

A case report of apical aneurysms and myocardial perfusion deficit with myocardial necrosis due to hypertrophic cardiomyopathy

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Abstract

Rationale: Hypertrophic cardiomyopathy (HCM) is a disease that is characterized by inappropriate left ventricular and/or right ventricular hypertrophy and hypercontractility that is often asymmetrical and associated with microscopic evidence of myocardial fiber disarray. The aim of this study was to present a previously under-recognized subset of HCM patients with left ventricular (LV) apical aneurysms.

Patients concerns: A 33-year-old man who presented with chest discomfort for 10 days. He had an emerging apical aneurysm in the LV without midventricular obstruction. He had been diagnosed with apical HCM via abnormal electrocardiograms (ECG) and single-photon emission computed tomography (SPECT) for 10 years. This time, a new significant change in ECG and SPECT was identified. Late gadolinium enhancement (LGE) was observed by cardiac magnetic resonance imaging (MRI), and SPECT showed myocardial fibrosis or necrosis involving the apical aneurysm and proximal portion of the heart, which was confirmed by left ventriculography.

Diagnoses: We present a relatively rare case of HCM patients with apical aneurysms, accompanying by myocardial necrosis markers increased due to ventricular muscle stress increases, rather than obstructive coronary artery disease.

Interventions: The patient was prescribed aspirin, metoprolol tartrate, perindopril, and atorvastatin and was strongly advised to quit cigarettes and reduce weight.

Outcomes: Follow-up at half a year turned out well.

Lessons: LGE with a notable progression by ECG and SPECT along with an increase in myocardial necrosis markers in HCM patients with apical aneurysms, as was noted in the present case, is a relatively rare occurrence. Our present case may provide unique insights into the adverse remodelling process and the formation of apical aneurysms in HCM patients.

Abbreviations: ECG = electrocardiograms, HCM = hypertrophic cardiomyopathy, LGE = late gadolinium enhancement, LV = left ventricular, MRI = magnetic resonance imaging, SPECT = single-photon emission computed tomography.

Keywords: apical aneurysm, hypertrophic cardiomyopathy, magnetic resonance imaging, myocardial necrosis, single-photon emission computed tomography

1. Introduction

Hypertrophic cardiomyopathy (HCM) is defined as a myocardial disorder that is characterized by hypertrophy of a nondilated left

ventricular (LV) cavity in the absence of underlying diseases.^[1] Apical HCM is a relatively rare variant of HCM that is characterized by myocardial hypertrophy occurring predominantly in the LV apical portion, with a spade-shaped LV configuration and a giant negative T wave.^[2] The patterns of myocardial hypertrophy and associated abnormalities, including coronary arterial dysfunction, myocardial fibrosis, and apical LV aneurysms, should be carefully observed in patients with HCM, as HCM contributes to symptoms and outcomes.^[1,3] LV apical aneurysms, in the absence of coronary artery disease, occur in approximately 1% of patients with HCM.^[4] Apical LV aneurysms induce clinical symptoms, including chest oppression and palpitation; electrocardiographic abnormalities, such as sustained ventricular tachycardia T-wave inversion; and mural thrombosis.^[5]

Echocardiography is the most commonly used imaging tool for the initial diagnosis and monitoring of HCM because of its portability and lower cost, but echocardiography is often insufficient for the observation of the LV apex because of its inherent limitations in providing complete 3-dimensional coverage of the heart and reproducibility.^[6] The potential role of electrocardiograms (ECGs) in the detection of apical aneurysms has been defined in HCM patients who exhibit distinctive ECG changes.^[7] Other imaging tests, such as magnetic resonance

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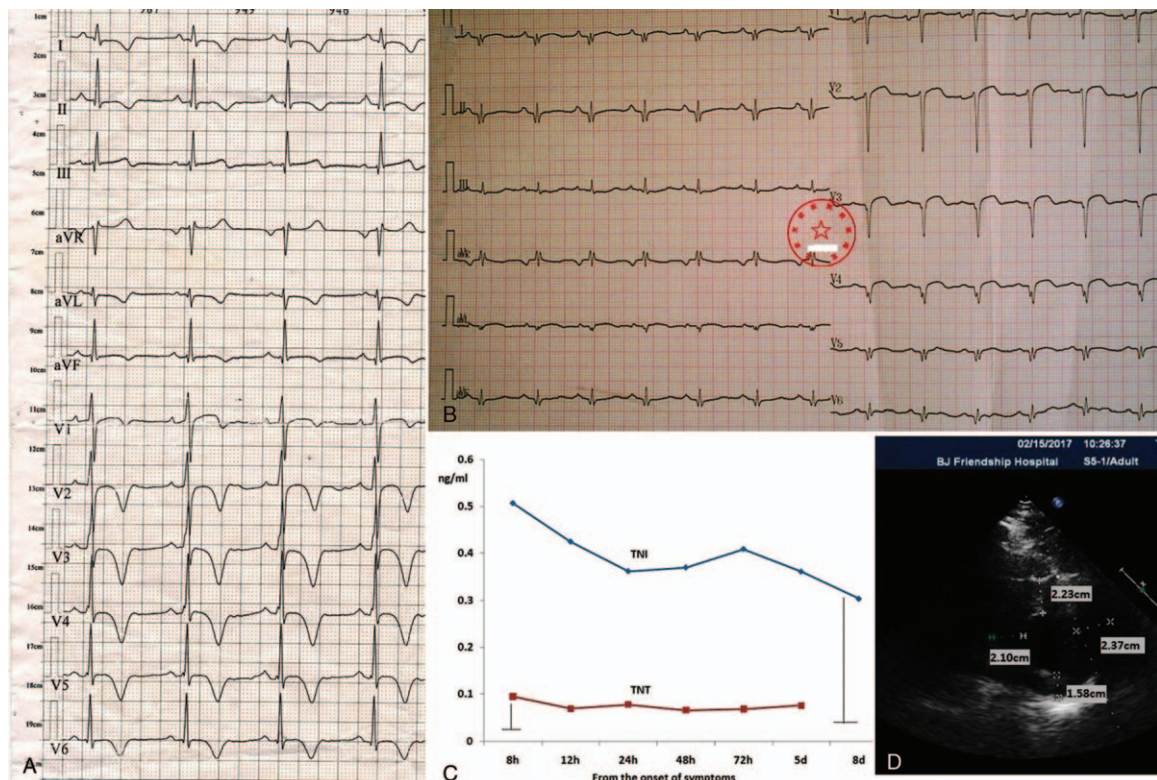


Figure 1. Electrocardiogram, echocardiogram, and troponin: (A) the electrocardiogram showed significant T wave inversion (I, II, aVL, and V2–V6) in 2007, when the patient was 23 years old. (B) The electrocardiogram showed a significant decrease in the amplitude of the QRS voltages and significant, persistent ST-segment elevation in most of the leads in 2017. (C) His TNI and TNT levels were persistently elevated in serial measurements. (D) The echocardiogram showed marked LV wall thickening, especially at the LV apical region, that was >2.37 cm. LV=left ventricular, TNI=troponin I, TNT=troponin T.

imaging (MRI) and left ventriculography, are also used to diagnose or confirm clinical suspicion of HCM. MRI can assess morphological patterns, cardiac functional parameters, myocardial perfusion, and myocardial scarring in a single examination with no limitations on the view and high spatial and high contrast resolutions.^[5,6,8] MRI has enabled the more frequent identification of a subset of patients with thin-walled, LV apical aneurysms, which are often associated with regional scarring and muscular mid-cavity obstruction.^[9] In patients with HCM, previous reports have suggested that the discrepancy in the myocardial distribution observed using single-photon emission computed tomography (SPECT) is related to myocardial damage when hypertrophic myocardium is revealed by high myocardial perfusion. Additionally, in cases of midventricular obstruction with an apical aneurysm, myocardial perfusion scintigraphy reveals fixed or reversible apical defects.^[10]

We herein report a rare case of LV apical aneurysms with HCM in an asymptomatic patient with myocardial LGE determined by MRI and irreversible myocardial perfusion defects determined by SPECT. However, his myocardial necrosis markers continuously increased and coronary angiography did not reveal severe atherosclerotic lesions. These performances were not observed in this patient by echocardiography and SPECT 10 years ago. Over the past 10 years, the patient's ECGs have revealed significant changes. This case may provide unique insights into the adverse remodelling process and formation of apical aneurysms in patients with HCM. Based on this case, we reviewed the pathogenesis, clinical

features, treatment, and prognosis of HCM according to the available literature.

2. Case report

A 33-year-old man was admitted to our department for atypical chest discomfort after ingesting a lot of food, which he had complained of for 2 weeks. A day prior to admission, he presented with chest discomfort again after ingesting a lot of meat that appeared to be worsening. His personal history included non-obstructive apical HCM 10 years prior, obesity 15 years prior, hypertension 1 year prior, and smoking for 10 years. However, he did not have diabetes mellitus or a family history of HCM, ischaemic heart disease, or other known cardiovascular risk factors.

On presentation, his blood pressure was 118/82 mmHg, his body mass index was 37 kg/m^2 , and his heart rate was 64 beats/min. A physical exam revealed cardiomegaly and no murmur at the heart valves on auscultation. A 12-lead ECG showed normal sinus rhythm with a significantly decreased amplitude of the QRS voltages and a significant, persistent ST-segment elevation in most of the leads, exhibiting distinctive changes compared with an ECG from 10 years ago (Fig. 1A and B). His level of NT-proBNP was 1039 pg/mL (normal, <125 pg/mL). His troponin I level was 0.507 ng/mL (normal, 0–0.03 U/L) with persistent elevation in serial measurements; troponin T level was 0.095 ng/mL (normal, 0.01–0.017 U/L); and creatine kinase-MB level was within normal limits (Fig. 1C). These myocardial markers didn't

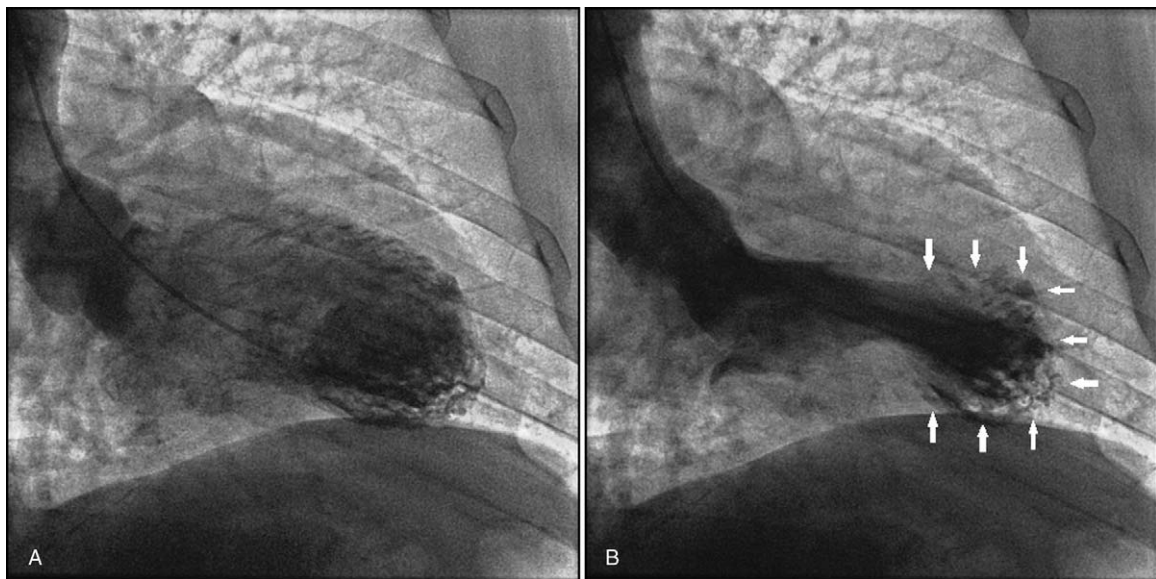


Figure 2. Left ventriculography images (right anterior oblique): (A) LV end-diastole. (B) Left ventriculography showed LV apical aneurysms without cavity obliteration in LV end-systole (white arrow). LV=left ventricular.

elevate 10 years ago. An echocardiogram was performed, revealing an LV end-diastolic diameter of 5.44 cm, no LV outflow obstruction, and marked LV wall thickening at the LV apical region that was >2.37 cm (Fig. 1D). The LV apex exhibited swelling with a weakened ventricular wall, and the EF was 65%. Based on his medical history, the changes in the ECG and increase in troponin I, acute non-ST elevation myocardial infarction was the suspected diagnosis, and the patient was treated with aspirin, clopidogrel, metoprolol tartrate, perindopril, and atorvastatin.

One day later, to confirm the diagnosis and to assess the coronary artery and underlying cardiac structural changes, we performed coronary angiography and left ventriculography, which confirmed the presence of LV apical aneurysms without cavity obliteration in the apical portion of the LV and the absence of stenotic lesions in the epicardial coronary arteries (Fig. 2). To assess the myocardial structure and to further confirm the suspected ventricular abnormalities based on echocardiography and LV angiography, the patient was scheduled for MRI and myocardial perfusion scintigraphy.

A cardiac MRI was performed and showed diastolic dysfunction and no LV cavity narrowing. The thickness of the LV segment was 0.8 to 3.1 cm, and the thickest part was in the middle of the interventricular septum. Reduced myocardial perfusion could be seen in the middle of the LV septal and lateral local wall, while the interventricular septum and apical myocardium exhibited late gadolinium enhancement. The valves of the heart did not exhibit regurgitation, and the LV outflow tract was not obstructed (Fig. 3).

SPECT was performed with 20 mCi of technetium-99m methoxyisobutylisocyanide after an exercise stress test and at rest; the results were markedly changed compared with those of the SPECT check from 10 years ago (Fig. 4). SPECT showed uneven LV wall thickening and particularly significant interventricular septal thickening. The electrocardiogram performed after exercise did not indicate significant ST-segment changes. From the images taken after stress, hypoperfusion was

observed in a part of the inferior wall near the apex and LV apex of the heart. Perfusion of these segments at rest was nearly absent, as shown on the images taken of the patient at rest. This indicates that most of the myocardial ischaemia was persistent and most of the subendocardial necrosis or/and fibrosis had already occurred. Altogether, the absence of significant electrocardiogram changes with elevated myocardial necrosis markers suggested that the HCM was related to a previous anterior myocardial infarction and that there was still myocardial necrosis at present.

The patient then underwent an HCM-related genetic test. The results showed that there were no mutations in the 3 common HCM-related genes MYH7, MYBPC3, and TNNT2. The 24-hour ambulatory ECG recording showed only isolated ventricular ectopic beats. Since the clinical and imaging evaluations supported the diagnosis of LV apical aneurysms and myocardial necrosis associated with HCM without significant coronary artery stenosis or ischaemic ECG changes, the patient received routine treatment for heart failure and hypertension. The patient was discharged without complications on the twelfth day after admission and has since experienced no further chest discomfort until follow-up 6 months. Written informed consent was obtained from the patient for the publication of this case report and the accompanying images.

3. Discussion

Our case indicates that HCM patients who develop LV apical aneurysms may exhibit distinctive ECG or SPECT changes and increased myocardial necrosis markers along with apical remodelling. The ECGs recorded before and after the development of LV apical aneurysms showed a notable progressive increase in fragmentation along with a decrease in the QRS-complex amplitude, a gradual and persistent ST-segment elevation with a reduction in the depth of negative T waves

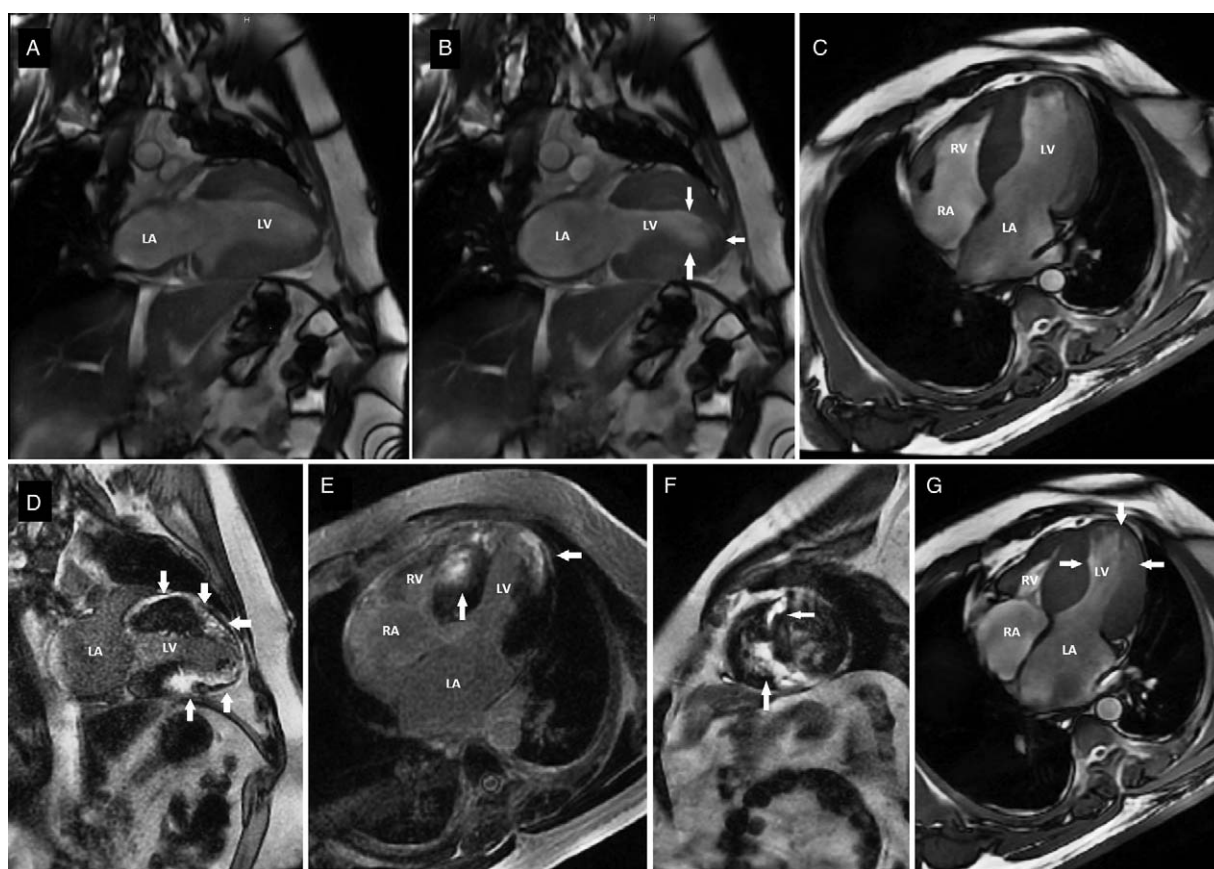


Figure 3. Cardiac MRI: (A, B, C, and G) MRI showed increased thickness of the LV segment, with the thickest part in the middle of the interventricular septum, and LV apical aneurysms (white arrow). (D, E and F) The interventricular septum and apical myocardium exhibited late gadolinium enhancement (white arrow). LV=left ventricular, MRI=magnetic resonance imaging.

and positivisation of negative T waves in leads I, II, aVL, and V1–V6. SPECT recorded before and after the development of LV apical aneurysms further confirmed this notable progression. Elevated cardiac markers suggest that myocardial necrosis may play a very important role in the pathophysiology of this disease.

HCM is a genetic cardiac disease that is characterized by a marked variability in natural history and phenotypic expression. A clinical diagnosis of HCM is conventionally made based on an LV wall thickness >15 mm upon MRI in the absence of other plausible underlying causes. An important minority of patients with HCM are at high risk of sudden death and/or progressive LV impairment. HCM patients with apical aneurysms represent a unique subgroup that typically exhibits normal coronary arteries that may eventually lead to sudden death, thrombosis, heart failure, arrhythmia, and electrocardiographic abnormalities.^[7,9,11] The incidence of HCM with LV apical aneurysms is reported to be approximately 1% to 4.8% among all HCM patients.^[4,9,12] Rowin retrospectively analyzed 1940 consecutive HCM patients at 2 centres, 93 of whom (4.8%) were shown to have LV apical aneurysms; the mean age of that cohort was 56 ± 13 years, and 69% was man.^[12] In the coming years, the prevalence of LV apical aneurysms in HCM patients is likely to increase due to increasing awareness; additionally, there may be more reports in the medical literature and increased diagnostic techniques, such as LV angiography and cardiac MRI.

Although the cause of LV apical aneurysms associated with HCM is not well understood, several mechanisms may be responsible its occurrence. Recent reports have suggested that midcavitary LV obstruction with elevated intracavitary systolic pressures, a genetic predisposition, and myocardial bridging are possible pathophysiological explanations.^[9,13] Approximately, 36% of apical aneurysm cases are found in conjunction with midventricular obstruction and intraventricular pressure gradients.^[9] Speculating on the reasons for this disorder, the severity of cavity obliteration during systole in patients with apical HCM, the consequent pressure overload on the apical myocardium and oxygen demand/supply mismatch may have been responsible for the development of apical aneurysms in patients with apical HCM.^[14] The elevated pressure may exceed the pressure from diastolic coronary blood flow due to the obstruction, resulting in circumferential apical scarring, and thinning over time. Since apical aneurysms can also be identified in patients with HCM without obstruction or intraventricular pressure gradients, the mechanisms responsible for their formation are currently unclear.^[15]

Myocardial fibrosis predominantly involves the ventricular apex in endomyocardial fibrosis. It has been reported that poor vascularization at the apex may result in failure to repair cardiac cells, subendocardial degeneration, and fibrosis.^[16] However, limited apical coronary flow and vasodilatory reserve are more

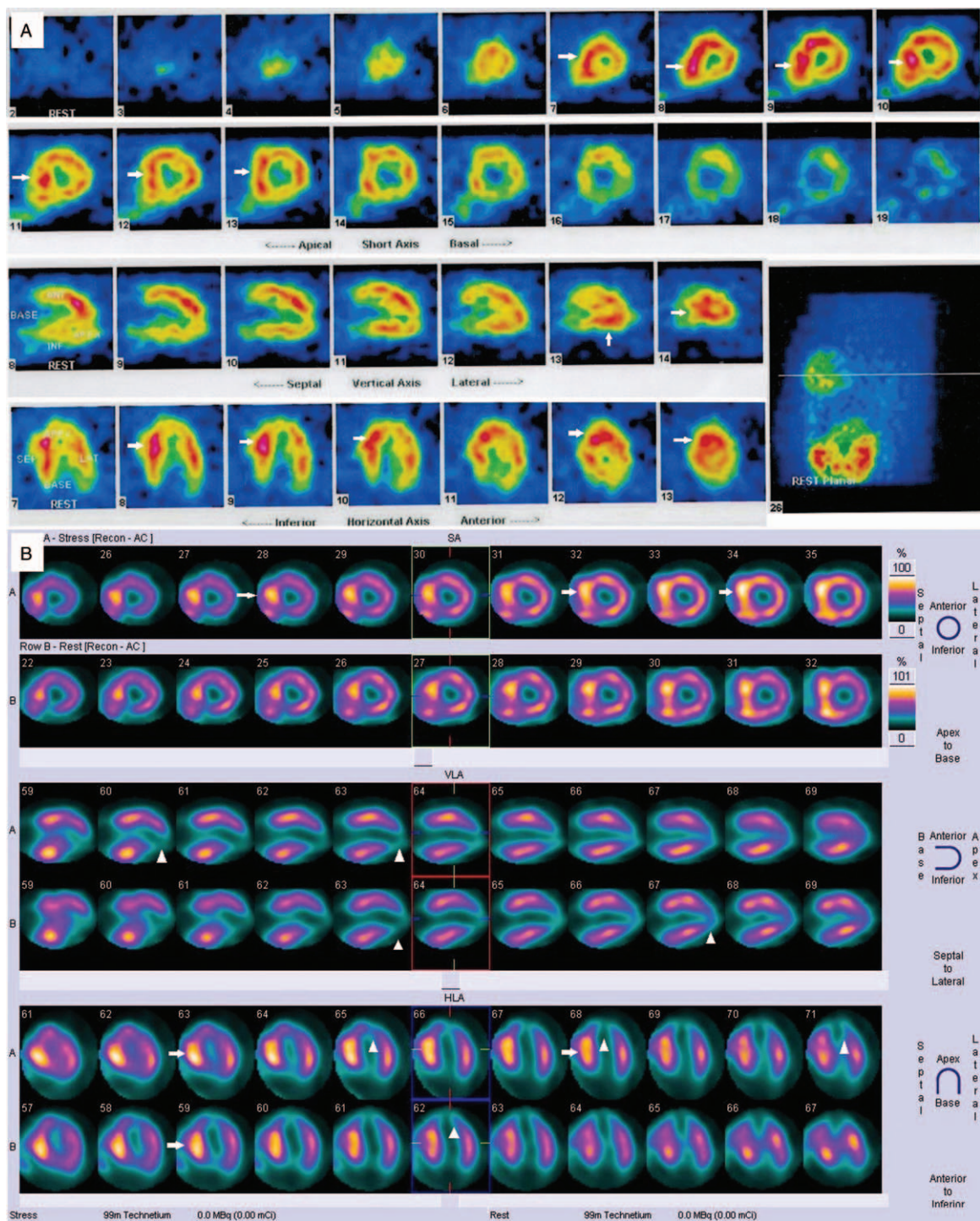


Figure 4. SPECT in the standard short-axis, horizontal long-axis, and vertical long-axis views. (A) SPECT from 10 years ago showed a significantly thickened left ventricular apex and ventricular septal wall and no significant reduction in segmental radioactive distribution. (B) SPECT during the present hospitalization showed uneven thickening of the LV wall and particularly significant thickening of the interventricular septum (white arrow). Top row: stress images clearly show left ventricular myocardial thickening. Part of the left ventricular inferior wall near the apex and the LV apex exhibit defects. Bottom row: the remaining images show that the above areas are not filled compared with the stress images (white triangle). LV=left ventricular, SPECT=single-photon emission computed tomography.

likely to cause limitations in apical coronary blood flow, which are responsible for the relatively ischaemic state of the myocardium under such conditions, in the absence of coronary artery stenosis.^[10] Moreover, histological examination of the hypertrophic apical myocardium surrounding the aneurysm reveals

extensive replacement of the myocardial tissue with fibrous tissue, including hypertrophic myocardial fibres.^[17] In apical HCM, sustained cavity obliteration, hypertrophy, and ischaemia are important pathophysiological conditions that are considered to be jointly related to the development of aneurysms.^[14] Matsubara

et al. investigated 46 patients with apical HCM and estimated the severity of cavity obliteration in the apical portion of the left ventricle and correlated it with various clinical findings, including apical aneurysms. The severe cavity obliteration group exclusively comprised 11 patients (100%) with apical aneurysms. Of the 11 patients, 10 exhibited irreversible defects on the exercise SPECT with thallium-201. All patients with moderate cavity obliteration showed reversible defects, and no patient with no/mild cavity obliteration showed any defects. Left ventriculography did not reveal cavity obliteration in our patient, but he exhibited irreversible defects on exercise SPECT with technetium 99. As myocardial necrosis markers were observed to continuously rise, subendocardial predisposition to ischaemic necrosis and fibrotic replacement, as determined by LGE and the observation of myocardial perfusion defects by SPECT, may explain the pathogenesis in the present case. Until now, the mechanism by which the development of LV apical aneurysms produces the observed ECG abnormalities is unclear.

Midventricular obstructive HCM associated with acute myocardial infarction and a left ventricular apical aneurysm has been reported.^[18] Non-obstructive HCM in association with an apical aneurysm along with cardiac-enzyme elevation has rarely been reported. For the present patient, it is interesting to note that the myocardial perfusion deficits were detected at the apex myocardial cells on delayed enhancement by MRI, whereas the entire epicardial coronary artery was free of apparent lesions on coronary angiography. Considering the course and range of myocardial blood flow in the coronary tree, we speculate that HCM caused myocardial necrosis and/or fibrosis in the patient. Furthermore, the persistent, significant and largely irreversible ischaemia determined by SPECT during exercise also supports a largely necrotic myocardium. Because our patient displayed elevated cardiac enzymes in the progressed phase of his illness, we inferred that the apical aneurysm originated from a recurrent acute coronary artery event, such as mechanical compression of the coronary artery or coronary microcirculation by increased pressure overload and systolic myocardial wall stress.^[18]

LV apical aneurysms in HCM patients are subject to misdiagnosis due to their nonspecific symptoms and are improperly treated when they are not recognized. Echocardiography is the most important modality for the diagnosis of HCM, but it is limited in the assessment of apical aneurysms and proved unreliable in detecting small ventricular aneurysms.^[7] Pennacchini's study examined serial ECGs of patients with HCM who gradually developed apical remodelling during a 9-year electrocardiographic follow-up.^[7] Various electrocardiographic patterns have been suggested as characteristic or at least suggestive of ventricular aneurysms. The recognition that progressive ECG changes develop along with apical remodelling makes ECG a useful tool for raising the clinical suspicion of apical aneurysms in HCM patients.^[7] Other imaging tests, such as cardiac MRI or LV angiography, can be used to diagnose this disease or to confirm clinical suspicion. Moon et al^[19] reported that LGE could reflect myocardial damage and predict prognosis in HCM patients. In our study, the diagnosis of HCM was confirmed after an additional MRI was performed and showed delayed enhancement that was suggestive of myocardial infarction or/and fibrosis.

Although many cases of HCM are asymptomatic and do not exhibit any complications, therapeutic approaches must be adapted for each patient. There are no formal guidelines for the management of patients with HCM. Chronic oral anticoagulation treatment is recommended in patients with LV thromboembolism. In cases of symptomatic ventricular arrhythmia in the

context of impaired systolic function, antiarrhythmic agents or implantable cardiac defibrillators are indicated for the prevention of a sustained event and potentially lethal arrhythmia.

The prognosis of HCM is determined by its complications. Early detection of apical aneurysms is extremely important, because patients with apical aneurysms are a high-risk subgroup with an unfavorable clinical course that is often punctuated by major arrhythmias, embolic stroke, and heart failure.^[20] Areas of hyperenhancement are observed by MRI in HCM patients. The extent of hyperenhancement is associated with the progression of the disease and the clinical risk of sudden death.^[19] HCM patients with LV apical aneurysms are at high risk for arrhythmic sudden death and thromboembolic events.^[12] Rate of HCM-related deaths combined with life-saving aborted disease-related events was 6.4%/year, 3-fold greater than the patients without aneurysms ($P < .001$).^[12] In our present report, the patient did not exhibit clinical manifestations of heart failure had a relatively stable LV ejection fraction >10 years; he was administered beta-blockers and angiotensin converting enzyme inhibitors to treat hypertension and prevent HF as well as aspirin for anti-coagulation treatment, as he had no malignant arrhythmias. With optimal management, his baseline functional status was preserved, and he was able to perform daily living activities without difficulty.

In conclusion, apical aneurysms in patients with HCM represent an under-recognized but clinically important subset of HCM patients. Echocardiography is the most commonly used imaging tool for the initial diagnosis and monitoring of HCM, but apical aneurysms may be frequently missed by echocardiography because of poor image quality at the LV apex. The 12-lead ECG may allow non-invasive evaluation of these patients and compensate for the limitations of echocardiography. Clinicians and, specifically, echocardiographers must pay special attention to the electrocardiogram to detect the frequently overlooked apical aneurysms in HCM patients. Our case indicates that HCM patients who develop LV apical aneurysms may exhibit distinctive ECG or SPECT changes and increases in myocardial necrosis markers along with apical remodelling. Elevated cardiac markers suggest that myocardial necrosis may play a very important role in the pathophysiology of LV apical aneurysms.

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References

- [1] Maron BJ, McKenna WJ, Danielson GK, et al. American College of Cardiology/European Society for Cardiology clinical expert consensus document on hypertrophic cardiomyopathy. A report of the American College of Cardiology task force on clinical expert consensus documents and the European Society for Cardiology Committee for Practice Guidelines Committee to develop an expert consensus document on hypertrophic cardiomyopathy. *J Am Coll Cardiol* 2003;42:1687–713.
- [2] Yamaguchi H, Ishimura T, Nishiyama S, et al. Hypertrophic non-obstructive cardiomyopathy with giant negative T waves (apical hypertrophy): ventriculographic and echocardiographic features in 30 patients. *Am J Cardiol* 1979;44:401–12.

- [3] Cecchi F, Olivetto I, Gistri R, et al. Coronary microvascular dysfunction and prognosis in hypertrophic cardiomyopathy. *N Engl J Med* 2003;349:1027–35.
- [4] Zenovich AG, Lesser JR, Hanna CA, et al. Identical twins with hypertrophic cardiomyopathy and apical aneurysm. *Am J Cardiol* 2006;97:1109.
- [5] Zenovich AG, Lesser JR, Casey SA, et al. Hypertrophic cardiomyopathy with apical aneurysm. *Circulation* 2004;110:e450.
- [6] Rickers C, Wilke NM, Jerosch-Herold M, et al. Utility of cardiac magnetic resonance imaging in the diagnosis of hypertrophic cardiomyopathy. *Circulation* 2005;112:855–61.
- [7] Pennacchini E, Musumeci MB, Conte MR, et al. Electrocardiographic evolution in patients with hypertrophic cardiomyopathy who develop a left ventricular apical aneurysm. *J Electrocardiol* 2015;48:818–25.
- [8] Amano Y, Takayama M, Kumita S. Magnetic resonance imaging of apical left ventricular aneurysm and thinning associated with hypertrophic cardiomyopathy. *J Comput Assist Tomogr* 2008;32:259–64.
- [9] Maron MS, Finley JJ, Bos JM, et al. Prevalence, clinical significance, and natural history of left ventricular apical aneurysms in hypertrophic cardiomyopathy. *Circulation* 2008;118:1541–9.
- [10] Webb JG, Sasson Z, Rakowski H, et al. Apical hypertrophic cardiomyopathy: clinical follow-up and diagnostic correlates. *J Am Coll Cardiol* 1990;15:83–90.
- [11] Shenoy C, Maron MS. Hypertrophic cardiomyopathy with left ventricular apical aneurysm in brothers. *Am J Cardiol* 2011;108:612–3.
- [12] Rowin EJ, Maron BJ, Haas TS, et al. Hypertrophic cardiomyopathy with left ventricular apical aneurysm: implications for risk stratification and management. *J Am Coll Cardiol* 2017;69:761–73.
- [13] Lazaros G, Kouvousis N, Kotsanis A, et al. Apical hypertrophic cardiomyopathy with midventricular obstruction and apical aneurysm. *Int J Cardiol* 2007;114:E45–7.
- [14] Matsubara K, Nakamura T, Kuribayashi T, et al. Sustained cavity obliteration and apical aneurysm formation in apical hypertrophic cardiomyopathy. *J Am Coll Cardiol* 2003;42:288–95.
- [15] Morita Y, Kato T, Okano M, et al. A rare case of hypertrophic cardiomyopathy with subendocardial late gadolinium enhancement in an apical aneurysm with thrombus. *Case Rep Radiol* 2014;2014:780840.
- [16] Mocumbi AO, Ferreira MB, Sidi D, et al. A population study of endomyocardial fibrosis in a rural area of Mozambique. *N Engl J Med* 2008;359:43–9.
- [17] Akutsu Y, Shinozuka A, Huang TY, et al. Hypertrophic cardiomyopathy with apical left ventricular aneurysm. *Jpn Circ J* 1998;62:127–31.
- [18] Sato Y, Matsumoto N, Matsuo S, et al. Mid-ventricular hypertrophic obstructive cardiomyopathy presenting with acute myocardial infarction. *Tex Heart Inst J* 2007;34:475–8.
- [19] Moon JC, McKenna WJ, McCrohon JA, et al. Toward clinical risk assessment in hypertrophic cardiomyopathy with gadolinium cardiovascular magnetic resonance. *J Am Coll Cardiol* 2003;41:1561–7.
- [20] Maron BJ, Braunwald E. Evolution of hypertrophic cardiomyopathy to a contemporary treatable disease. *Circulation* 2012;126:1640–4.