particular, the sampling rate for M-mode is around 1000 to 2000 pulses per second, which is far greater than the typical 2D frame rates of between 30 to 100 frames per second. Therefore, M-mode provides valuable information regarding fast moving structures such as cardiac valves and walls so subtle changes in valve or wall motions are also more readily appreciated with M-mode. For example, the high frequency vibrations produced by vegetations, early systolic closure of the aortic valve due to sub-aortic obstruction, and diastolic flutter of the mitral valve and/or interventricular septum due to aortic regurgitation (AR) are readily detected via M-mode (Fig. 3.2). Furthermore, subtle findings such early closure of the mitral valve and premature opening of the aortic valve as seen in acute severe AR may only be appreciated by M-mode.

In addition, as M-mode allows the display of multiple beats on a single trace, changes to chamber dimensions over the respiratory cycle can be easily identified. For example, reciprocal changes in right and left ventricular dimensions during respiration, which occur secondary to enhanced ventricular interdependence as seen in cardiac tamponade, can be easily identified (Fig. 3.3).

M-mode also provides excellent interface definition which may enhance the accuracy of chamber and great vessel measurements. This accuracy is further enhanced by utilising 2D imaging which assists in the precise alignment of the M-mode cursor as well as allowing the identification of anatomical structures transected by the cursor.

Colour Doppler M-mode incorporates both colour flow Doppler imaging (CFI) and M-mode. Therefore, colour Doppler M-mode provides information about time, distance, velocity and direction. This technique can be employed in the assessment of diastolic function of the left ventricle (LV) and can also be used in the timing of cardiac events and for the differentiation of constrictive pericarditis from restrictive cardiomyopathies.

In particular, the graphical display of colour Doppler M-mode allows the rapid and careful evaluation of time-related events which may be missed via 2D imaging and CFI alone. An example where colour Doppler M-mode is particularly helpful is the recognition of diastolic mitral regurgitation (MR) which may be seen in certain conduction abnormalities such as heart blocks as well as with acute, severe AR (Fig. 3.4). Colour Doppler M-mode can also be used in the assessment of AR to measure the AR jet height (Fig. 3.5) and/or to determine the presence of pan-diastolic flow reversal in the descending and/or abdominal aorta (Fig. 3.6).

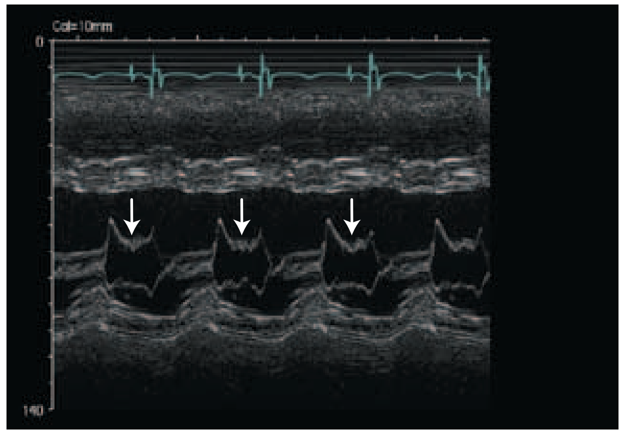

Figure 3.2 This M-mode trace displays diastolic flutter of the anterior mitral leaflet due to the aortic regurgitant jet hitting this leaflet (*arrows*). Observe the fine, high frequency vibrations displayed on this leaflet during diastole. The presence of diastolic flutter of the mitral valve is often the first clue to the presence of aortic regurgitation.

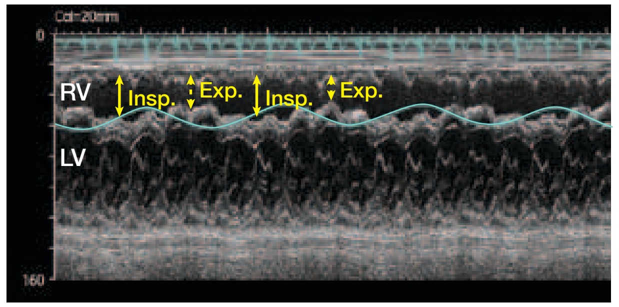

Figure 3.3 This M-mode trace displays enhanced ventricular interaction between the right and left ventricles over the respiratory cycle in a patient with cardiac tamponade. Observe that with inspiration (Insp.) the interventricular septum shifts towards the left ventricle (LV). This results in an increase in the right ventricular (RV) cavity size and a decrease in the LV cavity size. On expiration (Exp.) the opposite occurs; the IVS shifts towards the RV so the RV size decreases and the LV cavity size increases.

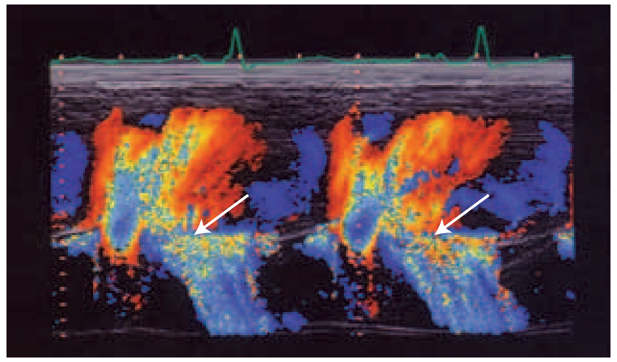

Figure 3.4 This colour Doppler M-mode trace displays diastolic mitral regurgitation [MR] (*arrows*) in a patient with first degree heart block. This trace was acquired from the apical four chamber view with the M-mode cursor transecting the mitral valve leaflets which are depicted by the white, linear echo in the centre of the M-mode trace. Observe the timing of the colour Doppler MR jet (the mosaic jet under the mitral leaflets) with the ECG; MR commences in mid-diastole, well before the QRS complex of the ECG. M-mode is useful in this instance as the precise timing of regurgitation may not be clear from the real-time colour flow Doppler image alone.

Disadvantages of M-Mode

The predominant limitation of M-mode is its lack of direct spatial information and its one dimensional nature such that only the structure(s) transected by the M-mode cursor are displayed.

Acquisition of data from a single dimension also poses significant limitations in providing information about a three-dimensional structure. When the LV is uniformly shaped with a long (major) axis to short (minor) axis ratio of 2:1, the M-mode-derived ejection fraction is relatively reliable. However, in most pathological states such as coronary artery disease, the long axis to short axis ratio is altered. In this instance, the M-mode-derived ejection fraction is often misleading. Furthermore, accuracy of M-mode measurements is also dependent on the recognition of clearly defined borders, which are often ambiguous.

In addition, many of the “older” M-mode measurements for the indirect assessment of LV performance, such as systolic time intervals, are affected by numerous variables and are, therefore, unreliable. Likewise, many of the M-mode “signs” of cardiac diseases such as those described for pulmonary hypertension, vegetations and aortic valve disease, are not specific or sensitive and have been superseded by more reliable and accurate Doppler techniques.

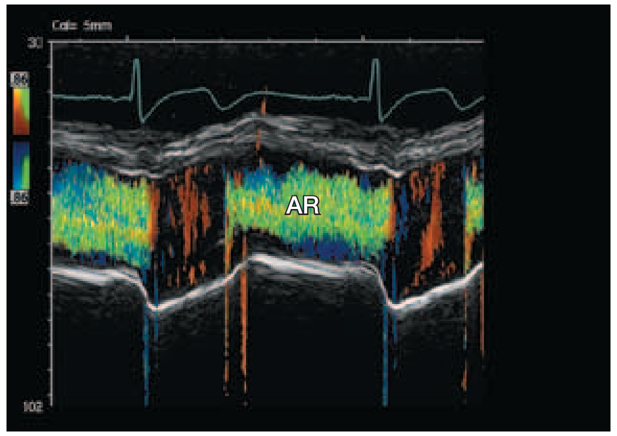

Figure 3.5 This colour Doppler M-mode trace displays aortic regurgitation (AR). This trace was acquired from the parasternal long axis of the left ventricle with the M-mode cursor transecting the left ventricular outflow tract (LVOT). Observe the mosaic AR jet within the LVOT during diastole. Measurement of the AR jet height and the LVOT height can be used in the semiquantification of the AR severity.

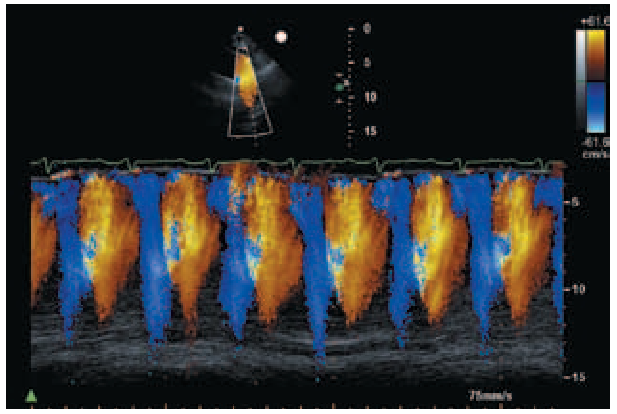

Figure 3.6 This colour Doppler M-mode trace displays pan-diastolic flow reversal in the descending aorta. This trace was acquired from the suprasternal long axis view with the M-mode cursor transecting through the descending aorta. Observe that blue flow (flow away from the transducer) occurs during systole (normal flow). The red flow within the aortic lumen (flow towards the transducer) commences at the beginning of diastole and continues throughout diastole (abnormal pan-diastolic flow reversal). Pan-diastolic flow reversal is an indirect sign of significant aortic regurgitation. M-mode is useful in this instance as the duration of flow may not be evident on the real-time colour flow Doppler image alone.

Optimisation of M-mode Traces

Many instrument controls used to optimise 2D images can also be manipulated to optimise M-mode traces. In particular, the gain and TGC should be adjusted to ensure that the blood pool appears echo free and that structures of similar acoustic properties are displayed at similar echo amplitudes. B-colour maps can also be applied to the M-mode trace in an attempt to enhance subtle soft tissue differences (Fig. 3.7).

Alignment of the M-mode cursor is of paramount importance when using M-mode for measurements. The M-mode cursor should be aligned perpendicular to the structure being measured. The sweep speed, which refers to the horizontal display rate of the M-mode trace, is adjusted according to information required. For example, sweep speeds of between 60-75 mm/s are adequate for linear measurements while faster sweep speeds of between 100-200 mm/s should be employed for any measurements relating to time. Slower sweep speeds between 25-50 mm/s are useful for observing respiratory variation in right and left ventricular dimensions as seen in cardiac tamponade and constrictive pericarditis.

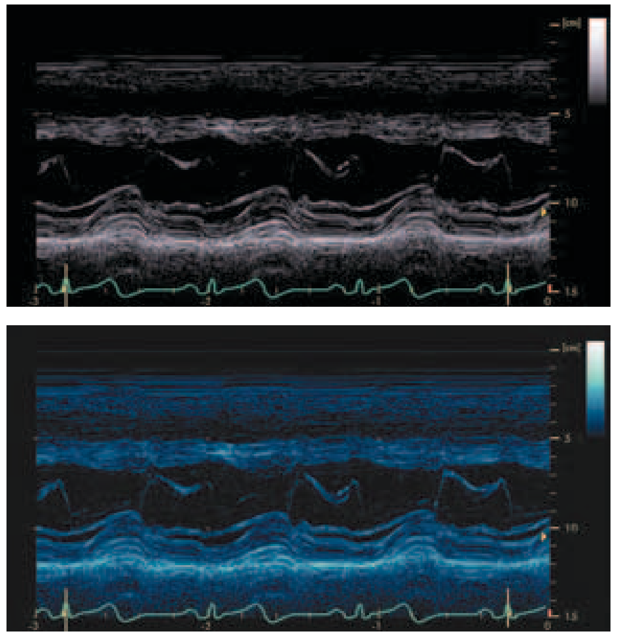

Figure 3.7 These two M-mode traces recorded through the left ventricle display a greyscale map (*top*) and a B-colour map (*bottom*). While the information is the same, the B-colour map appears to improve the contrast resolution.

Further Reading

(listed in alphabetical order):

Edelman SK. Understanding Ultrasound Physics. 4th Edition. E.S.P. Ultrasound, 2012.

Gill, R. The Physics and Technology of Diagnostic Ultrasound: A Practitioner’s Guide. High Frequency Publishing, 2012.

Kremkau FW. Sonography Principles and Instruments. 8th Edition, Saunders Elsevier, 2010.