Abstract—Background: M-mode or “motion” mode is a form of ultrasound imaging that is of high clinical utility in the emergency department. It can be used in a variety of situations to evaluate motion and timing, and can document tissue movement in a still image when the recording of a video clip is not feasible. Objectives: In this article we describe several straightforward and easily performed applications for the emergency physician to incorporate M-mode into his or her practice, including the evaluation for: 1) pneumothorax, 2) left ventricular systolic function, 3) cardiac tamponade, and 4) hypertrophic cardiomyopathy. Discussion: The emergency physician and other point-of-care ultrasound providers can use this versatile function in the evaluation of patients for a number of critical cardiopulmonary diagnoses. Conclusion: A great deal of important information may be obtained with M-mode imaging through views and measurements that are relatively easy to obtain. © 2015 Elsevier Inc.

Keywords—M-mode; ultrasound; pneumothorax; E-point septal separation; cardiac tamponade; hypertrophic cardiomyopathy

INTRODUCTION

M-mode or “motion” mode is a form of ultrasound imaging that is of high clinical utility in the emergency department (ED). It can be used in a variety of situations to evaluate motion or timing, and historically has been used for a variety of applications due to its superior temporal resolution. In the ED setting, bedside ultrasound machines are generally selected for their size and portability and may have varying capabilities and quality in terms of spectral, color, or power Doppler. Furthermore, Doppler imaging requires a high level of expertise and can be technically challenging in that the angle of insonation can cause widely varying results. M-mode can provide unique and specific information, is a relatively simple mode to understand and use, and it can assist in a number of important ED diagnoses.

M-mode is a one-dimensional (“icepick”) analysis of the tissue being evaluated. In an M-mode evaluation, echoes from underneath the icepick are displayed across the screen from left to right, creating a distance/time graph with time on the horizontal axis and tissue depth on the vertical axis. From this graph, important information can be assessed, such as the movement of the pleura and the cardiac valves, as well as the timing of the cardiac cycle. The latter is particularly useful because electrocardiographic leads are rarely available in the ED setting. Because it only requires the interpretation of returning echoes from a narrow field, M-mode allows a higher frame rate and thus, better temporal resolution than B-mode ultrasound. Using M-mode, information about tissue movement can also be documented as a still image when the recording of a video clip is not feasible, such
as when there are limitations with equipment or memory space. In this article we describe several straightforward and easily performed applications for the emergency physician to incorporate M-mode into his or her practice, including the evaluation for: 1) pneumothorax, 2) left ventricular systolic function, 3) cardiac tamponade, and 4) hypertrophic cardiomyopathy.

DISCUSSION

Pneumothorax

Ultrasound has been shown to be significantly more sensitive than anterior-posterior radiography and equally sensitive to computed tomography for diagnosing pneumothorax (1–10). The use of M-mode allows for easy visualization of regular lung movement.

In the absence of pleural disease and scarring, air in the pleural cavity rises to the anterior chest wall in a supine patient, making the anterior thorax the most sensitive location for pneumothorax evaluation. Using a high-frequency linear or low-frequency curvilinear or phased-array transducer, the probe is placed in the intercostal spaces with the indicator pointing cephalad in the sagittal plane. Ribs will appear as hyperechoic structures with posterior shadowing, whereas the interface of the parietal and visceral pleura will appear as a single horizontal hyperechoic line between the ribs. When the two pleural layers are in contact, the visceral pleura slides along the parietal pleura during respiration. This contact, and therefore the movement and sliding motion of the pleura, is lost when a pneumothorax is present. Evaluation of the pleural line for regular movement may be complicated by several factors, such as motion transmitted from cardiac activity (lung pulse) or chest compressions.

M-mode can be used to demonstrate regular lung motion (Figure 1). When the two pleural layers are in contact, the image demonstrates a pattern known as the “seashore sign.” The chest wall tissues superficial to the pleural line remain fairly still over time, like calm water. Deep to the pleural line, a granular or “sandy” appearance is noted from the motion of the lung tissue as it moves beneath the M-mode icepick (Figure 2) (11).

When air is present between the pleural layers, as in a pneumothorax, pleural sliding is absent. There is no visible lung movement and the M-mode image will demonstrate the same linear pattern superficial and deep to the pleural line. This is known as the “barcode” sign or, alternatively, the “stratosphere” sign due to its similar appearance to aircraft contrails (Figure 3) (11).

Importantly, the absence of regular lung movement does not always indicate the presence of a pneumothorax, as conditions such as massive atelectasis, right main stem intubation, acute respiratory distress syndrome, and pleural adhesions or blebs can also cause a motionless pleural line (12,13).

Because ultrasound can assess only what is directly underneath the probe, the more intercostal spaces that are visualized, the more sensitive the examination. At a minimum, the second to fourth intercostal spaces in the mid-clavicular line should be evaluated bilaterally throughout an entire respiratory cycle.

Because it is able to document motion in a still image, an M-mode thoracic evaluation can be used to document regular lung motion when video clip archiving is unavailable. For the purposes of image archiving, documentation, and quality assurance, a single still image of
a “seashore” sign in M-mode is as adequate as a video clip of lung sliding to confirm regular lung movement.

**E-Point Septal Separation**

It is essential for the emergency physician to be able to evaluate left ventricular (LV) systolic function rapidly and reliably, particularly in critically ill patients whose disease process may be undifferentiated and whose hemodynamic status is unclear (14,15). An important and highly practical application of M-mode is in the assessment of LV systolic function via mitral valve E-point septal separation (EPSS).

Although the simplest and most widely used method for emergency physicians to estimate LV systolic function is gross visual assessment, this strategy has several important pitfalls. Such assessment is subjective, it is highly operator-dependent, and it requires the sonographer to obtain at least two views of the heart to be able to evaluate the three-dimensional movement using two-dimensional imaging. It can also be difficult to estimate the LV systolic function in the presence of regional or asymmetric wall motion abnormalities (15,16).

EPSS is a relatively simple measurement and, unlike gross visual estimation, it requires only a single view of the heart. To obtain the EPSS measurement, the sonographer should obtain a parasternal long axis (PLAX) view of the heart with a phased-array low-frequency transducer (17). The M-mode icepick should be placed over the apical tip of the anterior leaflet of the mitral valve (Figure 4). The resultant M-mode tracing will demonstrate the movement of the leaflet toward the interventricular septum. Two characteristic waves created by the mitral valve leaflet will be visualized during each diastole, the larger first wave representing early filling (the E-wave) and the smaller second wave representing the atrial kick (the A-wave). This characteristic pattern is created as the mitral valve opens in early diastole, then starts to drift closed before it is pushed open again by blood from the atrial contraction. The E-point is the tallest point of the E-wave, and the EPSS is measured as the distance in millimeters between the E-point and the interventricular septum (15).

The opening of the anterior leaflet of the mitral valve toward the interventricular septum in diastole requires a pressure difference between the left atrium (LA) and left ventricle. When a patient has poor LV systolic function, there is still a full left ventricle at the end of systole. The pressure gradient between the LA and the left ventricle is not as great and the mitral leaflets will not snap open as vigorously. The EPSS measurement should be 6 mm or less in patients with normal LV systolic function; 6–12 mm suggests moderately depressed LV systolic function and > 12 mm signifies severely decreased LV systolic function (Figures 5, 6) (18).

Like any assessment of LV systolic function, the EPSS measurement has limitations. It may not be reliable in patients with valvular abnormalities such as mitral stenosis or aortic regurgitation, severe LV or septal hypertrophy, regional wall abnormalities, or severe LV dilatation. In addition, it may be inaccurate if a true PLAX view is not obtained, or if the view obtained necessitates placement of the M-mode icepick at an angle oblique to the interventricular septum (18).

**Cardiac Tamponade**

When a pericardial effusion is identified, there are several sonographic findings suggestive of tamponade, including right ventricular (RV) collapse during diastole and right atrial collapse during late diastole or early systole (19,20). M-mode can be particularly useful in detecting these often-subtle ultrasound findings.
RV diastolic collapse is highly specific, and is the most recognized sonographic sign of tamponade. Normally, the ventricles expand during diastole as they fill with blood; however, the RV free wall can collapse if intrapericardial pressure exceeds diastolic pressure within the chamber. The cardiac images are relatively easy to acquire, but the phases of the cardiac cycle (systole vs. diastole) can be difficult to discern when viewed dynamically, especially in the setting of tachycardia. Normal RV contraction during systole may easily be mistaken for pathologic diastolic collapse in this setting. Continuous electrocardiographic tracings on the ultrasound screen can be used to discern the phases of the cardiac cycle; however, this is rarely available in the ED setting (21).

M-mode makes use of mitral valve opening and closing to discern the phases of the cardiac cycle. It can be easily performed in the PLAX, or subxiphoid cardiac views. With the M-mode icepick placed so that it transects the RV free wall as well as the mitral valve leaflets, the movement of these structures can be compared simultaneously (Figure 7). If the RV free wall moves toward the interventricular septum while the mitral valve is open (diastole), then RV diastolic collapse can be identified (Figure 8).

Limitations to this technique are that it may not be reliable in patients with mitral valve abnormalities resulting in abnormal leaflet movement. In addition, patients with severe hypovolemia may exhibit diastolic chamber collapse even in the absence of elevated intrapericardial pressure, whereas elevated right heart pressures (e.g., from pulmonary hypertension or pulmonary embolism) may prevent diastolic collapse of the right ventricle. Thus, the sonographic findings must always be considered in the context of the clinical scenario (21).
Hypertrophic Cardiomyopathy

Hypertrophic cardiomyopathy (HCM) is another important and time-sensitive diagnosis with findings that can be identified with M-mode ultrasound. Patients with HCM may present to the ED with symptoms such as dyspnea, angina, or exertional syncope (21).

The first sonographic criteria for the diagnosis of HCM included B-mode and M-mode findings (22). B-mode echocardiographic assessment includes evaluation for asymmetrical interventricular septal hypertrophy (>15 mm), a ratio of interventricular septum to posterior wall thickness >1.3, and a small LV cavity. LV outflow tract obstruction from a thickened interventricular septum results in two easily identifiable M-mode findings in the PLAX view: systolic anterior motion of the mitral valve (SAM), and premature closure of the aortic valve (23–25).

SAM may be due to increased velocity of blood as it passes through a narrower aortic outflow tract or due to drag forces (23,26). To assess for SAM, the M-mode icepick is placed over the anterior leaflet of the mitral valve, similar to the location for EPSS measurement. In this case, however, the systolic phase of the tracing is examined (Figure 9). As opposed to its normal coaptation with the posterior leaflet, the anterior mitral valve leaflet will demonstrate movement toward the interventricular septum as outflow tract obstruction occurs (Figure 10). The severity of SAM can be estimated as mild, moderate, or severe based on the duration of outflow obstruction (27).

The second M-mode assessment for HCM is for aortic valve preclosure. The aortic valve usually remains open for the duration of systole; however, in HCM, outflow tract obstruction causes decreased pressure across the aortic valve, leading to early closure. In the PLAX view, the M-mode icepick is placed over the aortic valve leaflets (Figure 11) and the tracing will show the aortic valve leaflets closing earlier than normal (28). This will be depicted by early movement toward coaptation of the aortic valve leaflets prior to full descent of the RV free wall at end-systole (Figure 12). In suspected cases, the patient can be asked to perform maneuvers to provoke outflow tract obstruction, such as Valsalva, while the M-mode evaluation is repeated.

An important limitation of this technique is that SAM and aortic valve preclosure are each only 61% sensitive when compared to clinical and angiographic diagnosis of HCM (29). SAM has also been found in patients with HCM, but without evidence of obstruction (30). In addition, SAM has also been noted in patients with a number of other conditions, including left ventricular aneurysm, pericardial effusion, and atrial septal defect (31–33). Aortic valve preclosure has also been noted in patients with mitral regurgitation and ventricular septal defect (34). For these reasons, M-mode echocardiographic findings should be used in conjunction with B-mode diagnostic criteria as well as the clinical scenario.
Although a variety of Doppler imaging techniques have been proposed as having increased sensitivity for the diagnosis of HCM, despite their limitations, these two M-mode applications are easily performed by the emergency physician and can quickly provide valuable diagnostic information.

CONCLUSION

The use of M-mode in the ED may assist in diagnoses that would otherwise remain uncertain with traditional B-mode ultrasonography, yet it does not require the specific technology and expertise of Doppler imaging or the equipment necessary for simultaneous electrocardiographic monitoring. In addition, it can provide physiologic information that cannot be obtained any other way. M-mode can be used as an adjunct in the ultrasound diagnosis of pneumothorax to evaluate for regular lung movement. In patients presenting with undifferentiated dyspnea, identification of an abnormal EPSS can suggest left ventricular systolic dysfunction and guide appropriate management such as diuresis and administration of inotropes. In the evaluation of a patient with a pericardial effusion, M-mode may be an indicator of impending cardiac tamponade, allowing the provider time to intervene prior to hemodynamic deterioration. Finally, in cases of suspected hypertrophic cardiomyopathy, M-mode evaluation for SAM or premature closure of the aortic valve may quickly direct the provider to seek timely cardiology consultation.

In conclusion, a great deal of important information may be obtained with M-mode imaging through views and measurements that are relatively easy to obtain. The emergency physician and other point-of-care ultrasound providers can use this versatile function to supplement B-mode ultrasonography in the evaluation of patients for a number of critical cardiopulmonary diagnoses.

REFERENCES


