a composite of different measures should be used rather than any one. The different methods commonly used in the echocardiographic assessment of LV systolic function are:

1.Ejection fraction - M-mode LV dimensional method
Simpsons method
Visual gestalt
2.dP/dT of the mitral regurgitant jet
3.Doppler measurement of stroke volume...and therefore cardiac output

## Ejection fraction

This refers to the percentage of the end diastolic LV blood volume that is ejected out of the LV during systole. The normal ejection fraction is above 50%. It is a widely used measure of LV contractility. Simplicity and familiarity are advantages of the EF as a measure of LV systolic function.
For a certain degree of contractility (the intrinsic contractile strength of the myocardium or the amount of work that the heart can perform at a given load), the stroke volume (SV) of the ventricle is determined by the preload (the end diastolic ventricular volume, pressure or stretch) and afterload (the force opposing ejection). The ideal indicator of myocardial contractility should not be affected by preload or afterload.
Ejection fraction (an indicator of contractility) is less dependent of loading conditions as compared to SV. However, the EF is afterload dependent and is depressed in situations with a high afterload. EF is measured in the ICU in three ways.

## M-mode LV dimensional method:

First obtain a parasternal long axis view and place a M-mode cursor is placed through the septal and posterior LV walls just beyond the tip of the mitral leaflets.
In the resultant M-mode image take measurements of the RV internal dimension, interventricular septum thickness, LV internal dimension and LV posterior wall thickness at end-diastole (timed on ECG or point of largest LV internal dimension) and at end-systole (ECG timed or point of smallest LV internal dimension).

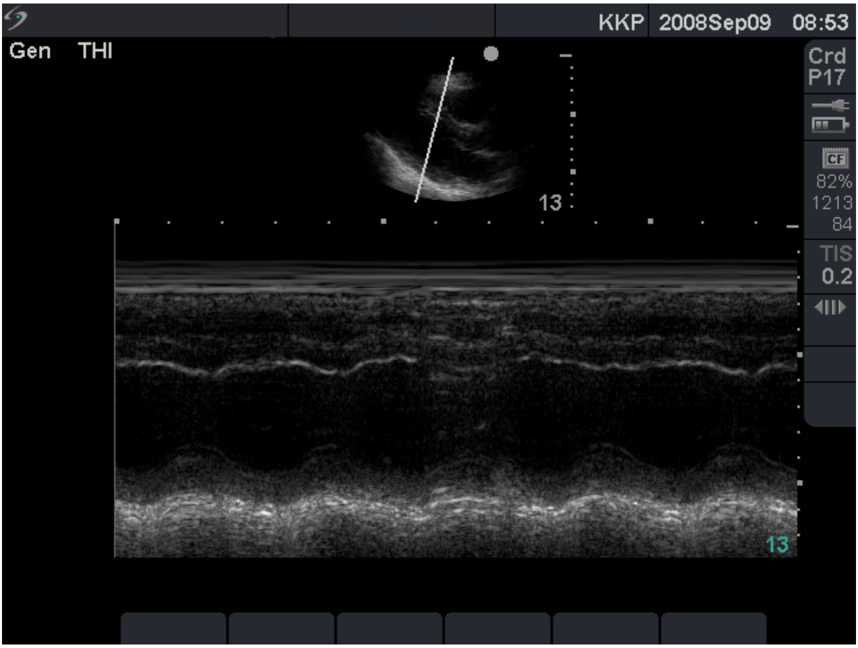


**Fig.1 M-mode of the LV in PLAX view**

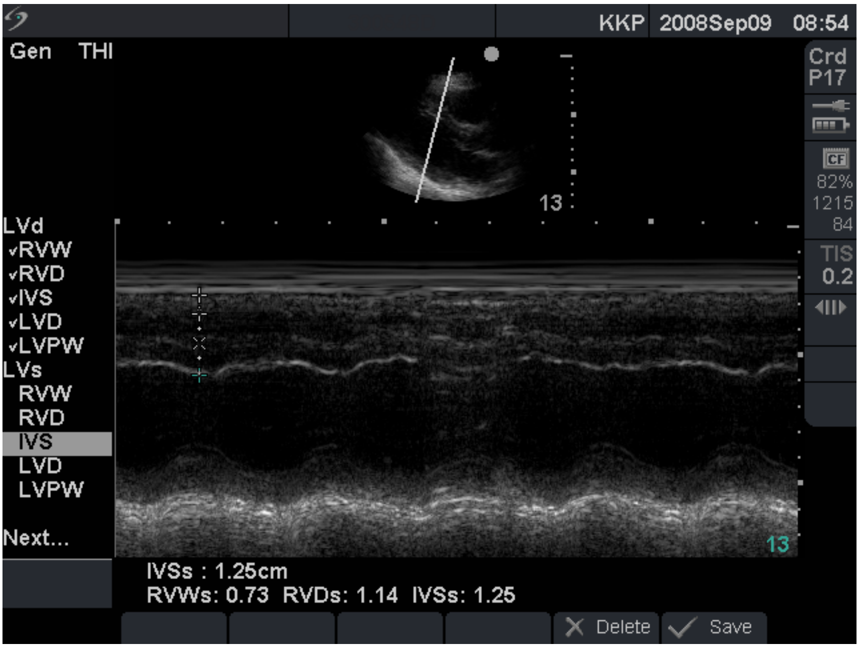


**Fig.2 Systolic measurements with a caliper in progress**

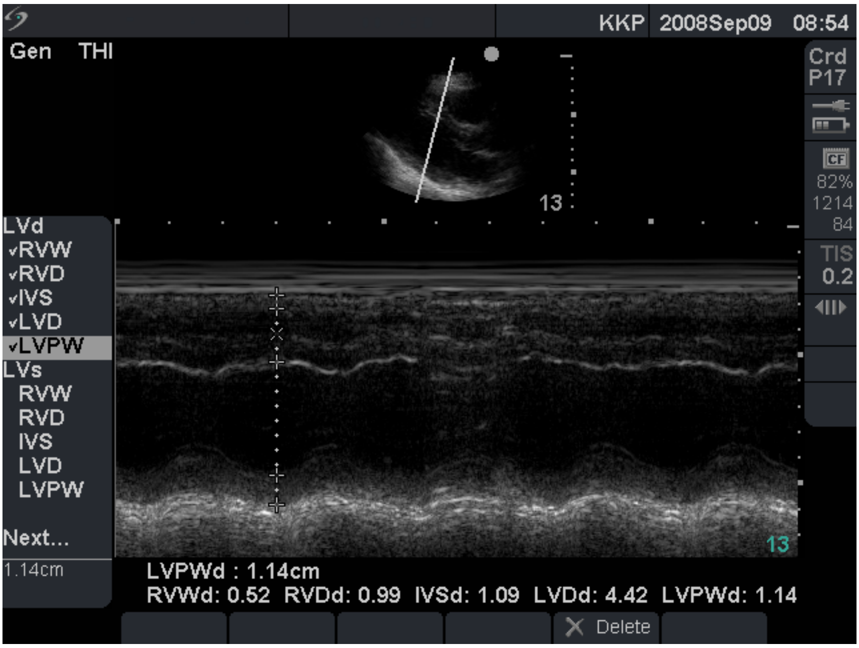


Fig.3 Diastolic measurements done with the calipers

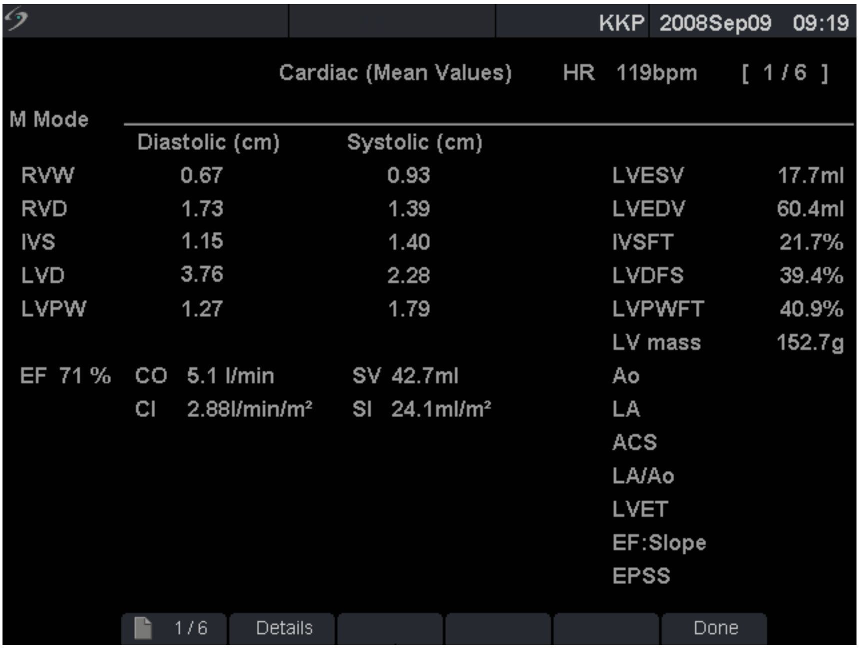


**Fig.4 Report of EF and FS generated**

With this information, most machines will be able to generate two numbers, the fractional shortening and the ejection fraction.
Fractional shortening is (LVEDd-LVESd) / LVEDd expressed as a percentage. The normal value is 30% to 45%.
Ejection fraction is calculated from derived volumes, which are computed based on the "cubed" or "Teichholtz" equations. The geometric assumptions made with the cubed method limits its usefulness in the abnormal ventricle. In dilated and spherical ventricles, the ratio of long to short axis in the ventricle increases and LV volumes will be overestimated. Using a derived formula by Teichholz instead of the cubed equation compensates for ventricles of abnormal size but only in the absence of asynergy (no RWMA's):
The normal ejection fraction is 50% to 75%.

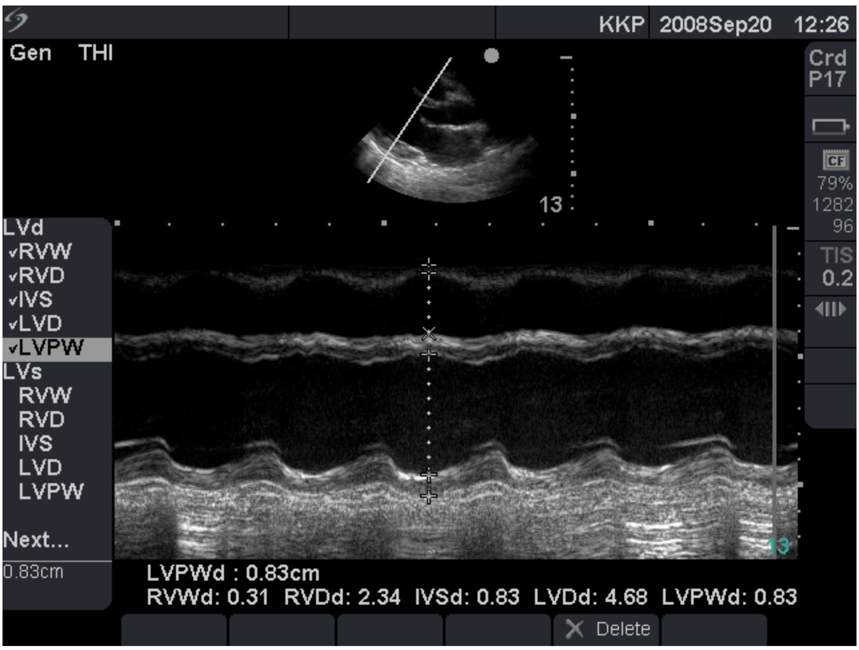


**Fig.5 M-mode of LV showing moderate LV dysfunction**

While the M-mode method of calculation of EF is easy to learn and perform, it has some drawbacks. The M-mode assessment provides information about contractility along a single line. In a patient with coronary artery disease and regional wall motion abnormalities, the severity of the dysfunction may be underestimated if only a normal region is interrogated or overestimated if the M-mode beam transits through the wall motion abnormality exclusively.
Another disadvantage of the M-mode asessment is that it does not reflect the true minor axis dimension. This is particularly common in elderly patients and in some patients with emphysema, in whom there is an angulation of the interventricular septum. In such cases, the M-mode beam traverses the ventricle in a tangential manner and often overestimates the true internal dimension

## 2-D method of Simpson

In this method, acquire A4C or A2C views, making sure that the endocardial borders are visualised well.

Freeze the image and scroll backward and forward to identify a frame at end diastole. This can be timed using the appearance of the ventricle - identifying a frame where the ventricle appears to have the largest volume; or with the ECG trace, where the peak of the R wave corresponds to end-diastole.
Open the "calculations" menu and select "LV volumes" and "A4C diastolic" or "A2C diastolic", whichever is appropriate. Place the cursor on the endocardial border where the anterior mitral leaflet meets the interventricular septum and trace the entire endocardial border of the left ventricle. You do not have to trace around the papillary muscles. Once this is done, the LV volume in diastole will be calculated.

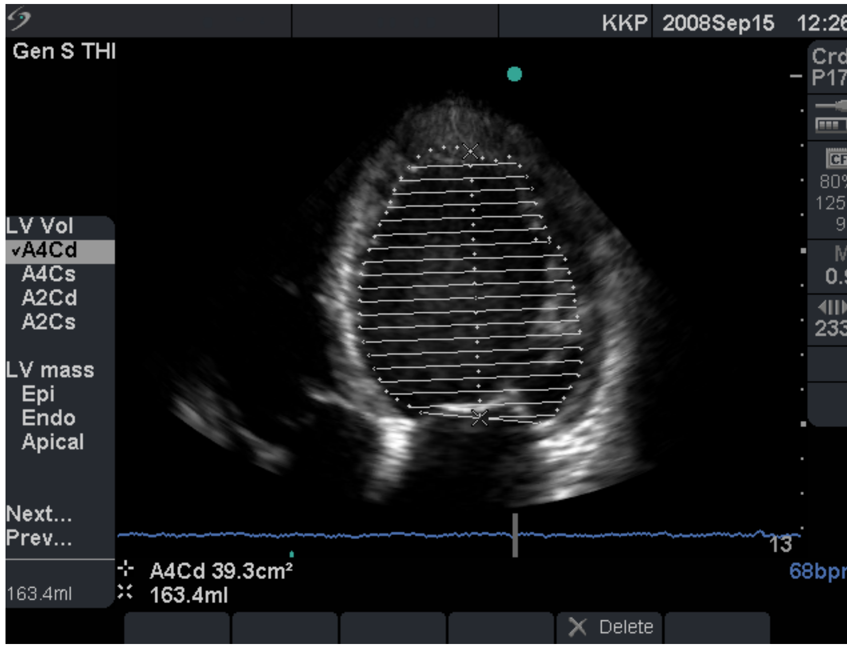


Fig.6 Calculation of LV volume in end-diastole

The frozen image is then scrolled forward or backward to identify a frame at end-systole. Again this can be done by identifying a frame where the ventricle appears to have the smallest volume, or correlating with the ECG trace, where the peak of the T wave corresponds to end-systole. Select "systolic LV volume" on the calculations menu and trace the outline of the endocardial border of the LV. Once this is done, the LV volume in systole will be calculated.

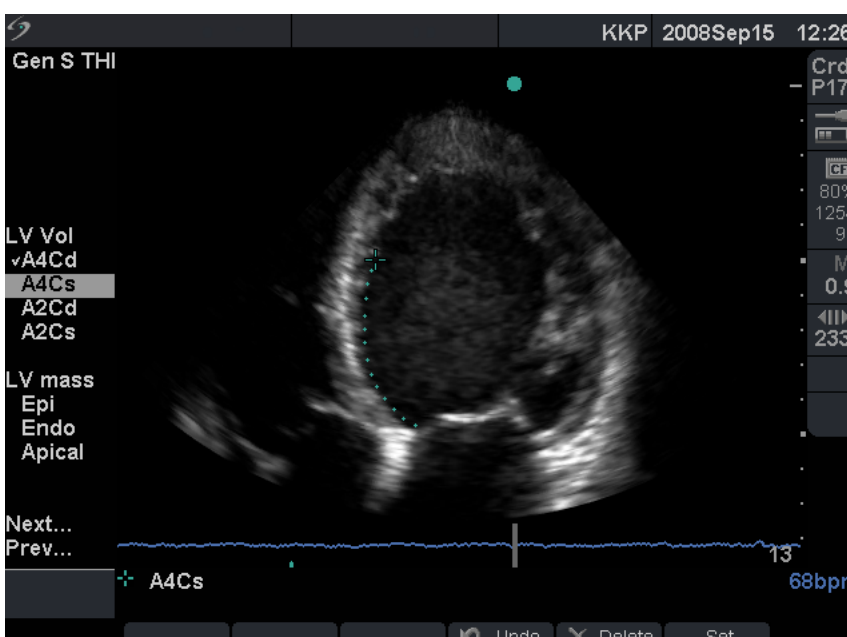


Fig.7 Tracing endocardial border in end-systole

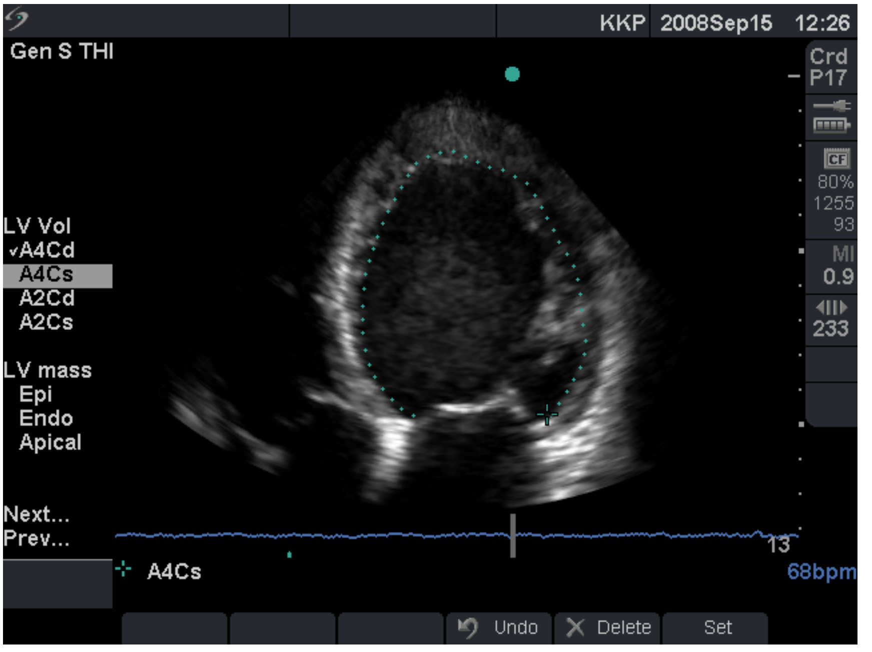


**Fig.8 Tracing of endocardium in end-systole completed**

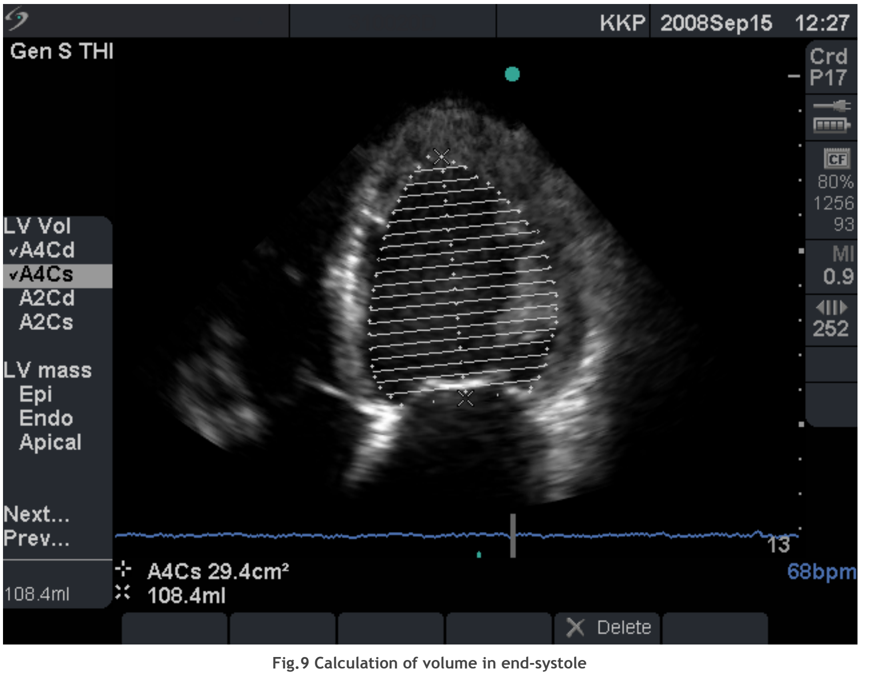


**Fig.9 Calculation of volume in end-systole**

The machine will then calculate the ejection fraction by using the formula:

$$\text{Ejection fraction} = \frac{\text{LVEDV} - \text{LVESV}}{\text{LVEDV}}$$

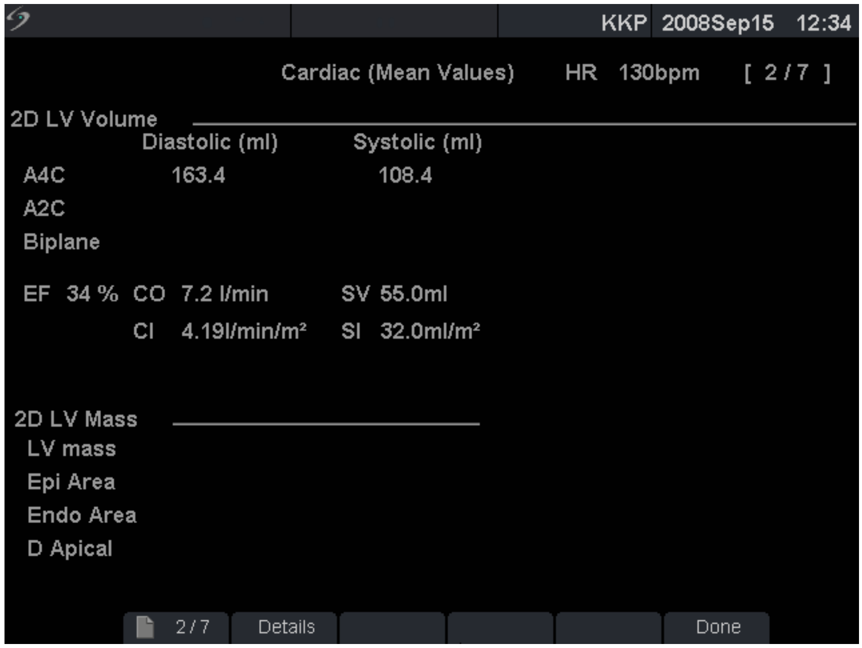


Fig.10 Report of ejection fraction generated

This method is more accurate if this procedure is done in both A4C and A2C views, but this is also more time consuming. Although this is a good method of estimating LV function, it suffers from a few drawbacks.

1.It is sometimes difficult to place the probe at the exact apex to get a full view of the LV cavity. This leads to foreshortening of the LV cavity and underestimation of LV volumes.
2.Because they are parallel to the ultrasound beam, some parts of the endocardial border are not well delineated, causing uncertainty in deciding where to trace the outline of the LV cavity. This results in inter and intra-observer variability of LV Volumes and EF.
3.Another cause of such variability is the choice of frame at end diastole and systole.
4.The LV volumes are calculated using some assumptions made about the shape of the LV cavity, which are not always valid, particularly in a heart with regional LV dysfunction.

However, this remains one of the most widely used methods to calculate LVEF.

## Visual Gestalt

Experienced echocardiographers frequently estimate EF by looking at the overall size and contractility as well as the inward movement and thickening of the various segments of the LV walls without actually taking measurements. Although it is dependent on the experience of the echocardiographer, it has been shown to correlate fairly well with angiographic assessment of the EF.

Parasternal long axis view:

Video 2. Moderate LV dysfunction

Video 3. Severe LV dysfunction

A4C view:

Video 4.  Normal LV function

Video 5. Moderate LV dysfunction

Video 6. Severe LV dysfunction

One method is to distinguish three grades of global LV systolic function based on the subjective radius change of the LV short axis in systole: Normal (³ 30% change in radius), moderate dysfunction (10-30% decrease in radius) and severe dysfunction (< 10% change in radius). A fourth grade, hyperdynamic can be used to describe the very vigorous ventricle that is seen in severe vasodilatation or mitral regurgitation with preserved LV function.
The other is to visually estimate ejection fraction in intervals of 5 to 10% or report as a range e.g. 20 - 30%. It is prone however to intra-observer variation. This assessment may also be unreliable for serial evaluation of LV function and when LV volumes critically influence the timing of cardiac surgery.

## Mitral regurgitaion dP/dT

This is another, traditionally underutilized indicator of LV function. Whilst, EF is affected by afterload, MR dP/dT is afterload independent but is influenced by the preload. This is because this is a measure of contractility of the LV in the isovolumic contraction phase.
This can only be used in patients who have a measurable mitral regurgitation. An A4C view is obtained and the mitral regurgitant jet is identified using color flow imaging. The continuous wave doppler cursor line is placed over the origin of the MR jet and a doppler trace is obtained.
After selecting MR dP/dT on the "calculations" menu, the cursor is used to mark a point on the slope of the MR jet trace at 1m/sec and another at 3m/sec. The time interval in seconds between these two points is noted (Ti). The dP/dT is given by the formula:
$dP/dT = 32/Ti$
Most machines will provide reference lines at 1 and 3 m/sec and will calculate and display dP/dT automatically. The normal dP/dT is>1200mmHg/sec. 800 to 1200mmHg/sec suggests mild LV dysfunction and <800mmHg/sec severe LV contractile dysfunction.

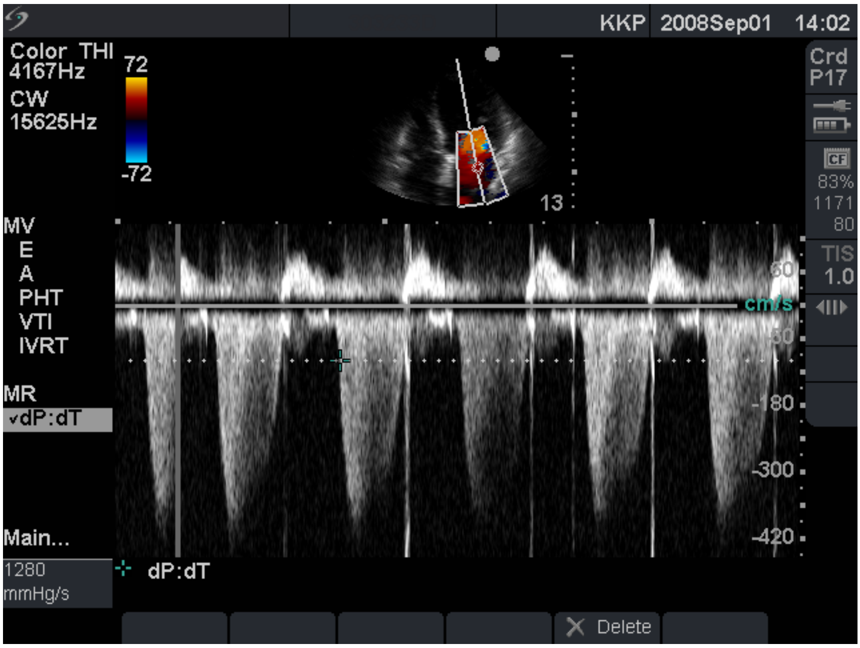


Fig.11 Placement of the first cursor point on the 1m/s line

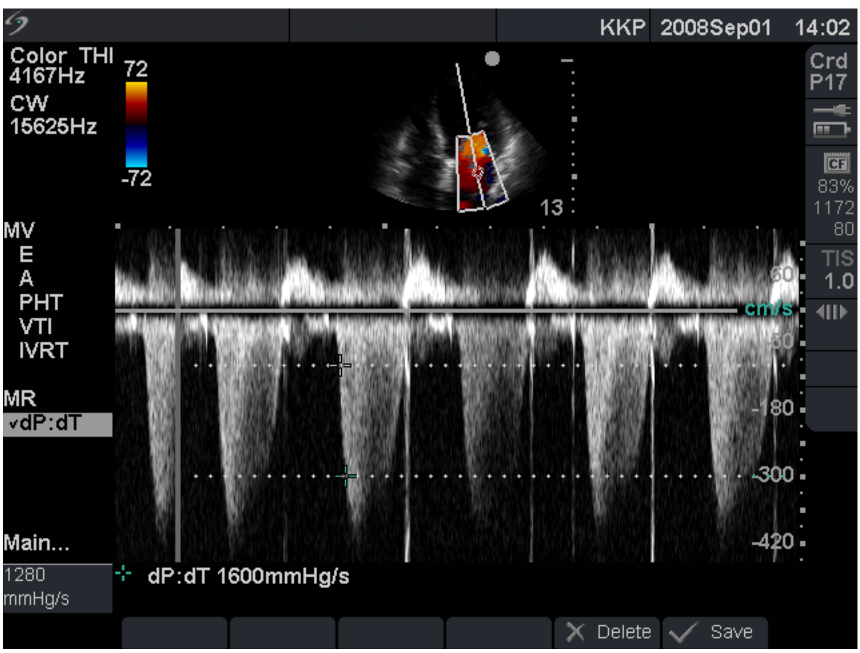


**Fig.12 Placement of the second cursor point on the 3m/s line:** The dP/dT in this case is normal

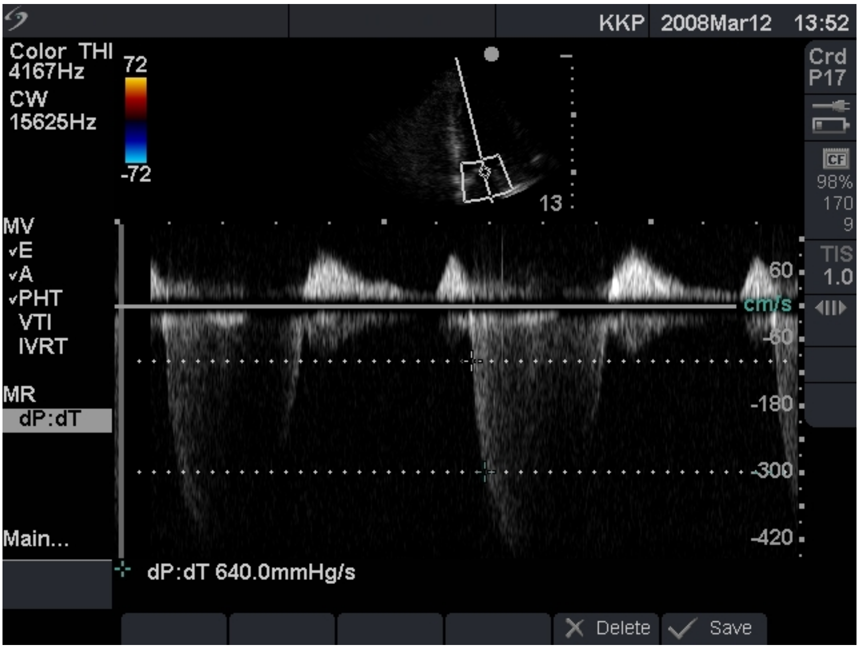


Fig.13 dP/dT in a patient with severe LV dysfunction

Limitations:

This method is only useful in patients with enough MR to obtain a well-defined velocity curve.
LA should be compliant.
Click artifact (caused by valve closure) can obscure the descending limb of the CWD envelope, which makes measurements difficult.
Eccentric MR jets may not reflect true velocity and will result in underestimation of dp/dt unless careful colour Doppler examination of the jet is made to minimize CWD error.
A normal dp/dt maybe present in hypertension and aortic stenosis even with impaired LV function.

## Doppler assessment of cardiac output

Although the above techniques are useful to assess the contractility of the mocardium, what is really of interest to the intensivist is the net result of myocardial stretch and contractility....the stroke volume and cardiac output.
Although cardiac output can be calculated using doppler at any of the valve orifices of the heart, the mitral or tricuspid annuli, the RVOT or the LVOT, the measurement is done most commonly at the LVOT.

First measure the LVOT diameter on a Parasternal Long Axis view. This is done by zooming into the LVOT on the PLAX view using the zoom tool and freezing the image. The images are scrolled backward and forward to capture a frame in which the aortic valve leaflets are wide open. The LVOT diameter is measured adjacent to the points of attachment of the leaflets. The machine will then calculate the cross sectional area (CSA) of the LVOT.

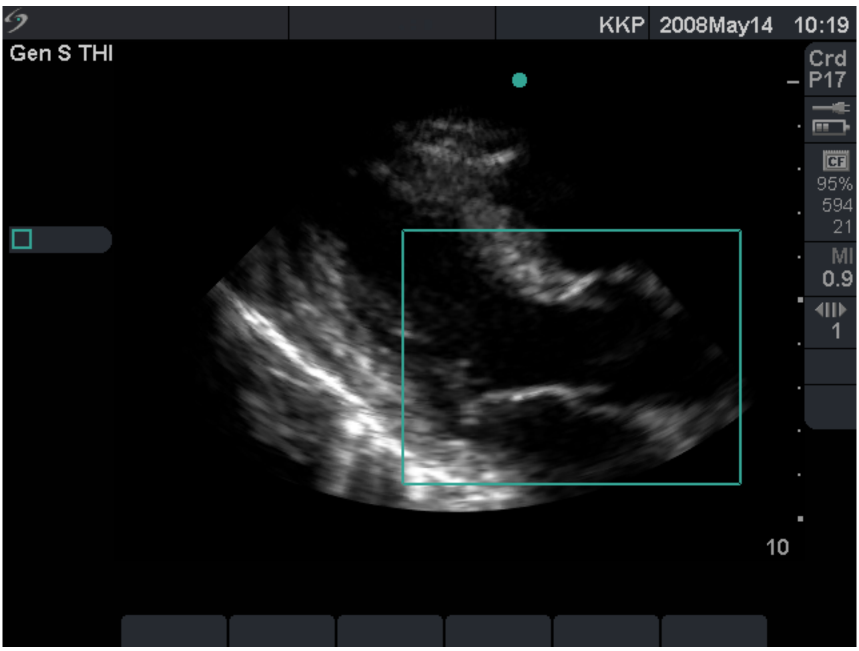

Fig.14 Zooming in on the LVOT in the PLAX view

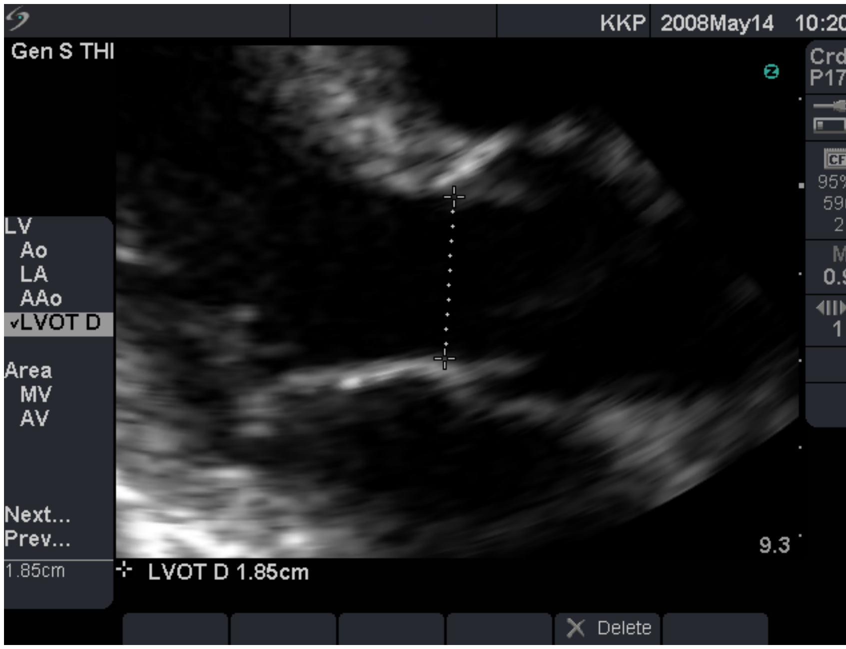


Fig.15 Measuring the LVOT diameter at attachments of the aortic leaflets

Next, obtain an apical 5-chamber view of the heart. As mentioned earlier, the A5C view is obtained from the A4C by slight anterior angulation of the transducer towards the chest wall. The 5th chamber added is the LVOT.

Place the Pulsed Wave Doppler cursor in the LVOT as close to the aortic valve as possible without including it in the sample volume. Acquire the PWD trace. The trace may be considered satisfactory if the closing click of thr aortic valve is visulaised. However, if the opening click is distincly seen before the ejection waveform, it means that the sample volume is too close to the aortic valve and needs to be moved a little away from the valve before another tracing is obtained.

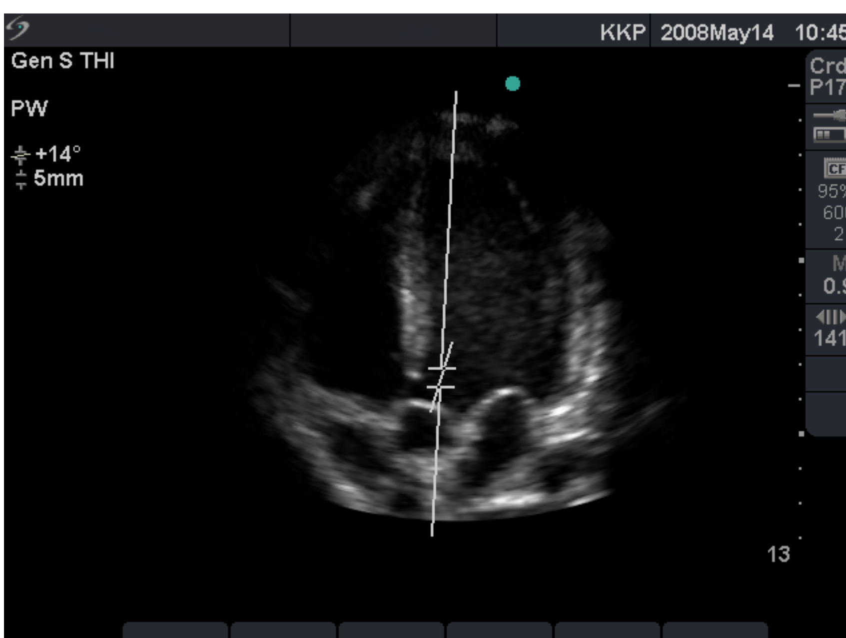


**Fig16. Placement of the PWD cusor in the LVOT in A4C view**

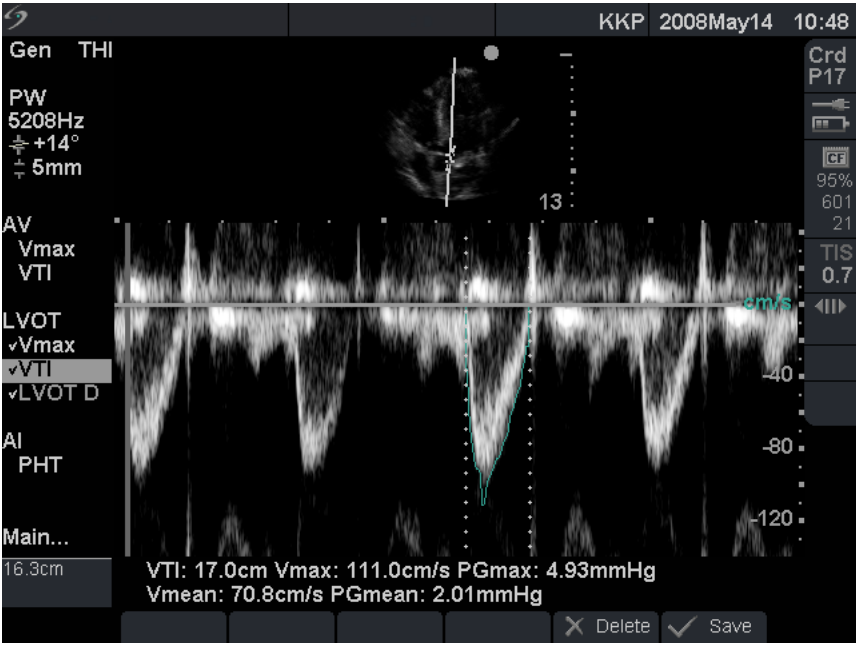


**Fig.17 Tracing the PWD waveform obtained in the LVOT**

Then choose LVOT VTI from the "calculation" menu and manually trace the PWD waveform. Some machines may be able to do this automatically. The machine will calculate the area under the curve and represent it as a Velocity Time Integral (VTI) in cms. Repeat the VTI measurement thrice to reduce sampling bias.
The stroke volume at the LVOT is then obtained by multipying the LVOT VTI with the LVOT CSA.

LVOT VTI X LVOT CSA = Stroke volume

Stroke volume X Heart rate = Cardiac output

Cardiac output = Cardiac index
Body surface area

This is a simple, non-invasive method of measuring cardiac output in ICU patients. It correlates well with measures of cardiac output obtained by thermodilution (r=0.95) with a tendency to underestimate it by about 0.24 l/min.
This measurement can be done repeatedly to see the trend of cardiac output. The LVOT CSA does not need to be calculated for repeat measurements as it does not change.

There are problems however with this technique.
1.Sometimes an adequate A5C view may not be obtainable. In such a case, an Apical 3-chamber view can be tried.
2.The LVOT may not be aligned with the direction of the PWD, leading to underestimation of velocities. In this situation, an apical 3-chamber view may sometimes offer better alignment. The other workaround is to use an angle correction factor. Although this is generally not advocated, it may be acceptable if the angle is kept to less than 20 degrees.
3.When the parasternal long axis view is not obtainable, a LVOT diameter of 2cms for males and 1.75cms for females can be assumed.
4.In patients who are taking deep breaths, the entire cardia may move with respiration making it very difficult to ensure that the PWD sample volume stays at the same place in the LVOT through the respiratory cycle. This can lead to variations in the VTI with respiration, which is not due to hypovolaemia.