Hypertrophic Cardiomyopathy

10

Hypertrophic cardiomyopathy (HCM) is a genetic cardiac disease characterized by diffuse or segmental left ventricle (LV) hypertrophy associated with a nondilated ventricular chamber, in the absence of other cardiac or systemic disease that might be capable of producing the same degree of hypertrophy [1]. It is an important cause of sudden cardiac death in any age group. The prevalence of HCM is approximately 0.2–0.5 % of the general population.

Pathologic hallmarks of HCM are myocyte disarray and interstitial fibrosis [2]. HCM is inherited as an autosomal dominant trait and is caused by mutations in a sarcomeric gene which encodes protein components of the cardiac sarcomeres.

HCM can be seen as part of certain genetic and metabolic syndromes. These include Noonan syndrome (associated with pulmonary valve dysplasia and septal defects), mitochondrial myopathies, glycogen storage diseases (type II Pompe disease), as well as other rare conditions. In older patients, other systemic diseases associated with left ventricular hypertrophy (LVH) include hypertension, Friedrich ataxia, pheochromocytoma, neurofibromatosis, tuberous sclerosis, amyloidosis, lentiginosis (referring to the presence of lentigines or spotted areas on the skin due to sun exposure), and Fabry disease, a rare X-linked autosomal recessive metabolic storage disorder caused by a lack of lysosomal a-galactosidase [3].

Imaging plays a role in detecting HCM, characterizing its pattern (phenotype), classifying disease severity, and providing risk stratification criteria for sudden cardiac death. Echocardiography is the conventional imaging modality to screen for this condition, as it can characterize the pattern and distribution of increased LV wall thickness. However, it can underestimate the degree of LV hypertrophy, especially at the apical endocardial border.

Cardiac MRI using delayed gadolinium-enhancement technique provides information regarding the location and extent of fibrosis and is considered the examination of choice to establish the diagnosis of HCM when echocardiography is inconclusive. It allows multiplanar imaging which has the advantages of allowing complete coverage of the myocardium and better characterization of the pattern and distribution of LV hypertrophy.

Cardiac CT is not routinely used in patients with HCM since it is associated with radiation exposure. However, CT can be useful in those patients in whom detailed anatomy of the coronary arteries is needed and in patients with contraindications to MRI such as a pacemaker or aneurysm clips. The spatial resolution of CT is usually superior to MRI, allowing exquisite, noninvasive coronary artery angiography. Cardiac CT also provides comprehensive anatomical and functional information about the heart chambers and myocardium [4]. In retrospectively gated cardiac CT acquisition, systolic anterior motion (SAM) of the mitral valve can be easily assessed. In addition, delayed enhancement CT scanning provides information about myocardial scarring and fibrosis similar to that provided by MRI [5, 6]. CT has been reported to be useful in the assessment of patients undergoing septal alcohol ablation by enabling depiction of the exact extent and location of septal hypertrophy, systolic anterior motion of the mitral valve, and mitral valve leaflet–septal contact as well as septal perforator anatomy, which is of utmost importance in guiding septal ablation [7, 8]. See Table 10.1 for the utility of CT in the evaluation of HCM.

It should be noted that myocardial bridging is common in patients with apical hypertrophy and has been reported in the majority of patients presenting with typical or

Table 10.1 The utility of CT in the evaluation of HCM

Distribution of hypertrophy
LV maximal wall thickness
LV outflow tract obstruction
Presence of fibrosis (delayed enhancement on CT)
Presence of systolic anterior motion of the mitral valve
Coronary anatomy
Evaluation of septal perforator arteries before alcohol septal ablation

W. Mazur et al., *CT Atlas of Adult Congenital Heart Disease*,
DOI 10.1007/978-1-4471-5088-6_10, © Springer-Verlag London 2013

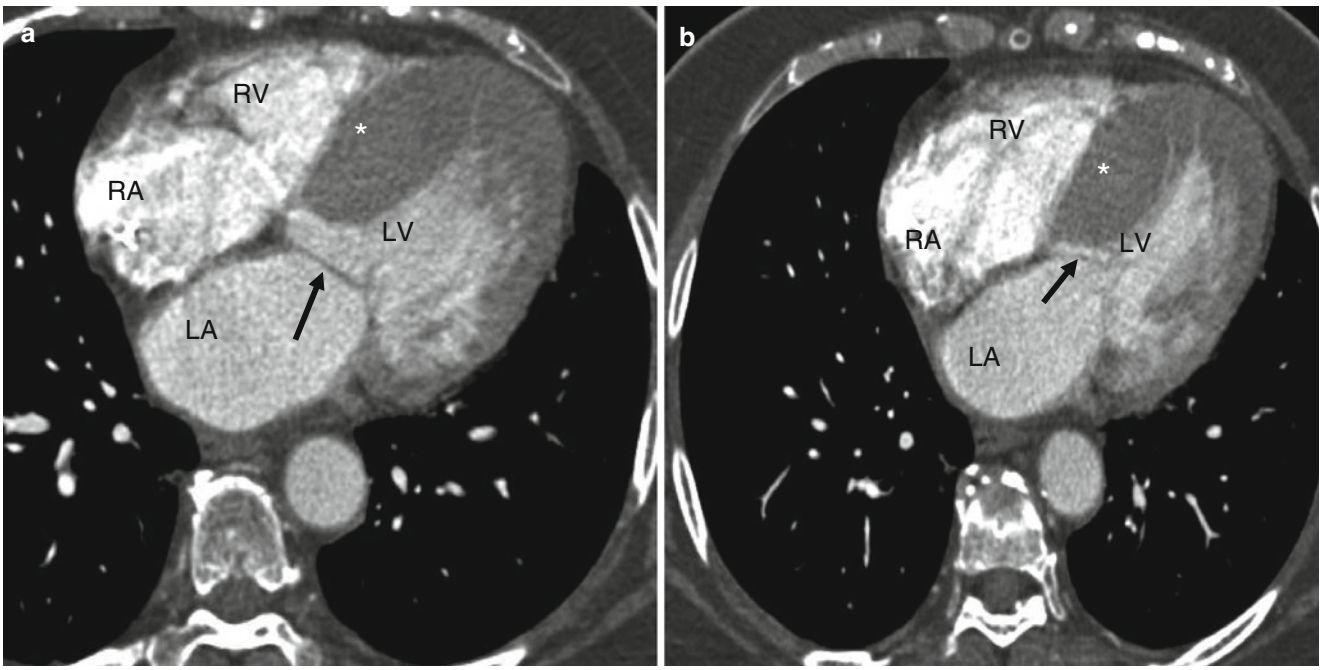

Fig. 10.1 Representation of the asymmetric (septal) phenotype of HCM: panel (**a**) is an axial CT reconstructed in diastole. Panel (**b**) is an axial CT reconstructed in end systole in the same patient. In panel (a), note the markedly increased thickness (>30 mm) of the apical septal wall (*asterisk*) of the left ventricle (LV), with a thickened mitral leaflet (*black arrow*). This meets the diagnostic criterion of HCM, which is LV wall thickness greater than or equal to 15 mm in the end-diastolic phase. Panel (b) demonstrates the systolic anterior motion of the mitral leaflet (*black arrow* in panel b) which causes left ventricular outflow obstruction. *LA* left atrium, *RA* right atrium, *RV* right ventricle

atypical chest pain [9]. It can lead to myocardial ischemia by narrowing the intramyocardial segment of the affected coronary artery, which can be especially well seen on CT.

10.1 Phenotype Analysis

HCM is diagnosed when the LV wall thickness (typically the septum) is ≥15 mm in the end-diastolic phase [10]. It can be classified based on the distribution of the wall hypertrophy into the following phenotypes: asymmetric (Fig. 10.1) with and without dynamic LV outflow tract (LVOT) obstruction, apical (Fig. 10.2), midventricular (Fig. 10.3), and symmetric, mass-like, and noncontiguous [9] (Figs. 10.4a and 10.5) (see Table 10.2). HCM does not involve the basal or inferolateral segments of the LV, a helpful feature in differentiating HCM from other causes of LV hypertrophy [11]. Occasionally apical infarct can be identified by CT in the absence of coronary artery disease as a result of constriction of a distal LAD bridge (Fig. 10.6, black arrow). Recently, left ventricular myocardial crypts have been identified as a distinctive morphologic expression of HCM, occurring in patients with and without hypertrophy. Crypts may identify individual HCM family members before development of typical phenotype. Crypts are confined to the basal LV, most commonly in the ventricular septum or posterior LV free wall [12]. Example of LV crypt is presented in Fig. 10.6 (white arrow).

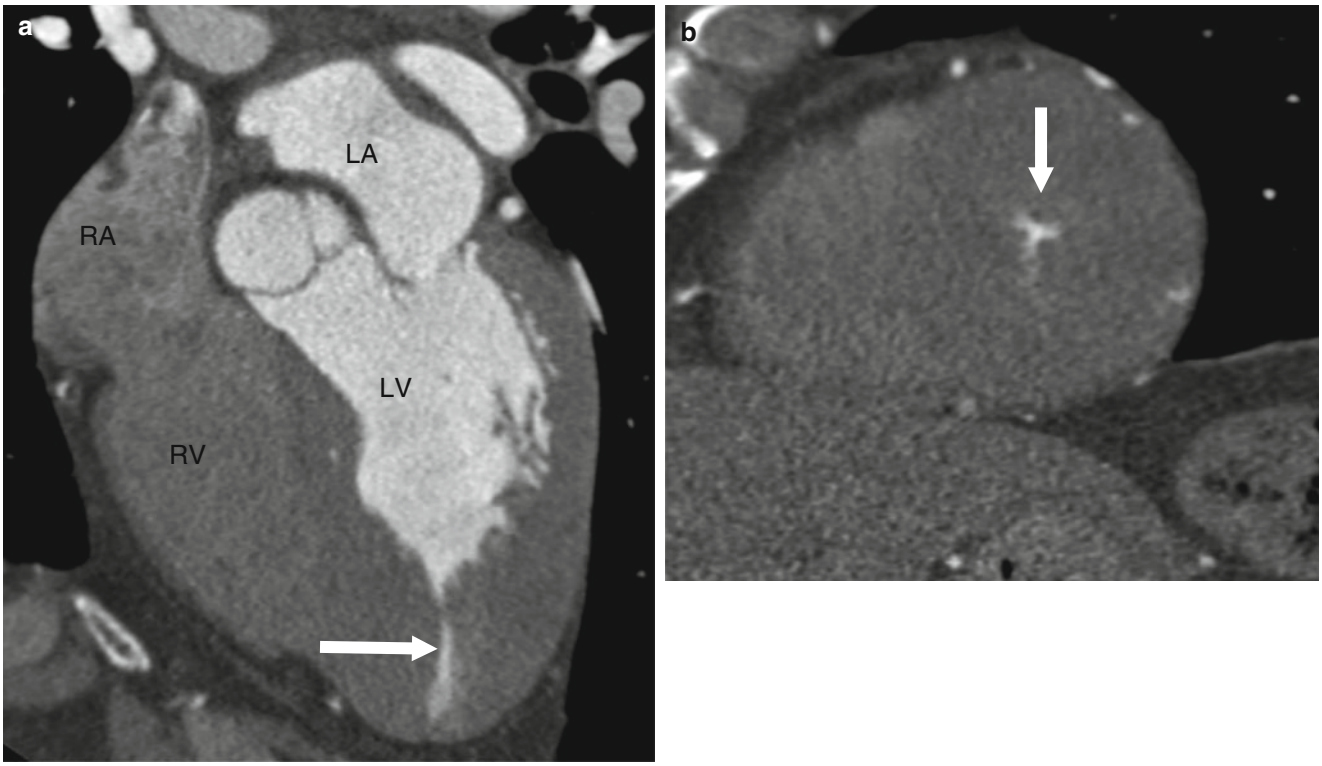

Fig. 10.2 An apical variant of HCM. Panel (**a**) is an apical four-chamber view demonstrating the thickened apical myocardium and near cavity obliteration at end systole. Panel (**b**) is a short-axis cut at the level of the apex demonstrating the apical hypertrophy and almost complete obliteration of the left ventricle apical lumen (*arrow*) at end systole. *RA* right atrium, *RV* right ventricle, *LA* left atrium, *LV* left ventricle

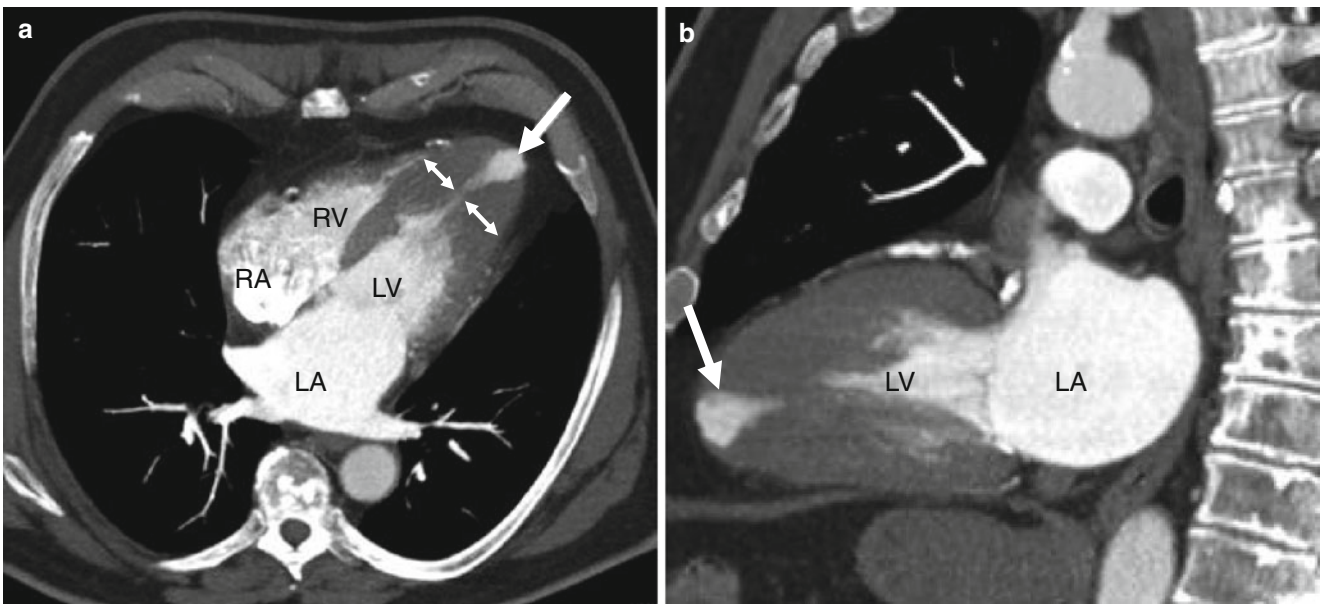

Fig. 10.3 Midventricular HCM. Panel (**a**) is a four-chamber CT orientation, while panel (**b**) is a two-chamber CT view. Each shows concentrically thickened myocardium (2.5 cm maximum thickness, *double-headed arrows*) located in the middle third of the left ventricle (*LV*) walls. There is an acquired apical diverticulum (*white arrows*) caused by the abnormal physiology of the LV. *LA* left atrium, *RA* right atrium, *RV* right ventricle

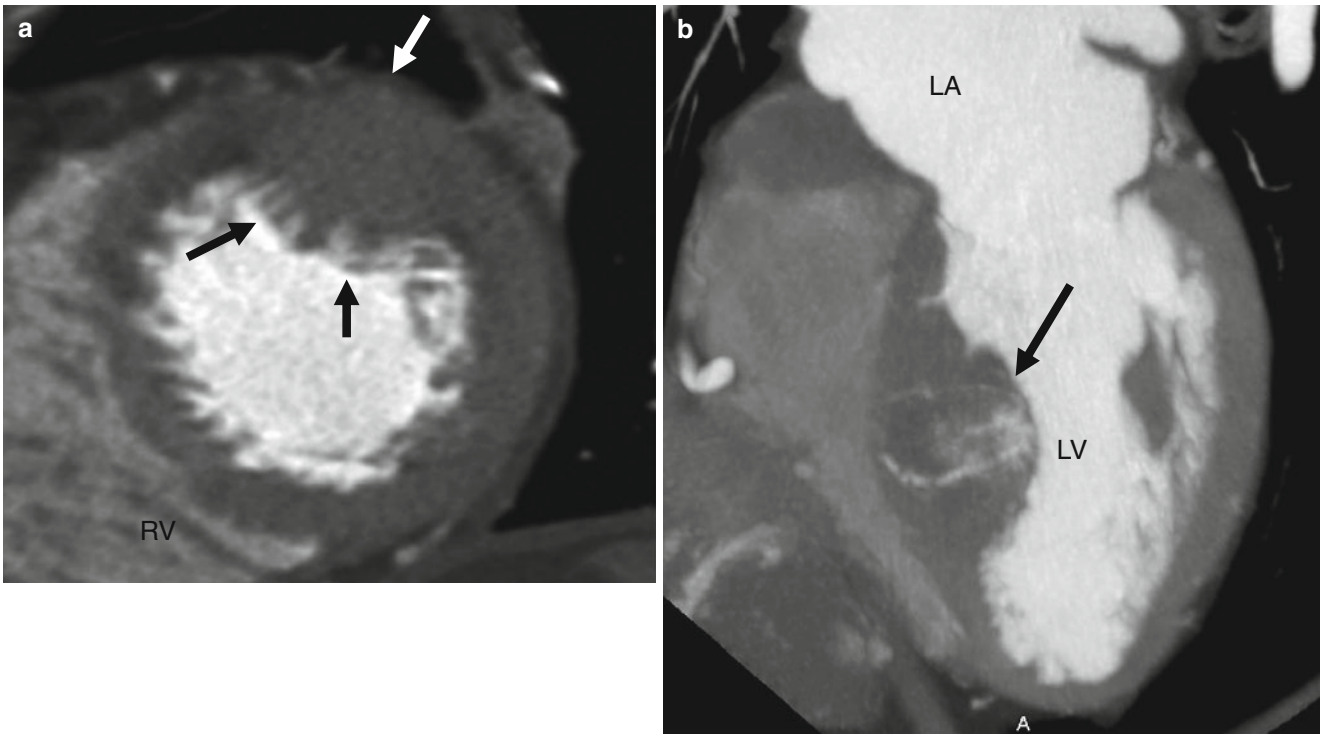

Fig. 10.4 Mass-like HCM. Panel (**a**), a short-axis CT view, shows LV hypertrophy with mass-like bulging at the apical anterolateral wall (surrounded by *black* and *white arrows*). This form of HCM needs to be differentiated from a neoplastic mass. For comparison, panel (**b**) is a 4-chamber CT image of a patient with an intramyocardial metastasis (*black arrow*). Note the areas of patchy contrast enhancement of the metastatic mass which represents vascularization of the tumor. While mass-like HCM shows characteristics and enhancement similar to normal myocardium, tumors possess attenuation values different from the surrounding myocardium and also commonly demonstrate enhancement characteristics of increased vascularity such as that seen in panel (b). *LV* left ventricle, *RV* right ventricle (Panel **a** reproduced from Chun et al. [3]. With kind permission of Radiological Society of North America, Oak Brook, IL)

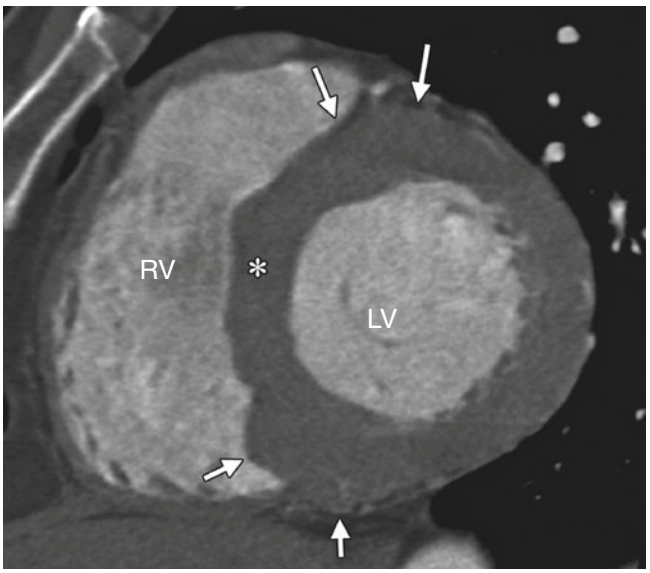

Fig. 10.5 Noncontiguous HCM. A short-axis CT image demonstrating noncontiguous left ventricular hypertrophy of the anteroseptal and inferoseptal walls (*arrows*). The septal wall thickness is nearly normal (*asterisk*). *LV* left ventricle, *RV* right ventricle (Reproduced from Chun et al. [3]. With kind permission of Radiological Society of North America, Oak Brook, IL)

Table 10.2 Phenotypic classifications of HCM

HCM phenotypes
Asymmetric with or without LV outflow obstruction
Apical
Symmetric
Mass-like
Noncontiguous

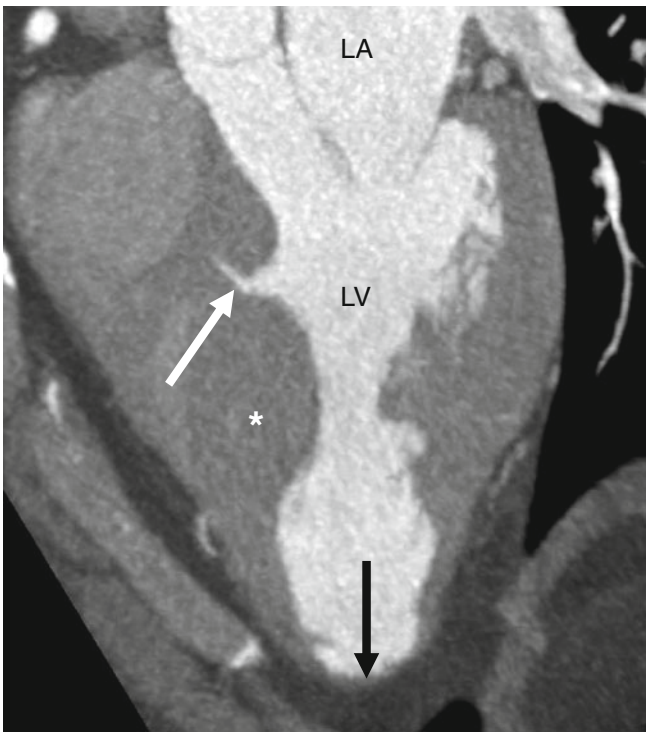

Fig. 10.6 A four-chamber reconstruction in an HCM patient demonstrating wall thinning (*black arrow*) resulting from prior apical infarct. This patient has no coronary artery disease and the likely cause of infarct is a result of constriction of a distal left anterior descending myocardial bridge. Note the presence of a left ventricular (LV) crypt in the inferoseptal segment (*white arrow*). Reports suggest that an LV crypt precedes development of LV hypertrophy and as such it may identify mutation carriers before full phenotype development becomes apparent. The *asterisk* marks the markedly thickened septal myocardium. *LA* left atrium, *LV* left ventricle

10.2 Risk Stratification Criteria

Contrast-enhanced CT enables the diagnosis of HCM by enabling accurate measurements of the myocardial thickness and demonstration of the classic spade-shaped ventricular cavity during systole. In addition, it allows identification of risk stratification criteria associated with sudden cardiac death which include (*a*) LV maximal wall thickness 30 mm or more, (*b*) marked LV outflow tract obstruction (best assessed with echocardiography; CT can suggest the presence, but cannot confirm it or grade its severity), (*c*) decreased LV ejection fraction, (*d*) presence of fibrosis, and (*e*) presence of a perfusion defect indicating ischemia. Global LV functional volume analysis and ejection fraction are acquired using end-diastolic and end-systolic reformats of the CT data. Delayed myocardial enhancement can be used to characterize perfusion defects and fibrosis [11]. The presence of narrowing of the intramyocardial segment of a coronary artery, which can lead to myocardial ischemia, can also be identified on CT. In addition, CT can provide information on LV volume and the degree of mitral regurgitation [9].

10.3 Differential Diagnoses

The differential diagnoses of HCM include infiltrative diseases such as amyloidosis and sarcoidosis, which cause restrictive cardiomyopathy as well as LV hypertrophy due to aortic stenosis or hypertension.

In amyloidosis, amyloid protein is deposited in the myocardium, causing diffuse, symmetrical thickening of both ventricles and the septum and this thickening may involve the interatrial septum and atria.

Sarcoidosis, characterized by noncaseating granulomas, usually involves the interventricular septum (particularly the basal portion) and the lateral LV wall. Right ventricular infiltration with sarcoidosis is rare. In addition, cardiac sarcoidosis is an unusual finding in the absence of signs of other systemic involvement such as mediastinal lymphadenopathy or pulmonary parenchymal disease.

With aortic stenosis and systemic hypertension (compensatory LV hypertrophy), the LV wall undergoes compensatory hypertrophy caused by pressure overload and thus demonstrates a more concentric pattern of hypertrophy. Differentiation between HCM and compensatory hypertrophy can be difficult. In compensatory hypertrophy, systolic function is often normal and the LV wall rarely exceeds 15 mm in maximal thickness and rarely shows increased enhancement with contrast.

Occasionally, metastatic malignancy can present as focal hypertrophy (mimicking mass-like HCM) (Fig. 10.4b).

References

1. Maron BJ, McKenna WJ, Danielson GK, Kappenberger LJ, Kuhn HJ, Seidman CE, et al. Task Force on Clinical Expert Consensus Documents. American College of Cardiology, Committee for Practice Guidelines. European Society of Cardiology American college of Cardiology/European society of cardiology clinical expert consensus document on hypertrophic cardiomyopathy. A report of the american college of cardiology foundation task force on clinical expert consensus documents and the european society of cardiology committee for practice guidelines. J Am Coll Cardiol. 2003;42:1687–713.
2. Soor GS, Luk A, Ahn E, Abraham JR, Woo A, Ralph-Edwards A, et al. Hypertrophic cardiomyopathy: current understanding and treatment objectives. J Clin Pathol. 2009;62:226–35. doi:10.1136/jcp.2008.061655.
3. Chun EJ, Choi SI, Jin KN, Kwag HJ, Kim YJ, Choi BW, et al. Hypertrophic cardiomyopathy: assessment with MR imaging and multidetector CT. Radiographics. 2010;30:1309–28. doi:10.1148/rg.305095074.
4. Ghersin E, Lessick J, Litmanovich D, Engel A, Reisner S. Comprehensive multidetector CT assessment of apical hypertrophic

cardiomyopathy. Br J Radiol. 2006;79:e200–4. doi:10.1259/bjr/53601277.
5. Saito H, Naito H, Takamiya M, Hamada S, Imakita S, Ohta M. Late enhancement of the left ventricular wall in hypertrophic cardiomyopathy by ultrafast computed tomography: a comparison with regional myocardial thickening. Br J Radiol. 1991;64:993–1000.
6. Shiozaki AA, Santos TS, Artega E, Rochitte CE. Images in cardiovascular medicine. myocardial delayed enhancement by computed tomography in hypertrophic cardiomyopathy. Circulation. 2007;115:e430–1.
7. Okayama S, Uemura S, Soeda T, Horii M, Saito Y. Role of cardiac computed tomography in planning and evaluating percutaneous transluminal septal myocardial ablation for hypertrophic obstructive cardiomyopathy. J Cardiovasc Comput Tomogr. 2010;4:62–5. doi:10.1016/j.jcct.2009.10.004.
8. Ghersin E, Soto V, Heldman AW. Multidetector computerized tomography can guide and document alcohol septal ablation in hypertrophic obstructive cardiomyopathy. Circulation. 2011;123:e5–7. doi:10.1161/CIRCULATIONAHA.110.975599.
9. Chen CC, Chen MT, Lei MH, Hsu YC, Chung SL, Sung YJ. Assessing myocardial bridging and left ventricular configuration by 64-slice computed tomography in patients with apical hypertrophic cardiomyopathy presenting with chest pain. J Comput Assist Tomogr. 2010;34:70–4.
10. Maron BJ. Hypertrophic cardiomyopathy: a systematic review. JAMA. 2002;287:1308–20.
11. Otto CM. Textbook of clinical echocardiography. Philadelphia: Saunders/Elsevier; 2009. p. 217–9.
12. Maron MS, Rowin EJ, Lin D, Appelbaum E, Chan RH, Gibson CM, et al. Prevalence and clinical profile of myocardial crypts in hypertrophic cardiomyopathy. Circ Cardiovasc Imaging. 2012;5(4):441–7. doi:10.1161/CIRCIMAGING. 112.972760.