Echocardiography in Detecting Mechanical Complications in Acute Coronary Syndrome

Paul Harnish, MD, Zeid Nesheiwat, DO, Shazil Mahmood, MD, Ronak Soni, MD, and Ehab Eltahawy, MD, MPH, FACC, *Toledo, Ohio*

INTRODUCTION

Acute coronary syndrome (ACS) is well known for both its breadth of clinical presentations and its complications. Rapid echocardiographic assessment in ACS has assumed a distinguished role in detecting early and late mechanical complications, assessing function, and guiding emergent clinical decision-making. Because of its noninvasive nature, broad accessibility, and rapid acquisition, echocardiography holds particular promise for implementation in a standardized algorithm for initial evaluation.

CASE PRESENTATIONS

Case 1

An 85-year-old woman with a medical history of coronary artery disease who had undergone drug-eluting stent placement presented to the emergency department after experiencing acute-onset chest pain and dyspnea. The patient arrived diaphoretic and hemodynamically unstable, with hypotension and tachycardia. Physical examination revealed jugular venous distension, tachycardia, and cool, clammy extremities. Initial electrocardiography demonstrated ST-segment elevation in leads II, III, and aVF with anterolateral T-wave inversions.

Given the patient's clinical presentation and electrocardiographic changes, emergent cardiac catheterization was performed. Coronary angiography demonstrated a 90% calcific stenosis of the left main coronary artery extending distally to the ostium of the left anterior descending coronary artery and left circumflex coronary artery. The left anterior descending coronary artery showed a 70% to 80% midvessel stenosis with Thrombolysis in Myocardial Infarction grade 2 flow distally. The right coronary artery was the dominant vessel, with 60% stenosis proximally and 70% stenosis distally and probable distal occlusion of the posterolateral branches. There was a patent stent in the midportion of the vessel with mild in-stent stenosis.

Although severe three-vessel disease was demonstrated, it was thought that the coronary anatomy could not fully explain the patient's hemodynamic instability. Therefore, urgent transthoracic echocardiography was performed with the patient on the catheterization laboratory table. This revealed a large pericardial effusion with significant thrombus burden suggestive of acute free wall rupture (FWR; Figures 1 and 2, Videos 1 and 2).

An intra-aortic balloon pump was placed and inotropic therapy was initiated for concurrent cardiogenic shock. Cardiothoracic surgery was consulted. The patient refused surgical intervention. At her request, her code status was changed to "do not resuscitate—comfort care arrest". She was transferred to the cardiac care unit, where she continued to deteriorate and died shortly thereafter.

FWR is a known and feared complication of myocardial infarction (MI) that typically occurs within the first 5 days following MI in about half of cases and within 2 weeks in more than 90% of cases.[1] It results from extensive myocardial tissue necrosis, structural compromise, and eventual perforation of the free wall, rapid accumulation of blood within the pericardium, and ultimately tamponade physiology. In most cases, the left anterior descending artery is involved, but the phenomenon can occur with any coronary vessel. Survival depends primarily upon the rapid recognition of wall rupture and immediate treatment, including advanced circulatory support and surgical consultation.

Echocardiography can quickly identify mechanical complications of MI in hemodynamically unstable patients. Although many cases of FWR result in death, some cases may be subacute, allowing a small window for treatment. Rapid echocardiographic assessment in a patient with cardiogenic shock can accurately quantify the severity of dysfunction and catch early mechanical complications, thus allowing more timely intervention.

In this patient's case, the presence of pericardial fluid and thrombus confirmed acute or subacute FWR. Percutaneous revascularization would likely not have changed the outcome. In essence, the earlier the ultrasound assessment is performed in the setting of a mechanical complication, the greater the window of opportunity to undertake a clinically significant intervention.

Case 2

A 59-year-old man with a medical history of type 2 diabetes mellitus presented with persistent chest pain starting 1 week prior, as well as hemodynamic instability with a heart rate of 127 beats/min and systemic blood pressure of 51/29 mm Hg. Initial electrocardiography revealed ST-segment elevation as well as large q waves in the anterolateral leads. The patient was emergently intubated and started on vasopressors shortly after arrival.

Immediate coronary angiography revealed complete thrombotic occlusion of the left anterior descending coronary artery. Hemodynamics on right heart catheterization demonstrated severely elevated pulmonary artery oxygen saturation of 95% consistent with a significant left-to-right shunt. An intra-aortic balloon pump and a Swan-Ganz catheter were inserted for ongoing monitoring and circulatory support.

Urgent echocardiography demonstrated severely reduced right ventricular systolic function with a large distal ventricular septal defect

From the Division of Cardiovascular Disease (P.H., R.S., E.E.); the Department of Internal Medicine (Z.N.), University of Toledo Medical Center, Toledo, Ohio; Department of Medicine, Henry Ford Hospital, (S.M.) Detroit, Michigan.

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VIDEO HIGHLIGHTS

Video 1: Baseline echocardiography in the subcostal view showing no pericardial effusion or thrombus from 1 year prior.
Video 2: Echocardiography in the subcostal view showing FWR with echogenic mass consistent with thrombus.
Video 3: Echocardiography in the apical four-chamber view of a VSD.
Video 4: Echocardiography in the subcostal view of a VSD with color Doppler.
Video 5: Three-dimensional echocardiography with color Doppler of a VSD.
Video 6: Echocardiography in the apical four-chamber view after VSD closure with an occluder.
Video 7: Echocardiography in the short-axis view after VSD closure with an occluder.

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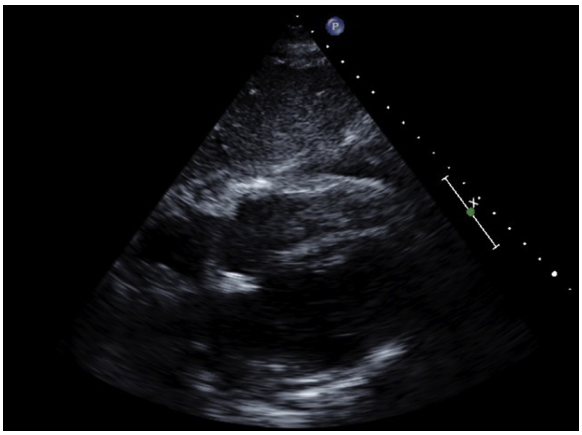

Figure 1 Baseline subcostal view from a prior year demonstrating no evidence of significant effusion or mass.

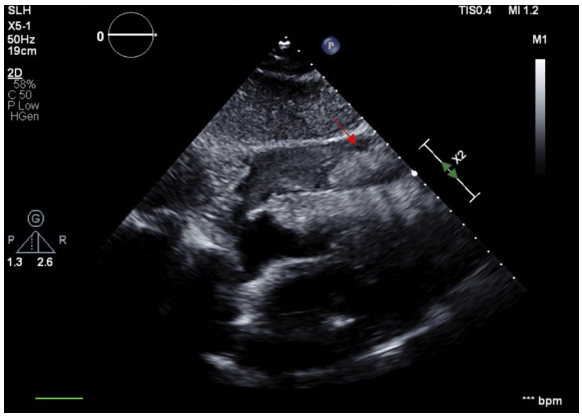

Figure 2 Subcostal four-chamber view showing an echogenic mass within the pericardial space anterior to the right ventricle (*arrow*); the appearance of this mass is consistent with thrombus.

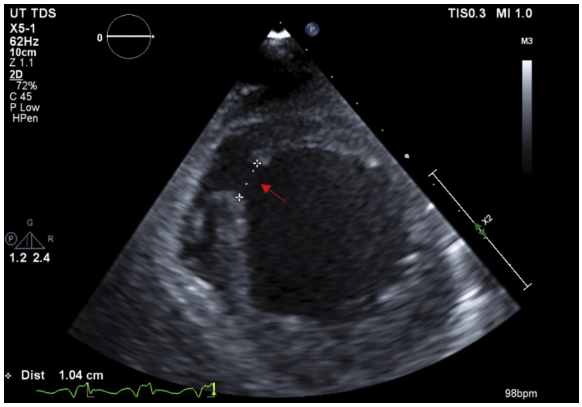

Figure 3 Parasternal short-axis view showing a large VSD. *Arrow* is showing a ventricular septal defect (VSD).

(VSD) with significant left-to-right shunting (Figure 3, Videos 3-5). Cardiothoracic surgery was consulted for consideration of closure, but the patient was deemed too unstable for open correction. The following day, the patient underwent percutaneous VSD closure using an Amplatzer septal occluder (Figure 4, Videos 6 and 7). Initially, a VSD occluder was attempted, but because of the large size of the VSD, an atrial septal defect occluder was used. Transesophageal echocardiography was performed and confirmed the closure device to be in a stable position, with significant improvement of the left-to-right shunt.

Unfortunately, the patient's stay was further complicated by a number of comorbid developments, including both ongoing bleeding as well as pneumonia. He continued to deteriorate clinically, and ultimately, after extensive discussion with the involved family, further care was withdrawn. The patient was extubated and died shortly thereafter.

Development of a VSD because of myocardial ischemia requires extensive tissue necrosis and perforation, with open communication between the left and right ventricles. It leads to massive left-to-right shunting of oxygenated blood, a profound drop in left ventricular (LV) afterload, reduced cardiac output to the aorta, and resultant cardiogenic shock. As with FWR as previously discussed, the use of echocardiography in a hemodynamically unstable patient can quickly identify this mechanical complication. In addition, a VSD is clinically difficult to distinguish from severe mitral regurgitation by physical examination, which is a much more common confounder of ischemia. Transthoracic echocardiography can identify the size and location of the rupture, providing rapid confirmation of the diagnosis as well as an assessment of the hemodynamic severity of the lesion. Again, the window for treatment is typically small, and rapid surgical or percutaneous closure is indicated if feasible. Early recognition of the complication by right heart hemodynamics as well as rapid ultrasound has the capacity to improve outcomes in these rare cases.

DISCUSSION

Advantages

The rapid use of echocardiography as a clinical decision-making tool in the setting of unstable ACS carries a number of potential advantages. These include early detection of regional wall motion abnormalities (WMAs) confirming a likely ischemic etiology and potentially for

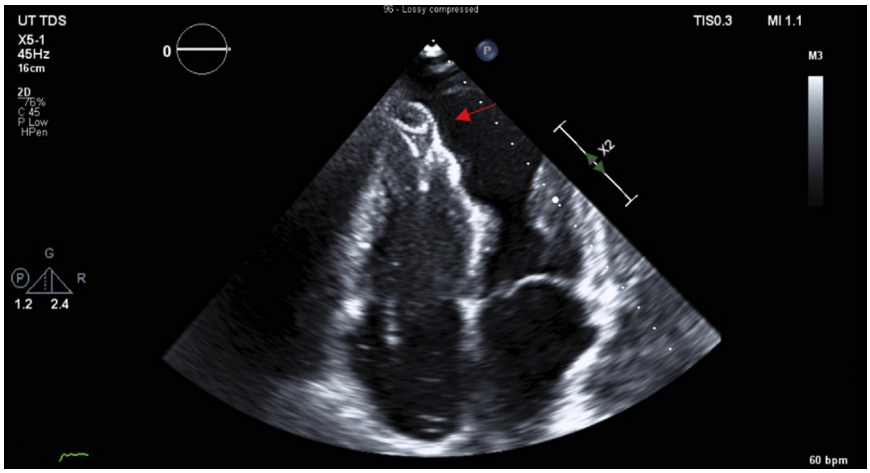

Figure 4 Apical four-chamber view showing closure of the VSD using an atrial septal defect occluder (*arrow*).

anatomic localization, estimation of LV function, early recognition of mechanical complications, and, perhaps most important, recognition of alternate etiologies with the potential to decrease unnecessary invasive procedures. We discuss each of these components in further detail.

Diagnostic Utility and Clarification. Echocardiography stands as a fairly rapid, noninvasive, and accurate test to detect early myocardial dysfunction.[2] Given that WMAs may manifest before the development of electrocardiographic changes or troponin elevation, it also has the potential for ruling in ischemia early in a patient's clinical course.[3] Perhaps one of the best uses of echocardiography is in the setting of mixed or atypical presentations of chest discomfort. In this context, it plays a crucial rule in ruling out other known culprits, such as tamponade, endocarditis, aortic dissection, severe valvular disease, hypertrophic cardiomyopathy, acute pulmonary embolism, and pericarditis, for which immediate cardiac catheterization would commit the patient to additional risks without the potential for benefit.

The focused cardiac ultrasound (FoCUS) examination has been described in the literature as an adjunct to physical examination to emergently recognize structural causes of cardiac dysfunction. The examination focuses on systolic function, chamber sizes, valvular abnormalities, the presence of pericardial effusion or tamponade, and the likelihood of volume responsiveness.[4] The use of echocardiography in this application can both guide and expedite treatment. For patients with cardiogenic shock, the FoCUS examination also serves as a critical guide ahead of mechanical circulatory support.

One recent study investigating the use of echocardiography in the evaluation of patients with ACS in the prehospital setting demonstrated sensitivity and specificity of prehospital transthoracic echocardiography for non–ST-segment elevation MI of 90.9% and 100%, respectively.[5] This demonstrates clear potential for the use of echocardiography as a standardized initial evaluation strategy.

In addition, the FoCUS examination can detect contraindications to certain cardiac mechanical support devices that may have resulted from ACS. Examples include LV Impella placement, which carries a strict contraindication in patients with LV thrombus; intra-aortic balloon pump placement, which has an absolute contraindication to moderate to severe aortic regurgitation; and the TandemHeart, which is contraindicated in the presence of left atrial thrombus. Any suspicion for these findings before or during cardiac catheterization should lead to further evaluation by FoCUS examination before proceeding with mechanical circulatory support.

Early Identification of Mechanical Complications of MI. Echocardiography remains the most accessible imaging modality to evaluate for structural cardiac disease. The management of life-threatening complications of ACS, including ventricular FWR, VSD, acute papillary muscle rupture, ventricular aneurysm, cardiac tamponade, and ventricular thrombus formation, benefits from early recognition. Although a thorough physical examination can frequently raise suspicion for one of these complications, it invariably requires confirmation by imaging.

Any patient presenting with cardiogenic shock and a newly auscultated murmur raises suspicion for a mechanical complication of an MI. An urgent, focused echocardiographic examination offers the possibility of immediate visualization of a VSD, new valvular dysfunction, and pericardial effusion associated with FWR.[6] Mechanical complications of MI carry a poor prognosis without immediate surgical intervention, so the time to diagnosis remains a critical component of their management. Coronary angiography in most of these scenarios may delay life-saving surgery.

Reduction in Unnecessary Cardiac Catheterizations. Prompt echocardiography in the setting of mixed chest pain presentation as well as secondary troponin elevations has the potential to reduce unnecessary cardiac catheterizations as well as associated procedural morbidity and mortality. Emergent coronary angiography is indicated when a thrombotic or embolic cause of ACS is suspected. In the absence of a strong indication, it may delay other more appropriate therapies and expose the patient to an invasive procedure with concomitant risks.

In cases such as LV thrombus, echocardiography may both confirm the need for catheterization (i.e., LV thrombus with associated WMA) and decrease complication rates by identifying the need to avoid LV pressure measurements.

Disadvantages

The additional step of performing echocardiography up front in cases of suspected mechanical complications also carries potential drawbacks. At many institutions, the ability to obtain an immediate

echocardiogram may be limited. If the etiology of ischemia is otherwise clear, any additional imaging reduces time to potential revascularization. Up-front evaluation by echocardiography relies upon a rapidly available technician and reading physician.

Delaying Time to the Catheterization Laboratory. Current guidelines for the treatment of ST-segment elevation MI recommend a 90-min door-to-balloon time at a catheterization-capable facility. Any delay for additional imaging should be avoided unless mechanical complications are suspected. A delay in care must be carefully balanced relative to its potential benefit. Patients to be targeted are those with troponin elevation without obvious type 1 MI and those in whom the diagnosis of a suspected mechanical complication will significantly affect outcomes.

The purpose of the previously established FoCUS examination is to perform a more limited, high-yield examination by a skilled provider. Loss of time remains an unavoidable drawback of adding additional diagnostic testing. A useful test needs to be incorporated into a system of implementation that allows timely performance and interpretation if there is an expectation for meaningful clinical impact (i.e., a reduction in morbidity or mortality).

Literature Review

A number of prior studies have investigated the utility of echocardiography as a preliminary diagnostic modality in evaluating patients with chest pain and suspected ACS. The results of these studies have been promising, and implementation up front in emergent ACS has yet to become a standardized protocol.[7-15]

Table 1 reviews nine studies that measured the accuracy of echocardiography as a predictor of cardiac events by assessing the presence and absence of WMAs. The primary end points of these studies range from major end points such as MI to revascularization, angiographic findings of coronary artery disease, and abnormal study findings.[9,15,16]

The positive predictive value (PPV) has wide variability from 31% to 100%, but it is important to note that PPV correlates with low-risk and high-risk patients. Conducting echocardiography for the assessment of ACS in a high-risk population, as in a study by Mohler *et al.*,[15] reveals high PPV in high-risk patients. This study identified all patients with new WMAs; of those, MI was identified in 43%, for a PPV of 100% and a negative predictive value (NPV) of 57%.

However, in low-risk populations, initial echocardiography seems to be less predictive. In a study by Sabia *et al.*,[9] who had a lower risk population, the overall prevalence of cardiac events was 17%, giving echocardiography a PPV of 31% and an NPV of 98%. In addition, Kontos *et al.*[7] found that the PPV and NPV between echocardiography and electrocardiography in the low-risk population were similar, with PPV of 44% and 60% and NPV of 98% and 44%, respectively. Overall, echocardiography is more useful in evaluating for ACS in moderate- to high-risk populations. Its value in low-risk populations is nonsuperior to that of standard electrocardiography.

Prior Studies Regarding the Use of Echocardiography in Patients with ACS. Most of the studies previously published evaluating the utility of early echocardiography in patients with ACS were completed by cardiac sonographers or cardiologists.[7,9,17] However, one prospective study did show that basic echocardiography training for emergency department physicians greatly improved their ability to interpret WMAs.[18] Two previous case series evaluating the use of point-of-care echocardiography by emergency department physicians concluded that echocardiography can provide a rapid detailed assessment of WMAs that may help speed clinical decision-making.[19,20] Detecting early WMAs may be imperative, as these occur even before electrocardiographic changes or chest pain in patients with ACS.[9] Another more recent study investigated the use of echocardiography in the evaluation of patients with ACS in the prehospital setting. The study demonstrated very high sensitivity (90%) and specificity (100%) for the early detection of non–ST-segment elevation MI.[5]

Implementation Strategy

As previously demonstrated, WMAs in ACS may occur before electrocardiographic changes and before significant chest pain.[17] Here we

Table 1 Prior studies investigating the correlation between WMA and cardiac events using echocardiography[16]

Author	Year published	Sample size	WMAs	Acute cardiac events, present/absent	PPV, %	NPV, %
Kontos *et al.*[7]	1998	260	Present	41/53	44	—
			Absent	4/162	—	98
Kontos *et al.*[8]	1998	130	Present	15/29	34	—
			Absent	6/80	—	93
Sabia *et al.*[9]	1991	169	Present	27/60	31	—
			Absent	2/80	—	98
Korosoglou *et al.*[10]	2004	98	Present	19/2	90	—
			Absent	18/59	—	77
Saeian *et al.*[11]	1994	60	Present	22/3	88	—
			Absent	2/33	—	94
Sasaki *et al.*[12]	1986	46	Present	17/1	94	—
			Absent	6/22	—	79
Horowitz *et al.*[13]	1982	65	Present	34/2	94	—
			Absent	2/27	—	93
Peels *et al.*[14]	1990	35	Present	22/4	85	—
			Absent	3/14	—	82
Mohler *et al.*[15]	1998	92	Present	27/0	100	
			Absent	28/37		57

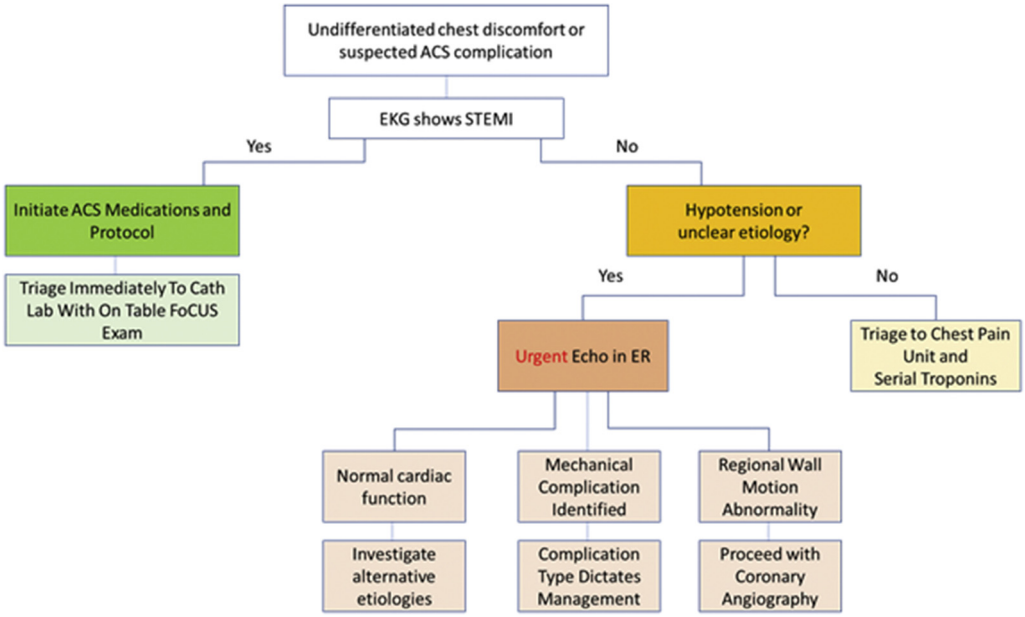

Figure 5 Algorithm for suspected ACS. An acute cardiac sonographer and an acute echocardiography reader are assigned. The goal is to perform and interpret acute echocardiography within a 45-min window. *EKG*, Electrocardiography; *ER*, emergency room; *STEMI*, ST-segment elevation MI.

suggest the implementation of rapid echocardiographic assessment for either suspected complications of ACS or undifferentiated chest discomfort in moderate- to high-risk patients presenting to the emergency department after initial electrocardiography is negative for ST-segment elevation MI (Figure 5). This may aid in identifying new WMAs for early categorization into an ischemic etiology while blood work is pending, as well as early identification of the previously discussed complications. A moderate- to high-risk patient who presents with an ST-segment elevation MI may also benefit from emergent echocardiography just before cardiac catheterization if the study does not delay door-to-balloon time (i.e., an "on-table examination"). This may be especially useful in patients with hemodynamic compromise to identify possible mechanical complications of the MI, in whom further interventions before coronary angiography (e.g., circulatory support, surgical consultation) may be critical. This algorithm is intended to be used in addition to traditional standard ACS management and not as a replacement. The assessment should be performed by a trained ultrasonographer in the emergency department or on the catherization table immediately preceding the procedure.

CONCLUSION

Echocardiography applied in the acute setting is an invaluable tool in the early assessment of both mixed ACS presentations and hemodynamically unstable patients. It can provide a rapid evaluation of global systolic function, rule in evidence of ischemia by identification of focal WMAs, assist in ruling out ischemia by demonstration of normal function, and identify mechanical and valvular complications. All of these findings may significantly alter the ideal course of treatment for a given patient. As an initial adjunct in the triage process, it carries notable promise for the reduction of catheterization laboratory complications by both guiding subsequent procedures and ruling out unnecessary procedures with an ultimate goal of reducing morbidity and mortality. Further study with a standardized implementation system is required to confirm this suspicion.

SUPPLEMENTARY DATA

Supplementary data related to this article can be found at https://doi.org/10.1016/j.case.2020.07.002.

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