Cardiac ischemia, particularly of the circumferential subendocardial region, commonly occurs in patients with severe aortic stenosis during hemodynamic stress, even in the setting of angiographically documented normal coronary arteries. The mechanism responsible for this type of ischemia is myocardial oxygen demand that exceeds supply and myocardial necrosis can even occur. Even if the occurrence of myocardial infarction is extrapolated from the myocardial ischemia, the myocardial necrosis would be located in the circumferential subendocardial wall of the left ventricle. In other words, when infarcts are located in the circumferential subendocardium, they are thought to be caused solely by aortic stenosis. Subendocardial necrosis caused by severe aortic stenosis often leads to left ventricular dysfunction and overt congestive heart failure. There have been only a few documented case of acute myocardial infarction caused solely by severe aortic stenosis; although silent ischemic necrosis has often been observed. In the present patient, who had marked left ventricular hypertrophy secondary to severe aortic stenosis and normal coronary arteriograms, the acute phase of myocardial infarction involving the circumferential subendocardial wall of the left ventricle was clearly documented by detection of a transient rise in the biochemical markers of myocardial necrosis and an abnormal accumulation of infarct-avid imaging agent in the irreversibly damaged myocardium.

Case Report

A 58-year-old man was admitted to hospital because of prolonged chest pain and loss of consciousness. He had a 2-year history of chest pain and shortness of breath during exertion. Two hours before admission, he had experienced these symptoms while watching television in excitement, and subsequently became unconscious. On admission, he had regained consciousness, but his chest pain persisted. Physical examination revealed a systemic blood pressure of 170/110 mmHg and a pulse rate of 100 beats/min. On auscultation, a grade IV/VI systolic ejection murmur was heard best at the upper right sternal border.

Fig 1. ECG obtained on admission shows high voltage in the left ventricle and ST-segment elevation in leads aVR and aVL, concomitant with marked ST-segment depression in leads I, II, III, aVR and V4-V6.
border. Fine crackles were audible over the bottom of both lungs. An ECG showed high voltage in the left ventricle and ST-segment elevation in leads aVR and aVL, concomitant with marked ST-segment depression in leads I, II, III, aVF, and V4–6 (Fig 1). A chest roentgenogram disclosed an enlarged cardiac silhouette with a cardiothoracic ratio of 55% and pulmonary vascular congestion. On echocardiographic examination, severe calcific aortic valve stenosis with a peak pressure gradient of 160 mmHg and concentric left ventricular hypertrophy were found (Fig 2). Mild aortic regurgitation also was detected. In addition, the mitral valve apparatus was mildly involved. However, no wall motion abnormality of the left ventricle was seen.

The patient’s plasma creatine kinase level peaked at 1,077 IU/L 14 h after the onset of chest pain. On the second day after admission, right- and left-heart catheterization was performed, although a catheter was not inserted into the left ventricle. The cardiac index and mean pulmonary artery wedge pressure were 2.78 L·min⁻¹·m⁻² and 38 mmHg, respectively. The coronary arteries appeared to be fully dilated in the control state (Fig 3); therefore, the provocation test for coronary vasospasm was not performed. Subsequently, coronary flow velocity waveforms were obtained by advancing a Doppler flow wire into the proximal left anterior descending coronary artery. Systolic flow reversal with a peak velocity of −25 cm/s was detected (Fig 4, upper). The diastolic flow velocity was high, with a peak velocity of 80 cm/s. The coronary flow reserve, measured by intracoronary injection of 10 mg papaverin hydrochloride, was decreased (Fig 4, lower). On the seventh day after admission, technetium-99m (99mTc) pyrophosphate scintigraphy coupled with rest thallium-201 (201Tl) imaging demonstrated an abnormal accumulation of the former tracer over most of the inner area of the left ventricle (Fig 5). A follow-up electrocardiogram showed no new Q waves. Therefore, the patient was diagnosed as having congestive heart failure mainly because of severe aortic stenosis with marked left ventricular hypertrophy and an accompanying non-Q wave myocardial infarction.

Subsequently, aortic valve replacement using a 21-mm Carbomedics bileaflet prosthesis was performed. Direct inspection of the aortic valve during surgery showed probable rheumatic aortic stenosis; a biopsy specimen of the left ventricle was not obtained.

**Discussion**

Myocardial ischemia, particularly of the left ventricular subendocardium, commonly occurs in cases of severe aortic stenosis during hemodynamic stress, even in the setting of coronary arteries documented angiographically as normal. Myocardial ischemia most likely occurs in the left ventricular subendocardium rather than in the subepicardium, even in patients without left ventricular hypertro-
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The left ventricular endocardium normally shortens more than the epicardium, and consequently has greater oxygen consumption. Myocardial oxygen demand is increased by the increased mass and thickness of the left ventricular wall secondary to the severe aortic stenosis. In severe aortic stenosis, systole is also often lengthened and thus myocardial wall tension is increased. Consequently, the systolic tension—time product, which represents cardiac work, is increased. By contrast, in patients with aortic stenosis who have concentric hypertrophy of the left ventricle, perfusion of the endocardium may be compromised by the following factors: failure of vascular growth, particularly of capillaries, to keep pace with the marked myocardial hypertrophy; increased diffusion distance between myocardial capillaries and the center of the hypertrophied myocardial cells; structural alterations in the microvasculature; shortening of diastole, which is the phase during which most coronary flow to the left ventricle occurs, because of the lengthening of systole; elevated diastolic pressure in the left ventricular cavity, which impedes coronary flow to the subendocardium; high intramyocardial pressure that promotes coronary flow reversal during systole and impedes flow during diastole; and relatively low aortic diastolic pressure in the aorta for perfusion of the coronary arteries. It has been demonstrated that reversed systolic flow velocity compensated by enhanced diastolic flow velocity, as seen in this patient (Fig 4), is related to symptoms, such as angina or syncope, caused by the aortic stenosis.

The present patient’s infarct was very unusual in view of the involvement of the left ventricular circumferential subendocardium. In patients with severe aortic stenosis and normal or nearly normal coronary arteriograms, myocardial infarction can result from factors other than atherosclerosis, such as coronary vasospasm or thromboembolism, including calcium embolization. However, it is unlikely that the myocardial infarction in this case resulted from any of those factors. Even if the occurrence of myocardial infarction in severe aortic stenosis is extrapolated from the myocardial ischemia, the myocardial necrosis in this setting would be expected to be located in the circumferential subendocardial wall of the left ventricle. In other words, when infarcts are located in the circumferential subendocardium, they are thought to be caused solely by aortic stenosis, rather than by coexistent coronary artery disease. Therefore, the myocardial infarction in the present case is thought to have been an extension of myocardial ischemia resulting from severe aortic stenosis.

However, the following question remains: what precipitated the myocardial infarction? Hypotension and tachycardia can act as triggers in patients with hypertrophic obstructive cardiomyopathy associated with myocardial infarction involving the circumferential endocardial wall of the left ventricle. The patient’s myocardial infarction occurred when he became excited while watching television. His heart rate and systemic blood pressure at the onset of chest pain might have been higher than at rest. Considering the pressure gradient across the aortic valve, the peak systolic left ventricular pressure and consequent myocardial oxygen demand represented as a pressure—rate product would have been very high and could have promoted myocardial oxygen demand—supply imbalance. Moreover, we speculate that once myocardial ischemia occurred, the left ventricular end-diastolic pressure became elevated and subsequently, coronary blood flow into the subendocardium would have been increasingly impeded. Ultimately, it was the myocardial ischemia that probably caused the loss of consciousness.

Single photon-emission computed tomography (SPECT) using both 99mTc pyrophosphate, which identifies necrotic myocardial cells by binding to the increased calcium stores present in irreversibly damaged cells, and 201Tl clearly demonstrated the patient’s infarct region. There are several reasons for the success in imaging the infarct in this case. First, 99mTc pyrophosphate uptake occurs preferentially in areas of necrosis with preserved blood flow, as seen here, rather than in areas with permanent occlusion of the infarct-related coronary artery. Second, this tracer is thought to be taken up by reversibly injured myocytes located in the peri-infarct area that accumulate excess calcium, but survive without infarction, as well as by irreversibly damaged myocytes. In the present case, the infarct is thought to have been caused by the extreme disparity between myocardial oxygen supply and demand in the setting of severe left ventricular hypertrophy and normal coronary arteries, so there would have been some injured, but viable, myocytes. Third, a timely scintigraphic examination was performed because the patient, who had prolonged angina, was suspected of having a myocardial infarction. SPECT is an ideal method for localizing regions of damaged myocardium because of the 3-dimensional nature of the tomographic reconstructed images.

In conclusion, this case is unique because it is a documented case of acute myocardial infarction involving the circumferential subendocardial wall of the left ventricle in a patient with severe aortic stenosis, marked left ventricular hypertrophy, and angiographically normal coronary arteriograms. His myocardial infarction is thought to have been caused solely by aortic stenosis because the infarct was located only in the circumferential subendocardium, in the setting of severe aortic stenosis. We speculate that the mechanism responsible for this myocardial infarction was a myocardial oxygen demand—supply imbalance, particularly in the subendocardium.

References