Anteroapical Stunning and Left Ventricular Outflow Tract Obstruction

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Dynamic left ventricular outflow tract (LVOT) obstruction is typically observed in the setting of hypertrophic cardiomyopathy. It has also been reported with concentric LV hypertrophy, excessive sympathetic stimulation, and acute myocardial infarction. We describe 3 patients with chest discomfort after emotional stress, who had pronounced abnormalities on electrocardiograms, insignificant obstructive coronary disease and hemodynamic instability with LVOT obstruction, and regional wall motion abnormalities. Suppression of contractility with β-blockers resulted in resolution of the gradient and in clinical improvement. On follow-up, functional recovery was excellent, and ventricular function had normalized. The conditions and mechanisms that may produce this sequence of events are discussed. The most probable scenario is that an acute ischemic insult secondary to vasospasm, LV stunning, and acute geometric remodeling produced a substrate for LVOT obstruction that was exacerbated by basal LV hypercontractility. The importance of this observation is that routine treatment of cardiogenic shock cannot be used and that conservative management results in excellent prognosis.


CK = creatine kinase; ECG = electrocardiogram; HCM = hypertrophic cardiomyopathy; LVOT = left ventricular outflow tract; SAM = systolic anterior motion

The term stunned myocardium was introduced by Braunwald and Kloner1 in 1982 to describe a reversible myocardial contraction abnormality that occurs after ischemia due to epicardial coronary artery disease. More recently, it was reported in the setting of hypertrophic cardiomyopathy (HCM), subarachnoid hemorrhage, and vasospastic disease.2-4 Dynamic left ventricular outflow tract (LVOT) obstruction, typically observed in the setting of HCM with asymmetrical septal hypertrophy, has also been reported with concentric LV hypertrophy, excessive sympathetic stimulation, and acute myocardial infarction.5-9 We describe 3 patients with anteroapical stunning and dynamic LVOT obstruction, which we believe were secondary to epicardial coronary artery spasm.

REPORT OF CASES

Case 1
A 62-year-old woman with hypertension presented with a 24-hour history of anterior chest and throat discomfort after an argument with her daughter. Findings on physical examination showed tachycardia. An electrocardiogram (ECG) showed diffuse symmetrical T-wave inversion with QT prolongation (QTc, 570 milliseconds). In the ensuing 12 hours, she developed progressive cardiovascular compromise with hypotension and pulmonary edema. A new harsh 3/6 systolic murmur was noted over the apex and left parasternal border. These conditions failed to improve with the addition of intra-aortic balloon counterpulsation and a dopamine infusion. An urgent echocardiogram revealed anteroapical akinesis, systolic anterior motion (SAM) of the mitral valve, dynamic LVOT gradient of 40 mm Hg, but no evidence of HCM. Emergent coronary angiography revealed normal coronary arteries. Left ventriculography confirmed the presence of severe anteroapical wall motion abnormalities. Pull back pressures (pressure recording during catheter withdrawal) confirmed the presence of an LVOT gradient that was abolished with metoprolol, 5 mg administered intravenously. Intra-aortic balloon counterpulsation was discontinued. Her subsequent management consisted of β-blockers, intravenous fluids, and a short course of intravenous phenylephrine. The systolic murmur ceased to be audible, and the creatine kinase (CK), CK-MB, and troponin I levels remained within the reference range. No clinical or laboratory evidence suggested myocarditis, sarcoidosis, or any of the vasculitides. Additional testing included thallium scintigraphy, which showed no evidence of irreversible injury to the myocardium, and ultrafast computed tomography, which uncovered focal calcification in the proximal left anterior descending coronary artery. Serial ECGs demonstrated resolution of the aforementioned abnormalities. At 1-month follow-up, the patient had excellent functional recovery. An echocardiogram showed normalization of wall motion and LV systolic function.
Case 2

A 71-year-old woman presented to a hospital elsewhere because of chest discomfort and syncope shortly after advanced esophageal cancer had been diagnosed. An ECG showed diffuse symmetrical T-wave inversion and QT prolongation (QTc, 490 milliseconds). The troponin I level was elevated at 14.1 ng/mL; the CK and CK-MB values were within normal limits. The patient was transferred to our institution for further evaluation and treatment. On transfer, her blood pressure was 80/60 mm Hg. A harsh 3/6 systolic murmur was present over the apex and left parasternal border. Echocardiography revealed akinesis of the anteroapical LV myocardium, no asymmetrical septal hypertrophy, severe SAM of the mitral valve, and presence of an LVOT gradient of 55 mm Hg. Coronary angiography revealed minimal plaque in the left anterior descending and right coronary arteries. Left ventriculography confirmed the presence of a severe anteroapical wall motion abnormality, and pull back pressures registered an LVOT gradient of 54 mm Hg. After cautious volume administration and treatment with metoprolol (initially, 3 doses of 5 mg intravenously; then, 5 mg every 6 hours with an additional dose every 3 hours as needed; finally, 200 mg in a sustained-release preparation per day), her blood pressure, urine output, and clinical state improved dramatically. The murmur ceased to be audible, and no additional increase in cardiac enzymes was noted. Repeated echocardiography revealed improvement in LV function and resolution of the LVOT gradient. Serial ECGs showed resolution of the T-wave abnormality and normalization of the QT interval. At 3-week follow-up, echocardiography showed normalization of wall motion and LV function.

Case 3

A 74-year-old woman with hypertension, chronic obstructive pulmonary disease, and mitral valve prolapse presented to the emergency department because of 4 hours of unremitting chest pain after an argument with her husband. Her blood pressure was 80/50 mm Hg. A harsh 3/6 systolic murmur was heard at the apex. An ECG showed diffuse, deep symmetrical T-wave inversion and QT prolongation (QTc, 678 milliseconds). The troponin I level was elevated at 4 ng/mL. The CK and CK-MB values were normal. Echocardiography revealed dyskinesis of the anteroapical LV, severe SAM, a dynamic LVOT gradient of 64 mm Hg, but no evidence of HCM. The mitral valve was myxomatous and redundant with 3+ regurgitation. Emergent coronary angiography showed no epicardial coronary stenosis. Left ventriculography confirmed the presence of severe anteroapical dyskinesis with basal hyperkinesis. An LVOT gradient of 62 mm Hg was abolished after administration of metoprolol, 5 mg intravenously. The patient’s hemodynamic state subsequently normalized with oral metoprolol at 150 mg/d. The systolic murmur was no longer audible, and there was no further increase in cardiac enzymes. Serial ECGs demonstrated resolution of the T-wave abnormality and QT prolongation. At discharge, an echocardiogram revealed mild anteroapical hypokinesis, improvement of LV function, and trivial mitral regurgitation. At 1-month follow-up, the LV function and wall motion had completely normalized.

DISCUSSION

Our 3 female patients had new-onset chest discomfort, hemodynamic instability due to LVOT obstruction (Figures 1 and 2), focal wall motion abnormalities, and abnormalities on ECGs (Figure 3) in the absence of epicardial coronary artery disease or HCM. Suppression of ventricular contractility with β-blockers resulted in resolution of the LVOT gradient (Figure 4) and clinical improvement. On follow-up, the wall motion and LV function had normalized.

The scenarios that may conceivably produce this sequence of events are focal myocarditis, neurologically mediated myocardial injury, and primary hemodynamic instability with LVOT obstruction producing secondary myocardial ischemia and stunning. Based on the patients’ reported symptoms, ECG abnormalities, and pattern of LV dysfunction, the most probable clinical scenario is that an acute ischemic insult produced transient contractile dysfunction, acute geometric remodeling, and a dynamic LVOT obstruction. Two of our patients (cases 1 and 2) had evidence of noncritical atherosclerosis in the left anterior descending coronary artery. Thus, we hypothesize that acute emotional stress provoked vasospasm at the site of noncritical atherosclerosis, producing the described clinical syndrome.

A recent case series described the development of dynamic LVOT obstruction and cardiogenic shock in the setting of an acute coronary syndrome. Three patients presented with chest pain, ST-segment elevation, and elevated cardiac enzymes. Coronary angiography revealed severe coronary artery disease. Intractable hypotension ensued that responded to β-blockade. While these clinical features closely resemble those described in our patients, important differences exist. We identified a distinct temporal relationship with intense emotional stress. None of our patients had documented ST-segment elevation or severe coronary disease on angiography. The CK and CK-MB enzymes were all within normal limits, although the troponin I level was elevated in 2 of our patients (cases 2 and 3). These cases demonstrate a syndrome of cardiogenic shock associated with LVOT obstruction occurring after intense emotional stress but without severe myocardial necrosis.

All 3 of our patients experienced chest discomfort after intense emotional stress. Although this finding is nonspecific, it certainly suggests angina pectoris due to myocardial ischemia.
The observed ECG abnormalities included symmetrical diffuse T-wave inversion and QT interval prolongation, a pattern that has been associated with LV stunning in unstable ischemic syndromes.\textsuperscript{10,11} Left ventricular contractile dysfunction that conformed to the territory of the left anterior descending coronary artery was also observed. Finally, at brief follow-up, both the ECG abnormalities and the contractile dysfunction had resolved, similar to the observations reported in unstable ischemic syndromes.\textsuperscript{11}

Our inability to detect ST-segment elevation or epicardial coronary stenosis suggests transient vasospasm, thrombosis with spontaneous resolution, or some form of direct myocardial injury. Previous literature reports have described a similar syndrome of an anterior repolarization abnormality and reversible ventricular dysfunction occurring in the setting of acute neurologic injury and severe noncardiac illnesses, such as sepsis or pancreatitis.\textsuperscript{3,12} Several theories have been advanced to explain this phenomenon, including neurologically mediated epicardial coronary spasm, arteriolar dysfunction, and direct myocardial injury.\textsuperscript{3,12} The central theme of all these theories is enhanced sympathetic tone.
Excessive sympathetic nerve discharge has been suggested as a mechanism for producing myocyte injury in the absence of coronary stenosis. High concentrations of catecholamines may produce myocytolysis.\textsuperscript{13} In animal models, sympathectomy prevents myocardial injury after brain injury.\textsuperscript{14} Furthermore, administration of the adrenergic receptor antagonists propranolol and phentolamine militates against myocardial necrosis after subarachnoid hemorrhage.\textsuperscript{15} Adrenoceptor density varies throughout the heart with greater density in the apex of the LV, perhaps explaining the more frequent observation of dysfunction in this territory.\textsuperscript{16} Conversely, sympathetic discharge may produce vasospasm that may also be prevented by sympathectomy or administration of phentolamine. Therefore, differential adrenoceptor density may also be used to advocate that spasm is most likely to occur in the left anterior descending coronary artery. While we were unable to demonstrate ST-segment elevation or complete occlusion at angiography to fulfill the classic criteria for vasospasm, the ECG findings of T-wave inversion and QT prolongation have been described in unstable ischemic syndromes.\textsuperscript{11} Furthermore, the close relationship between wall motion abnormalities and distribution of the left anterior descending coronary artery observed in our patients advocates that impaired blood flow through the epicardial coronary artery was the cause of transient LV dysfunction. The absence of any stenosis or filling defect further suggests that vasospasm, rather than thrombosis and spontaneous thrombolysis, was the most likely cause.

Myocarditis with regional differences in severity has been described.\textsuperscript{17} Enhanced sympathetic tone with compensatory hyperkinesis of the unaffected LV can conceivably result in dynamic LVOT obstruction. Unfortunately, this possibility cannot be reliably excluded in our patients based on the available information. In fact, even if an endomyocardial biopsy had been performed, the possibility of a sampling error in the event of normal biopsy findings would render the information to be of questionable value.\textsuperscript{18} The clinical history, although unreliable, is not suggestive of myocarditis. A close association between intense emotional stress and sudden-onset myocarditis seems most unlikely.

Although the development of LVOT obstruction in acute coronary syndromes has been described, primary myocardial stunning or injury is not the only possible explanation for the observation of LVOT obstruction with focal wall motion abnormalities.\textsuperscript{7-9} Patients with a sigmoid interventricular septum, small LVOT and reduced LV volumes (primarily in women), and an abnormal orientation of a slack mitral apparatus have a geometric predisposition to dynamic LVOT obstruction, which may manifest in the setting of intense adrenergic stimulation or hypovolemia.\textsuperscript{10-21} With LVOT obstruction, apical and anterior wall stress and LV filling pressures increase while systemic blood pressure decreases. Increased oxygen demand and reduced coronary perfusion pressure may combine to produce myocardial ischemia, stunning, regional wall motion abnormalities, and associated T-wave changes. In susceptible patients (all 3 of our patients were female), this raises the possibility of increased adrenergic tone leading to primary LVOT obstruction with secondary ischemia and focal wall motion abnormalities.

The treatment of cardiogenic shock due to presumed ischemic insult typically involves administration of vasoressors, inotropic agents, mechanical ventricular support, and urgent revascularization. We describe development of cardiogenic shock due to LV stunning and dynamic LVOT obstruction, and the successful treatment centered on suppression of ventricular contractility, which is not the typical treatment approach. The presence of a systolic murmur and characteristic ECG findings in the setting of cardiogenic shock suggest ventricular stunning and LVOT obstruction as the mechanism. Urgent echocardiography is key to establishing this diagnosis so that appropriate therapy may be given.

Therapeutic maneuvers that may be beneficial include β-adrenoceptor blockade, α-adrenoceptor agonism, and volume expansion. β-Adrenoceptor antagonism reduces LV hyperkinesis and heart rate, resulting in an increase in LV volume and LVOT area. Similarly, expansion of extra-
cellular volume increases LVOT area. α-Adrenergic receptor stimulation increases arterial impedance, which reduces LV ejection velocity and increases LV volume. The combination of increased LVOT volume/area and reduced ejection velocity reduces dynamic LVOT obstruction, similar to observations in HCM. Antagonism of vasodilatory β,-adrenergic receptor effects combined with α-adrenergic receptor stimulation in epicardial arteries may theoretically worsen vasospasm. However, no deleterious effects were seen in our patients. Although volume expansion is of clear benefit, care must be taken during intravascular volume expansion in patients with cardiogenic shock. Even minor increases in left atrial pressure may produce or exacerbate pulmonary edema.

REFERENCES