LV Mass

As described in Chapter 9, the LV mass is determined from the LV muscle volume and the specific gravity of muscle. LV muscle volume is equal to the total ventricular volume contained within the epicardial boundaries of the ventricle [epicardial volume] minus the chamber volume contained by the endocardial surfaces [endocardial volume] (see Fig. 9.9). LV mass is then calculated by multiplying the LV muscle volume by the specific gravity of muscle (1.04 g/ml).

Both the total epicardial volume and the endocardial volume can be estimated from linear LV measurements as described for the 2D linear estimation of LV mass (see Chapter 9). Therefore, LV mass via M-mode is also estimated from measurements of the LVEDD, IVS and PW (Fig. 10.6):

Equation 10.1

$$LVM = [1.04\,([LVEDD + PW + IVS]^3 - LVEDD^3) \times 0.8] + 0.6$$

where LVM = left ventricular mass (g)
1.04 = specific gravity of muscle (g/mL)
LVEDD = left ventricular end-diastolic dimension (cm)
PW = left ventricular posterior wall thickness (cm)
IVS = interventricular septal thickness (cm)
0.8, 0.6 = 'correction factors'

LV mass has been shown to correlate with body surface area (BSA) and is significantly different between men and women. Therefore, LV mass should be indexed for the BSA by simply dividing the calculated LV mass by the BSA. The normal values and partition values for severity are listed in Table 9.3.

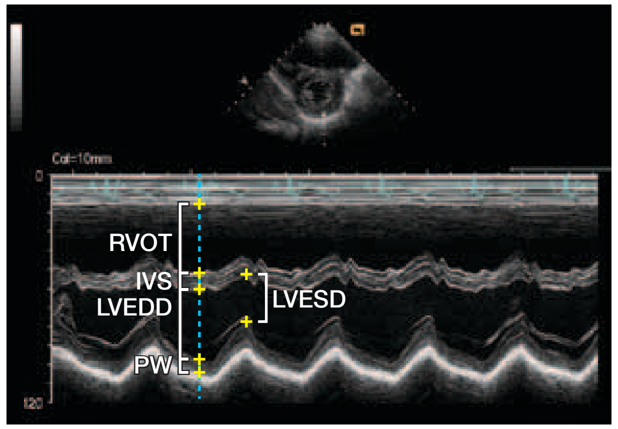

Figure 10.5 This image demonstrates M-mode measurements of the left ventricle (LV) from the parasternal short axis view at the level of the papillary muscles. The M-mode cursor is aligned perpendicular to the interventricular septum (IVS) and posterior wall (PW). End-diastolic measurements are performed at the onset of the QRS complex on the ECG; measurements include the IVS measured from the leading edge to the trailing edge of the IVS, the LV end-diastolic dimension (LVEDD) measured from the trailing edge of the IVS to the leading edge of the PW and the PW thickness measured from leading edge of the PW to the leading edge of the pericardial (epicardial) interface. As IVS motion is abnormal, the LV end-systolic dimension (LVESD) is measured from the leading edge of the most anterior point of the PW back up to the trailing edge of the IVS. Measurement of the right ventricular outflow tract (RVOT) is also shown. The RVOT is measured at the onset of the QRS complex from the trailing edge of the RV anterior wall to the leading edge of the IVS.

i LV mass calculations using M-mode are most accurate when the LV geometry is normal; that is, when the length of the LV is twice its diameter at the papillary muscle level. However, the accuracy of this method is significantly affected by: (1) alterations or distortion in LV shape such as that which may occur with chronic severe right or left ventricular volume overload, (2) regional wall motion abnormalities, or (3) asymmetric septal hypertrophy. In these instances, the 2D estimation of LV mass via the area-length or truncated ellipse methods is considered more accurate as the 2D estimates account for variations in LV geometry.

Method for Calculating LV Mass by M-Mode

Step 1: Measure the following parameters from the LV M-mode trace:
- left ventricular end-diastolic dimension (LVEDD)
- interventricular septal thickness (IVS) at end-diastole
- posterior wall thickness (PW) at end-diastole

Step 2: Calculate the total left ventricular epicardial volume (LVVep):
$LVVep = (LVEDD + IVS + PW)^3$

Step 3: Calculate the left ventricular endocardial or chamber volume (LVVen):
$LVVen = (LVEDD)^3$

Step 4: Determine the left ventricular muscle volume (LVVm):
$LVVm = LVVep - LVVen$ or
$LVVm = (LVEDD + IVS + PW)^3 - (LVEDD)^3$

Step 5: Calculate the left ventricular mass (LVM):
$LVM\ (g) = [(1.04 \times LVVm) \times 0.8] + 0.6$

Step 6: Index the LV mass to the BSA (ILVM):
$ILVM\ (g/m^2) = LVM \div BSA$

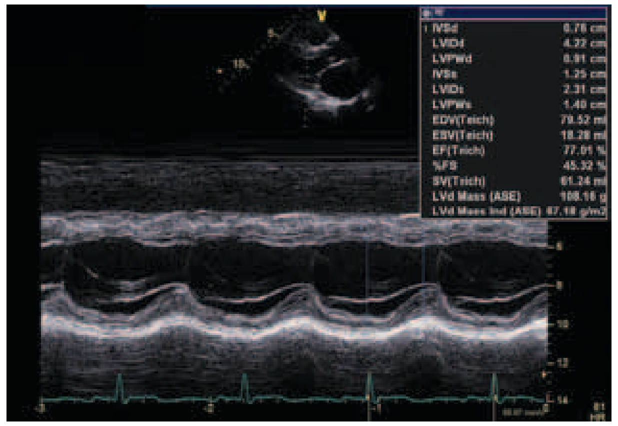

Figure 10.6 For the M-mode method for estimating LV mass, measurements of the interventricular septum (IVSd), the LV cavity (LVIDd) and the posterior wall (LVPWd) are performed at end-diastole and at the blood-tissue interfaces. In this example the LV mass (LVd Mass) is calculated as:

$$\begin{aligned} LVd\ Mass\ (g) &= [1.04\,([LVIDd + LVPWd + IVSd]^3 - LVIDd^3) \times 0.8] + 0.6 \\ &= [1.04\,([4.22 + 0.91 + 0.76]^3 - 4.22^3) \times 0.8] + 0.6 \\ &= 108\ g \end{aligned}$$

The body surface area (BSA) in this patient was 1.61 m², so the indexed LV mass (LVd Mass Ind) is calculated as:

$$\begin{aligned} LVd\ Mass\ Ind\ (g/m^2) &= LVd\ Mass \div BSA \\ &= 108 \div 1.61 \\ &= 67\ g/m^2 \end{aligned}$$

LV Volumes

As described in Chapter 9, LV volumes can be estimated from the LVEDD and the LVESD via the cubed method and the Teichholz equation.

The cubed method is based on the assumption that the LV is shaped as a prolate ellipsoid. Then assuming that: (1) the LV internal diameter (short axis) is equal to one of the minor axes of the ellipse (D_1), (2) both axes are equal ($D_1 = D_2$), and (3) the major axis to minor axis ratio is 2:1 ($L = 2\,D_1$), LV volume can be estimated as:

Equation 10.2

$$LVV = D^3$$

where LVV = left ventricular volume (mL)
D = diameter at end-diastole or end-systole (cm)

The Teichholz equation essentially corrects for changes in the relationship between the major and minor axes as the LV dilates:

Equation 10.3

$$LVV = \left(\frac{7.0}{2.4 + D}\right) \times D^3$$

where LVV = left ventricular volume (mL)
D = diameter at end-diastole or end-systole (cm)

Using the Teichholz equation, the LV end-diastolic volume (LVEDV) and the LV end-systolic volume (LVESV) can be estimated from the LVEDD and the LVESD (see Practical Example 9.1 in Chapter 9).

Global LV Systolic Function

Measurements of global LV systolic function include the: (1) fractional shortening (FS), (2) ejection fraction (EF), and (3) stroke volume (SV), cardiac output (CO) and cardiac index (CI). As described in Chapter 9, these indices can be estimated from the LV end-diastolic and end-systolic diameters, and from the LV end-diastolic and end-systolic volumes. The definitions and equations for each of these indices have been described in Chapter 9 and are summarised below.

Additional M-mode measurements such as the mitral E-point-septal separation (EPSS) and LV systolic time intervals have also been used in the assessment of global LV systolic function. While these parameters are no longer measured routinely, simple 'eyeballing' of these measurements may provide indirect clues to overall LV systolic function.

Fractional Shortening and Ejection Fraction

The fractional shortening (FS) or shortening fraction is the percentage of change in the LV cavity dimension with systole and is calculated as:

Equation 10.4

$$FS = [(LVEDD - LVESD) \div LVEDD] \times 100$$

where FS = fractional shortening (%)
LVEDD = left ventricular end-diastolic dimension (cm)
LVESD = left ventricular end-systolic dimension (cm)

The ejection fraction (EF) is the percentage of the LV diastolic volume that is ejected with systole and is calculated as:

Equation 10.5

$$EF = [(LVEDV - LVESV) \div LVEDV] \times 100$$

where EF = ejection fraction (%)
LVEDV = left ventricular end-diastolic volume (mL)
LVESV = left ventricular end-systolic volume (mL)

The EF can also be calculated via the simplified Quiñones's method:

Equation 10.6

$$EF = \{\%\Delta D^2 + [(1 - \%\Delta D^2)\,(\%\Delta L)]\} \times 100$$

where EF = ejection fraction (%)
$\%D^2 = (LVEDD^2 - LVESD^2) \div LVEDD^2$
$\%\Delta L$ = apical contractility:
- normal apical contraction = 0.15
- hypokinetic apical contraction = 0.05
- akinetic apical contraction = 0
- dyskinetic apical contraction = 0.05
- frankly dyskinetic apical contraction = -0.10

Practical Example 10.1 compares the estimation of the EF via the cubed method, the Teichholz method and the simplified Quiñones's method.

Stroke Volume, Cardiac Output, and Cardiac Index

Stroke volume refers to the amount of blood pumped by the heart on each single beat. The cardiac output is the volume of blood pumped by the heart per minute. Both the cardiac output and stroke volume can be calculated using the end-diastolic and end-systolic volumes which can be derived from the M-Mode measurements of the LV. In order to compare measurements between individuals of different sizes, measurement of the cardiac output is often expressed in terms of the cardiac index which is simply the cardiac output divided by the BSA.

Equation 10.7

$$SV = LVEDV - LVESV$$

Equation 10.8

$$CO = (SV \times HR) \div 1000$$

Equation 10.9

$$CI = CO \div BSA$$

where SV = stroke volume (mL)
CO = cardiac output (L/min)
CI = cardiac index (L/min/m²)
BSA = body surface area (m²)
LVEDV = left ventricular end-diastolic volume (mL)
LVESV = left ventricular end-systolic volume (mL)
HR = heart rate (bpm)
1000 = conversion of mL to litres

The primary limitations of M-mode-derived measurements for LV systolic function parameters includes the geometric assumptions for estimating LV volumes from a linear measurement as well as errors related to measurement technique. The most common error is oblique measurements of the LV due to poor alignment of the M-mode cursor.