Chapter 1

# Echocardiography Findings in Common Primary and Secondary Cardiomyopathies

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Additional information is available at the end of the chapter

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## 1. Introduction

Cardiomyopathy is a heterogeneous group of disorders of varying etiology. Heart failure from systolic and/or diastolic cardiac dysfunction is common to all. Certain disorders are distinguished by life threatening arrhythmia. Onset of symptoms may be acute or progress from preclinical to symptomatic state over time and at a variable rate. Early recognition permits therapeutic intervention thereby retarding clinical progression and in some reversal or arrest of pathologic state. Echocardiography being the most frequently used and readily available cardiac imaging technique has established itself as the cardiac imaging modality of choice in diagnosis and longitudinal follow up of patients with cardiomyopathy. Complementary information from other imaging techniques, e.g., tissue characterization with cardiac MRI in iron overload states and evaluation of coronary anatomy with cardiac CT as in some cases of dilated cardiomyopathy, usually follows recognition of cardiomyopathy on echocardiogram.

An understanding of conventional echocardiogram and knowledge of novel applications of existing methods and emerging imaging echo techniques is important for effective clinical use of echocardiography.

### 1.1. Standard 2-D and M-mode echocardiogram

Standard echocardiogram includes analysis of myocardial and valvular structure, chamber quantification and estimation of function based on qualitative assessment and quantification by 2-D and M-mode echocardiography. Blood flow dynamics through different cardiac chambers and heart valves is assessed using spectral and color Doppler methods. Through prior work, pressure gradient across heart valves can be derived from measured flow velocity by using the modified Bernoulli equation ($4V^2$); flow velocity is directly measured from

spectral Doppler display. Color Doppler techniques are useful in analyzing regurgitant valve lesions and in drawing attention to turbulent flow through stenotic valves as well as abnormal flow between cardiac chambers as in cases of atrial or ventricular septal defect.

### 1.2. Three Dimensional Echocardiography (3DE)

In patients with adequate imaging window, 3DE provides more accurate chamber quantification (Figure-1). Left ventricular end-diastolic and end-systolic volumes derived from 3DE has been validated against cardiac MRI [1], which is the current reference standard for such measurements. In routine clinical practice important use of 3DE derived chamber quantification is in establishing an accurate baseline, and in longitudinal follow up of patients. In addition to chamber quantification and determination of global left ventricular function, automated quantification also permits contractile assessment at regional and segmental level. The graphical display of this contractile information is plotted as segmental change in volume over time. Discrepant timing of this segmental volume change over time has been used to assess left ventricular dyssynchrony as that seen in patients with left bundle branch block (LBBB) pattern on ECG (Figure-1). However, concerns with reproducibility in patients with low left ventricular ejection fraction have compromised the diagnostic utility of this parameter in selecting patients for cardiac resynchronization therapy [2].

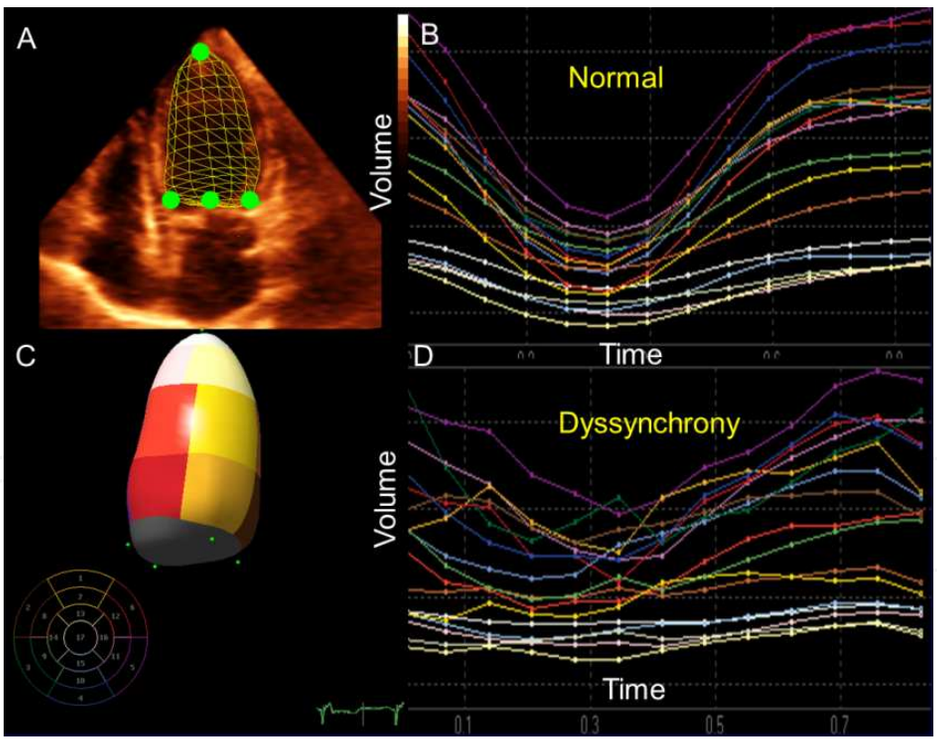


**Figure 1.** Panel-A: 3D data set of the heart is automatically cropped to display a 4-chamber and 2-chamber (not shown) projection of the heart. Left ventricular volume is tracked in end-diastole and end-systole from which volumetric LVEF is calculated. In panel-C segmental model of the heart is displayed. Each segment is color coded. Graphical display of the volume (y-axis) change over time (x-axis) is shown in panels-B and D. Each colored line corresponds to a segment of similar color in panel-C. In a normal heart all segments reach a minimum volume at the same time (panel-B). In panel-D there is a disarray of this time-volume curve signifying left ventricular dyssynchrony.

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### 1.3. Doppler tissue velocity and doppler strain

Modification of the spectral tissue Doppler technique with filters that display high amplitude and low velocity signal permits segmental interrogation of myocardium for both systolic and diastolic function. Tissue Doppler at the mitral annulus level has long been used to assess myocardial diastolic function. Reversal of high early diastolic velocity (E′) with diastolic velocity coinciding with atrial systole (A′) is a flow independent marker of diastolic impairment. An elevated ratio of early mitral inflow Doppler velocity (E) with early tissue Doppler velocity (E′) is considered a reliable sign of elevated left ventricular end diastolic pressure [3-4].

Color encoded display of myocardial velocities on a 2-D image of the LV permits parametric assessment of myocardial contraction and Doppler based interrogation of multiple myocardial segments in the same frame. The latter is used for estimation of myocardial velocity and strain (Figure-2). Myocardial velocity in the long axis determines myocardial displacement, which may be active contraction or passive motion from contraction of adjacent segments [5]. Hence, its usefulness is limited when assessing segmental function. On the other hand, Doppler-derived longitudinal and circumferential strain measures segmental myocardial lengthening or shortening (deformation), signifying active contraction of the interrogated segment [5]. Strain is a dimensionless index (change in length/original length) of myocardial mechanics. The technique has been used for determination of cardiomyopathy in hereditary conditions,

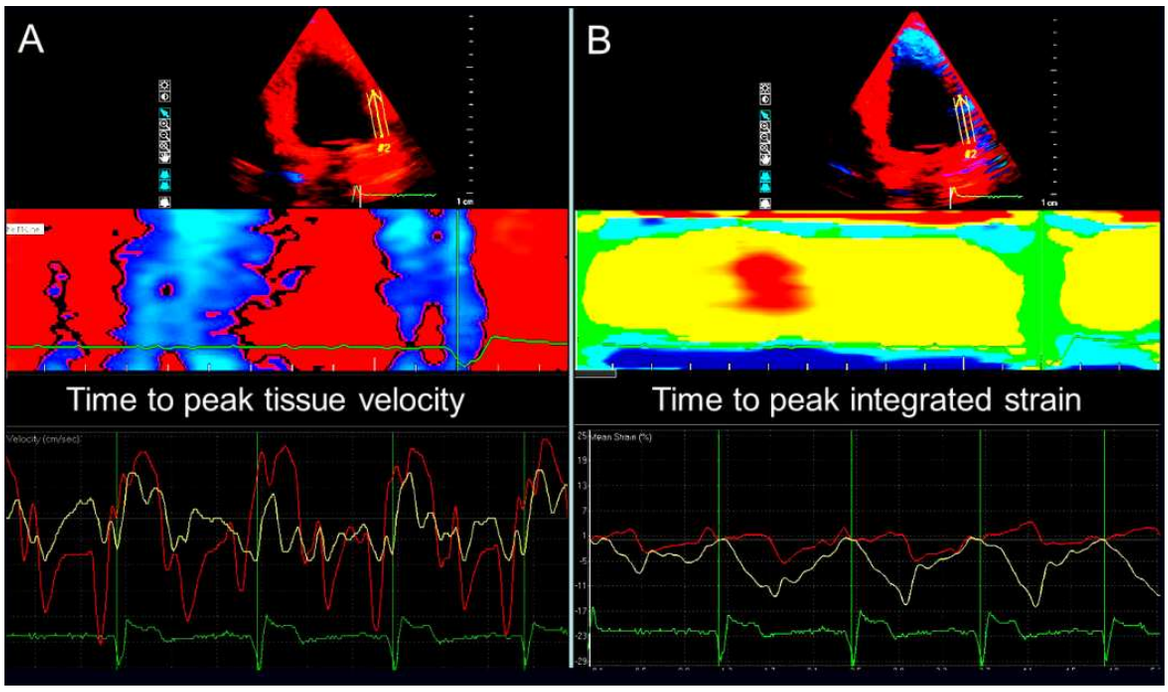


**Figure 2.** Color tissue Doppler derived tissue velocity (panel-A) and longitudinal strain (panel-B) is shown. Basal inferoseptum and lateral walls are interrogated. Panel-A: time (x-axis) to peak systolic tissue velocity (y-axis) measured from the onset of QRS (ECG displayed at the bottom of each panel in green color) of inferoseptum (red) is delayed when compared to the lateral wall (yellow). This signifies dyssynchrony. Longitudinal strain is shown in panel-B. Inferoseptum timing is again delayed. Note, however, that peak strain (strain is a negative value when measured in the long axis of the heart due to compression/shortening of the interrogated segment in systole) of inferoseptum is decreased signifying contractile dysfunction.

in differentiation of physiologic hypertrophy in elite athletes from pathologic variants [6, 23], in assessment of myocardial dyssynchrony [7], and in differentiating constrictive from restrictive physiology.

### 1.4. 2D or speckle strain and LV torsion

Doppler-based strain imaging is limited by angle dependency [8]. Innovation in imaging hardware and software now permit tissue-based measurement of segmental, regional and global myocardial function by determining tissue strain and torsion (Figure-3). The technique relies on good 2-D image quality for tracking tissue characteristics, termed "speckles", in regions of interest on a 2-D image through the entire cardiac cycle. To improve spatial resolution, image acquisition is performed at a slower frame rate contrasting with higher frame rate of Doppler-based techniques [9]. This may influence the accuracy of time dependent measurement of myocardial function as in milder forms of left ventricular dyssynchrony. Potentially valuable clinical information can be derived from speckle strain in a variety of cardiac disorders, including asymptomatic stages of cardiomyopathy [9].

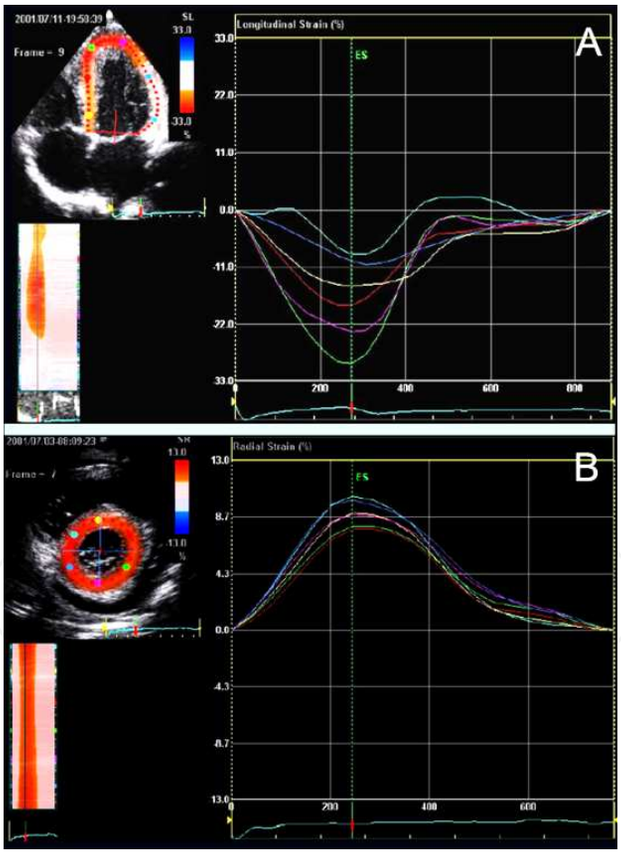


**Figure 3.** Speckle strain measurement inlongitudinal and radial direction is performed.In Panel-A, longitudinal strain is determinedat multiple levels from base to apex. Because contraction in longitudinal direction results in fiber shortening, strain values are negative. Segmental impairment of longitudinalstrain or contractility is present. In panel-B radial strain is depicted as a positive value due to fiber lengthening radially in systole. All segments at this level show normal contractility.LV torsion can be determined from the same data set.

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Ratio of basal clockwise rotation to apical counterclockwise when viewed from the apex is as a measure of left ventricle twist or torsion. It is produced by contraction of helically oriented myofibers. Left ventricle torsion is affected in both systolic and diastolic myocardial dysfunction. When compared to a normal population, left ventricle torsion is decreased in dilated cardiomyopathy and increased in patients with hypertrophic cardiomyopathy [10].

## 2. Echo findings in cardiomyopathies

For this review a modification of 1995 World Health Organization /International Society and Federation of Cardiology (WHO/ISFC) Task Force on the Definition and Classification of Cardiomyopathies [11] and 2006 American Heart Association classification of cardiomyopathic disorders [12] is used. Discussion on echocardiographic findings will be limited to more frequently encountered disorders and to conditions with unique echo features.

### 2.1. Modified classification of primary and secondary cardiomyopathies

**i.** Genetic:

- Hypertrophic cardiomyopathy (HCM)
- Arrhythmogenic right ventricular cardiomyopathy/dysplasia (ARVC/D)
- Left ventricular non compaction (LVNC)

**ii.** Mixed (pre-dominantly non genetic):

- Dilated cardiomyopathy (DCM)
- Restrictive cardiomyopathy (non hypertrophied and non dilated) (RCM)

**iii.** Acquired Primary and Secondary Cardiomyopathy:

- Inflammatory myocarditis
- Stress provoked (takotsubo cardiomyopathy)
- Peripartum cardiomyopathy
- Tachycardia induced cardiomyopathy
- Ischemic cardiomyopathy
- Valvular cardiomyopathy
- Hypertensive cardiomyopathy
- Metabolic cardiomyopathy including amyloidosis and hemochromatosis
- Toxic cardiomyopathy: Alcohol and anthracyclines
- Connective Tissue Disorders: RA, SLE, PAN, scleroderma

- Muscular dystrophies: Duchenne, Becker-type and myotonic dystrophy
- Neuromuscular disorder: Friedreich's ataxia, Noonan's syndrome and lentiginosis

## 3. Genetic cardiomyopathies

Echocardiography remains the cornerstone for the detection and longitudinal follow up of patients with genetic cardiomyopathy. Inherited cardiomyopathies may have autosomal dominant pattern of inheritance. As such, surveillance echocardiogram of asymptomatic family members may allow early detection and life saving therapeutic intervention.

### 3.1. Hypertrophic Cardiomyopathy (HCM)

#### *3.1.1. Introduction*

HCM is the most frequently encountered inherited cardiomyopathy. Echocardiography plays a central role in diagnosis of HCM and in elucidating the pathophysiology of this disorder.

#### *3.1.2. Features of HCM on standard echocardiogram:*

Key diagnostic features of HCM are apparent on standard echocardiogram and are described below.

**Distribution of left ventricular hypertrophy:**

Several morphologic variants are known. Asymmetrical septal hypertrophy is the most frequently encountered (Figure-4). Hypertrophy of more than one region of left ventricular wall and at times of right ventricular wall is also seen. In the apical variant of HCM, myocardial hypertrophy is confined to the apical region of the left ventricle. This type is more frequently encountered in non-Caucasians.

**Diagnostic criteria of Asymmetrical Septal Hypertrophy (ASH):**

Septal thickness of >15 mm and a septal to posterior free wall ratio (interventricular septum/posterior wall ratio) >1.3 are established echocardiographic criteria for the diagnosis of ASH [12]. However asymmetric left ventricular hypertrophy by itself is not pathognomonic of HCM as it may be encountered in a variety of congenital or acquired conditions, including systemic hypertension, aortic stenosis and cardiac amyloidosis [14].

**Left ventricular function:**

Systolic function is usually normal or above normal. Despite preservation of global left ventricular function [15], significant impairment of longitudinal contractile function is present with attenuation of annular velocities, longitudinal strain and strain rate (see below) [16]. Progressive myocardial fibrosis in advanced disease state is associated with impairment of systolic function, segmental myocardial thinning and left ventricle cavity enlargement [17]. Given myocardial characteristics, impaired myocardial relaxation is frequently observed [18].

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Echo methods of estimating left ventricular end-diastolic pressure (E/E' ratio) show heterogeneity and lack specificity in HCM [19].

**Systolic Anterior Motion (SAM) of mitral valve:**

Systolic anterior motion of the anterior mitral leaflet with or without obstruction to flow across the left ventricular outflow tract is highly suggestive of HCM (Figure-4). This finding has a specificity of > 90% [20]. Of note, SAM may also be encountered in hypercontractile states, following mitral valve repair, with anomalous papillary muscle insertion, in patients with anteroapical infarction, in takotsubo cardiomyopathy who have hyperkinesia of basal left ventricular segment and in elderly women with left ventricular hypertrophy and sigmoid shaped septum [21].

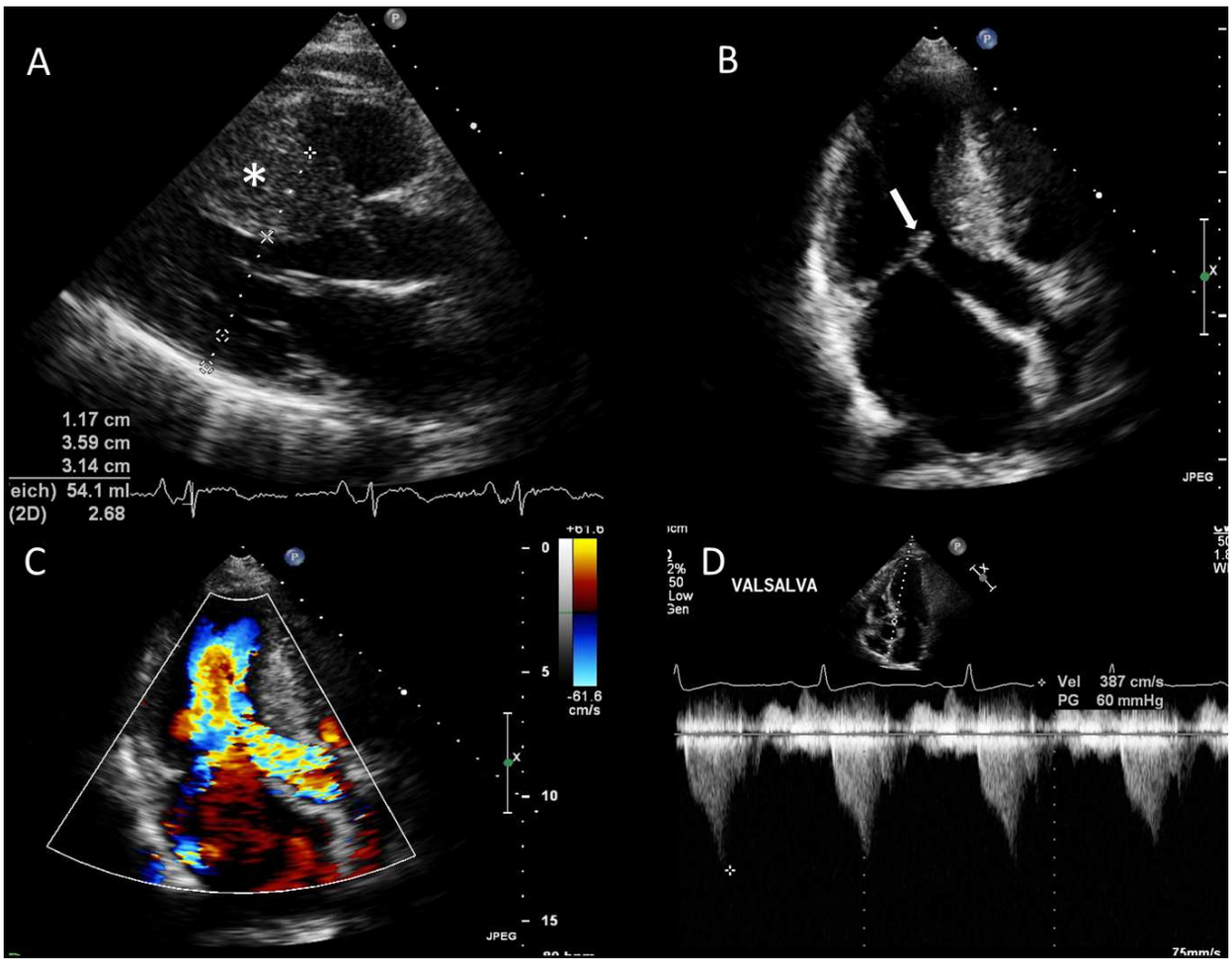


**Figure 4.** In panel A marked asymmetric septal hypertrophy (ASH) is noted (asterisk) in parasternal long axis display. Systolic anterior motion (SAM) of the mitral valve is seen in panel B (arrow). Turbulence of blood flow through the left ventricular outflow tract (LVOT) associated with posteriorly directed mitral regurgitation due to LVOT obstruction from SAM is present (panel C). Spectral Doppler through the LVOT confirms LVOT obstruction with a late peaking gradient of 60 mmHg (panel D). In this example Valsalva maneuver was used to confirm dynamic LVOT obstruction.

*3.1.3. Tissue doppler imaging and speckle strain*

Tissue Doppler and 2-D speckle techniques demonstrate impaired longitudinal velocity and strain even in non-hypertrophied myocardial segments. These indices of longitudinal fiber function are abnormal in inherited HCM even prior to grossly manifest left ventricular hypertrophy. The degree of functional impairment by these measures correlates with clinical outcome [22]. Furthermore, differentiation between pathologic and physiologic left ventricular hypertrophy is possible by documenting preserved longitudinal function in the latter which is impaired in HCM even when global left ventricular function is normal [23].

*3.1.4. Three dimensional echo*

A more accurate assessment of left ventricle mass and chamber volumes is made possible by 3DE. The clinical impact of this in routine clinical care is less apparent.

**3.2. Arrhythmogenic right ventricular cardiomyopathy/dysplasia**

*3.2.1. Introduction*

Arrhythmogenic right ventricular cardiomyopathy/dysplasia (ARVC/D) is a genetic cardiomyopathy with autosomal dominant inheritance. However, phenotypes with cutaneous manifestations have autosomal recessive inheritance. The disorder is pathologically characterized by fibrofatty infiltration of the right ventricle (RV) wall. In early stages, dysplasia is localized, affecting the RV inflow, RV outflow or RV apex. Progression to diffuse form is common. Clinical manifestation is with ventricular arrhythmias and RV systolic dysfunction [24-25].

*3.2.2. Echo diagnosis of ARVC/D*

Morphological and functional changes affecting the RV are divided into major and minor diagnostic criteria. In the proposed revision of ARVC/D task force document [26], right ventricle outflow tract (RVOT) long axis dimension of ≥ 32 mm (sensitivity/specificity: 75% and 95%, respectively), RVOT short axis dimension of ≥ 36 mm (sensitivity/specificity: 62% and 95%, respectively) and RV fractional area change of ≤33% (sensitivity/specificity: 55% and 95%, respectively) are considered as major criteria for the diagnosis of ARVC/D. Minor echo criteria are RVOT long axis dimension of ≥ 29 mm (sensitivity/specificity: 87% and 87%, respectively), RVOT short axis dimension of ≥ 32 mm (sensitivity/specificity: 80% and 80%, respectively) and RV fractional area change of ≤40% (sensitivity/specificity: 76% and 76%, respectively) [26]. Of interest, diastolic dimensions of the RV taken from the apical four-chamber view were least commonly enlarged [27]. Regional wall motion abnormality of the apex and anterior wall is seen in approximately 70% of patients [27]. Other frequent morphologic abnormality include trabecular derangement, occurring in 54%, hyper-reflective moderator band in 34% and sacculations of RV free wall in 17% [27]. Given its predominant autosomal dominant inheritance screening of family members is recommended.

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### 3.3. Left ventricular non-compaction

#### *3.3.1. Introduction*

Left ventricular non-compaction (LVNC) is a distinct cardiomyopathy resulting from arrest of fetal development of the heart [28]. This leads to altered myocardial architecture that is seen as a two layered myocardium with a thin, compacted epicardial layer and a thick, non-compacted endocardial region (Figure-5). The non-compacted myocardial region is comprised of prominent trabeculations and deep intertrabecular recesses that directly communicate with the left ventricular cavity [29-30].The condition may present without any associated cardiac malformation and is then labeled isolated left ventricular non compaction (LVNC). Non compacted myocardium is also seen in conjunction with other cardiac abnormalities including cyanotic congenital heart disease, Ebstein's anomaly and other cardiomyopathies. Clinical presentation in LVNC is seen with congestive heart failure, ventricular arrhythmia and systemic thromboembolism.

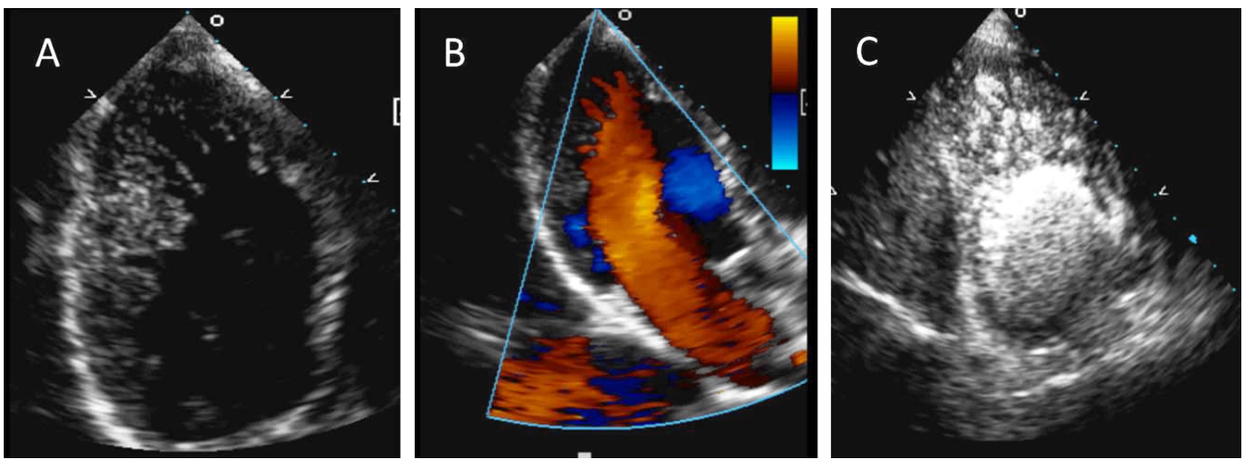


**Figure 5.** Marked trabeculation of LV myocardium is seen in the apical and inferolateral distribution (panel A) in this off axis projection of apical long axis of the heart. Ratio of non comapcted to compacted myocardium is consistent with the diagnosis of left ventricular non-compaction. Communication of deep intertrabecular recesses with LV cavity is noted on color Doppler (panel B) and following administration of echo contrast (panel C). Visual appearance of the non compacted myocardium is also enhanced following echo contrast.

#### *3.3.2. Diagnostic criteria on cardiac imaging*

Trabeculation in the left ventricle wall is seen even in healthy volunteers. To separate benign left ventricular trabeculation from pathological LVNC following diagnostic criteria is proposed.

- Echocardiogram: ratio of non-compacted to compacted myocardium in end-systole of > 2:1 [31]
- Cardiac MRI: ratio of non-compacted to compacted myocardium in end-diastole of > 2.3:1 [32]

The most frequently involved segments are apical, followed by the inferior and lateral mid-segments. Severity and distribution of non compacted segment is better appreciated with use of contrast echo.

Left ventricle contractile abnormality is present in patients with LVNC. The spectrum of myocardial function may range from normal to severe systolic dysfunction. Documentation of direct flow from ventricular cavity into inter-trabecular recesses either with color Doppler technique or following use of echo contrast is helpful in differentiating LVNC from other apical echocardiographic abnormalities such as apical hypertrophic cardiomyopathy and apical mural thrombus [31]. Information from 3DE is also helpful in identifying the extent of LVNC [33]. Screening of family members is advised.

## 4. Mixed genetic and non genetic cardiomyopathy

### 4.1. Dilated Cardiomyopathy (DCM)

#### *4.1.1. Introduction*

The prevalence of idiopathic dilated cardiomyopathy is not well understood but an estimate in the USA is ~40 per 100 000 persons [34]. DCM is the most common cardiomyopathy, accounting for 60% of all primary cardiomyopathies [35] and is a leading cause of heart failure and arrhythmia. Familial and sporadic forms of DCM are well described. Genetic factors are important, with 20% of cases having a familial basis with an autosomal dominant inheritance [36]. This has important implications for screening of first-degree relatives.

#### *4.1.2. Features of DCM on standard echocardiogram*

**Wall motion abnormalities**: Wall motion abnormality is global as opposed to regional abnormalities in ischemic cardiomyopathy. However, some regional variation in myocardial contractility may be encountered. Preservation of contractile function of basal inferolateral segment is not infrequent. Due to these overlapping features, ischemic cardiomyopathy should be conclusively excluded when appropriate.

**Cardiac Chamber Enlargement**: Left ventricular (LV) cavity enlargement and systolic dysfunction in the absence of valvular or ischemic heart disease are key diagnostic features of DCM. Dilatation of both left and right ventricles is encountered. Left ventricular cavity assumes a spherical shape in advanced cases (Figure-6). Chamber quantification is preferred over visual estimation for serial comparison. In addition to linear cavity dimension, which is increased in DCM, calculation of left ventricle volume and systolic function derived from modified biplane Simpson's method is recommended.

**Low Flow State**: Consequent to sluggish blood flow velocity, patients are at risk of developing LV mural thrombus. Low circulatory state can be appreciated by spontaneous echo contrast in left ventricle and by an increase in separation of mitral valve E point to ventricular septum and partial opening and early closure of aortic valve in systole. The latter is particularly

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important, as aortic stenosis may be overestimated on 2D echo (pseudo aortic stenosis) and underestimated by Doppler (low-gradient aortic stenosis) due to low flow state. Contractile augmentation with dobutamine is helpful in clarification in such situations [64].

**Secondary Mitral Regurgitation**: Altered mitral valve geometry from progressive LV cavity enlargement will lead to mitral regurgitation, which may be severe in advanced cases [37]. Presence of mitral regurgitation predicts poor outcome [38].

**Diastolic Dysfunction**: Presence of diastolic abnormality is established by Doppler interrogation of mitral inflow and mitral annular velocities. Severity of diastolic abnormality may be insightful and partly explanatory for the frequently observed discordance between degree of LV systolic dysfunction and severity of clinical symptoms. Patients with earlier stage of diastolic abnormality are less symptomatic when compared to those with more advanced diastolic dysfunction. Reduction in effective diastolic filling period is reflected by fusion of mitral diastolic E-wave and A-wave (Figure-6).

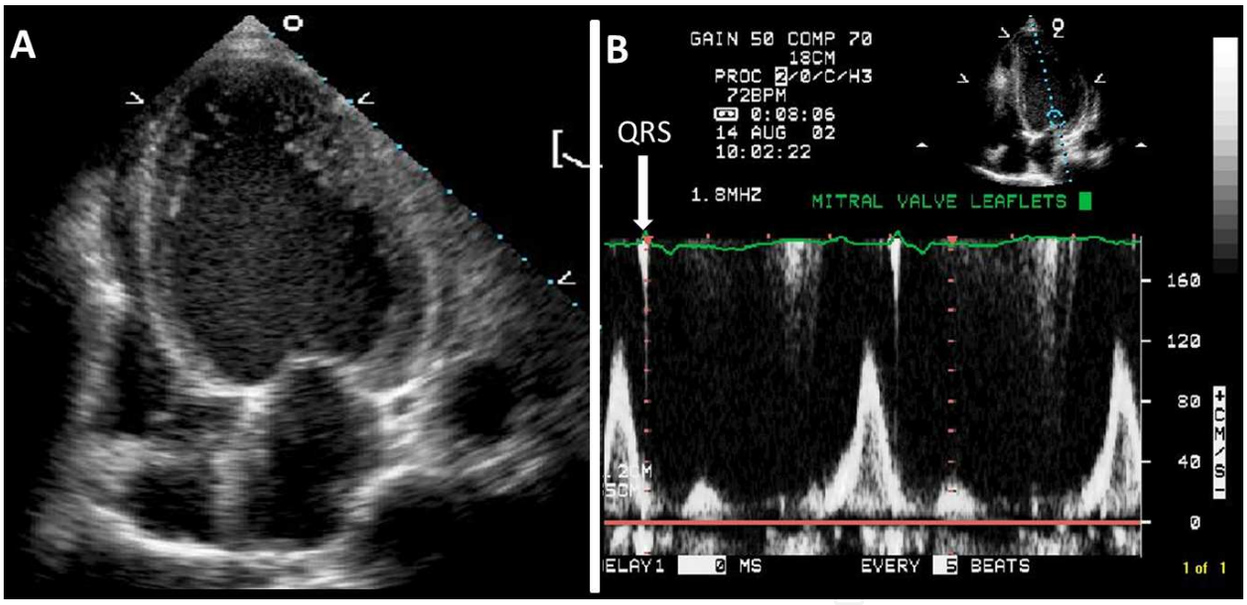


**Figure 6.** Apical four chamber view shows a dilated LV cavity with a spherical appearance. RV cavity is normal in this example. Pulse-wave Doppler at mitral leaflet tip shows fusion of diastolic E and A waves. Latter is a reflection of reduced diastolic filling period.

**Right Ventricular (RV) Function**: RV enlargement to a similar degree as the LV is associated with poor outcome [39]. RV systolic function can be measured by fractional area change or by tricuspid annular plane systolic excursion (TAPSE) [40]. TAPSE < 14 mm is associated with

adverse prognosis [41]. In another study, 3DE derived measurement of RV volume and function was superior to conventional method [42].

*4.1.3. Novel echo techniques*

Routine use of Doppler-derived strain and 2D strain may have limited application in clinically manifest disease. Application of these techniques in preclinical state and in asymptomatic family members with inherited type of DCM may identify at risk subset of patients. Observation of intersegmental discordance in the timing of strain measures, particularly those of opposing segments identify a subset of DCM patients with LV dyssynchrony, who may benefit from cardiac resynchronization therapy.

**4.2. Restrictive cardiomyopathy (non-hypertrophied and non-dilated)**

*4.2.1. Introduction*

Primary restrictive cardiomyopathy (RCM) predominantly affects the elderly, with a slight female predominance [43]. Clinical presentation is with signs and symptoms of systemic and pulmonary venous congestion from diastolic heart failure and pulmonary HTN [43]. As opposed to other types of primary cardiomyopathies which have distinctive morphologic abnormalities, the diagnosis of RCM is largely dependent on an altered physiology of blood flow through the heart consequent to a non compliant ventricle. The condition has no distinctive histologic features [44]. RCM should be distinguished from infiltrative disorders of the heart where, in addition to restrictive physiology which may be indistinguishable from RCM, distinctive morphologic and histopathologic changes are present. Amyloid heart disease and endomyocardial fibrosis are typical examples of the latter.

*4.2.2. Features of RCM on standard echocardiogram*

Left ventricle (LV) appearance and contractility is usually normal. LV cavity size may be small. Biatrial enlargement in the absence of significant regurgitation of mitral and tricuspid valves or atrial fibrillation and with normal LV kinetics in patients with signs and symptoms of heart failure should prompt consideration of RCM (Figure-7). Impaired diastolic relaxation of the LV is encountered but a key diagnostic feature is the presence of restrictive physiology on Doppler as evidenced by an increase in E:A ratio >2 with rapid deceleration of early mitral inflow (E) velocity, usually to < 150 msec (Figure-7) [45]. This, in conjunction with reduced early mitral annular velocity (E') and elevated E/E' ratio, is confirmatory of elevated left ventricular end diastolic pressure (LVEDP). Reduced E' velocity, reflecting underlying myocardial disease, is useful in distinguishing RCM from constrictive pericarditis where mitral annular velocities are preserved [46-47]. Deformation of the LV on 2D speckle strain is constrained in the circumferential direction in constrictive pericarditis and in the longitudinal direction in RCM [48]. Flow propagation velocity on color M-mode of mitral inflow can provide additional insight into diastolic dysfunction of RCM.

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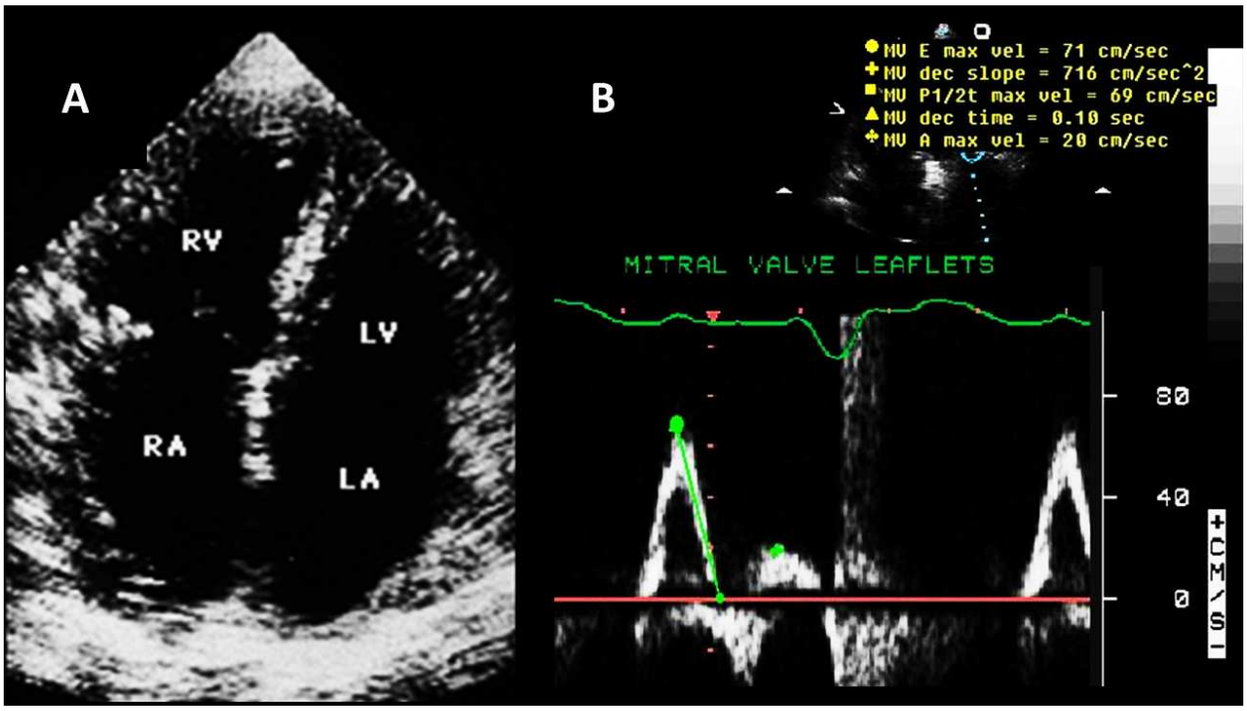


**Figure 7.** Morphologic and functional abnormality in restrictive cardiomyopathy is represented in this example. There is biatrial enlargement on apical four chamber view (panel A). Restrictive diastolic filling abnormality (E: A ratio of > 2 with rapid deceleration of early mitral inflow velocity) by Doppler is noted (panel B).

## 5. Acquired primary and secondary cardiomyopathy

For the purpose of this review, discussion will be limited to key features of commonly encountered acquired cardiomyopathy.

### 5.1. Inflammatory myocarditis

Inflammatory cardiomyopathy is defined by myocarditis in association with cardiac dysfunction [11]. Idiopathic, autoimmune, and infectious forms of inflammatory cardiomyopathy are recognized [11]. Echo findings are of non-specific LV cavity dilatation associated with global LV dysfunction similar to that seen in idiopathic dilated cardiomyopathy. Regional variation in LV contractility is not infrequently encountered.

### 5.2. Takotsubo cardiomyopathy (stress cardiomyopathy)

A transient and reversible cardiomyopathy first reported in Japan by Dote, et al., in 1991 [49]. Clinical presentation may be indistinguishable from acute coronary syndrome, invariably necessitating coronary angiography for exclusion of obstructive coronary artery disease. Prevalence is about 1-2% of patients undergoing coronary angiography for acute coronary syndrome. A precipitating emotional or physical stressor is typical. Complimentary imaging

modalities including echocardiography and cardiac MRI are helpful in diagnosis and in monitoring clinical recovery. In fact, LV morphology at echocardiography is characteristic as it resembles a takotsubo (Japanese octopus trap) with dilatation of the apical region of the heart and preserved contractility of basal segments (Figure-8). About a fifth of patients will have hyperdynamic contractility of basal LV segments with consequent left ventricular outflow tract obstruction and systemic hypotension. Early recognition of this by echo has marked influence on therapeutic choice [50]. Reverse pattern of LV contractile dysfunction has been described. Right ventricular involvement in takotsubo is seen in 25-30% of patients and is associated with a more complicated clinical course [51]. It is encountered in patients with more severe LV involvement [52]. However, isolated right ventricular takotsubo has been reported [53]. The condition is prone to formation of LV apical mural thrombus which should be carefully excluded in all.

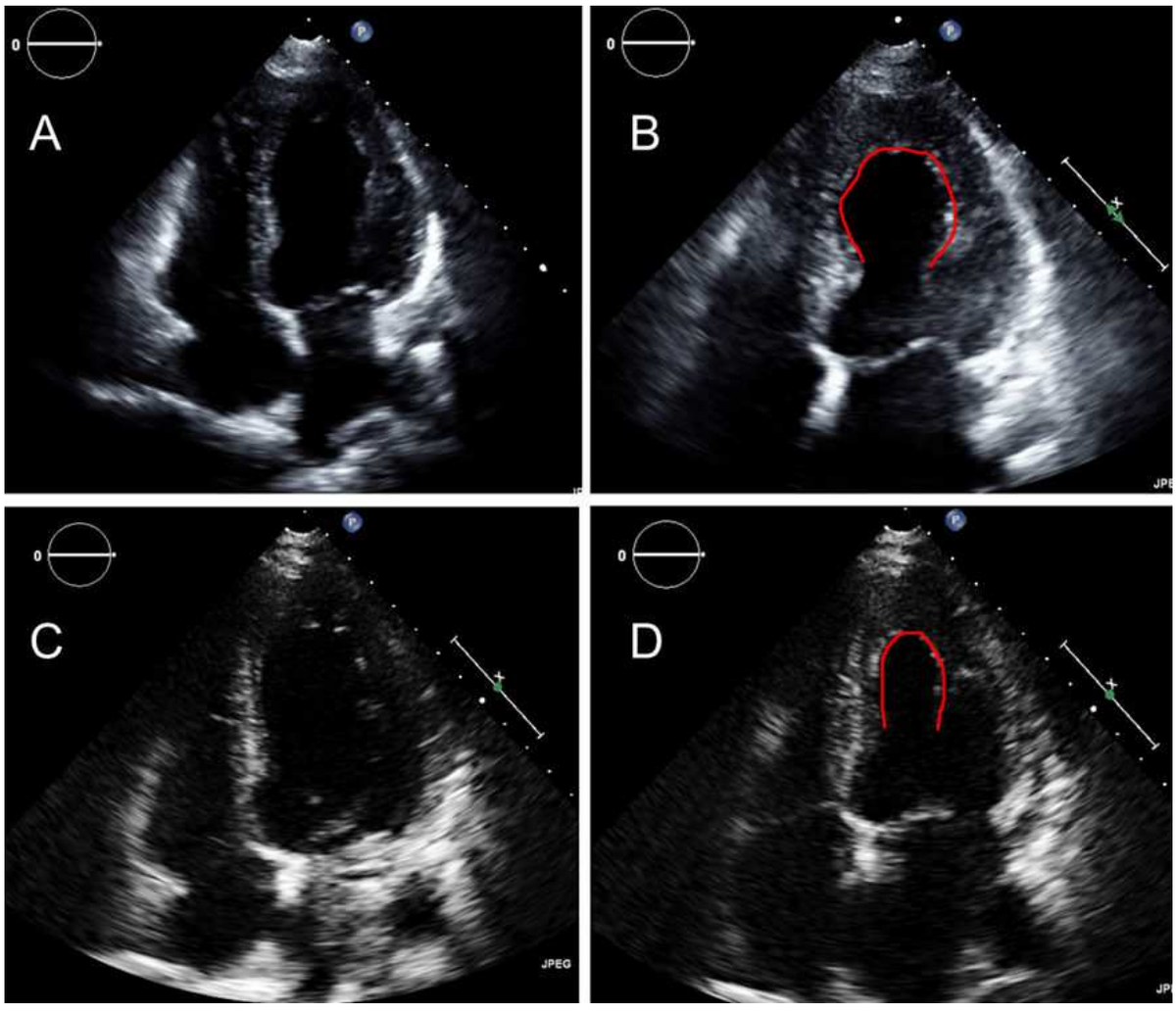


**Figure 8.** Diastolic and systolic frame of the LV in acute phase of takotsubo cardiomyopathy (panels A and B, respectively) and during recovery (panels C and D, respectively). Apical systolic expansion is noted during acute illness (panel B). Apical endocardial border is highlighted in red. Normalization of apical systolic morphology and function is noted upon recovery (panel D).

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### 5.3. PeriPartum Cardiomyopathy (PPCM)

The diagnosis of PPCM rests on the echocardiographic identification of new left ventricular systolic dysfunction during a limited period surrounding childbirth. Other causes of cardiomyopathy should be excluded [54]. Features are typically that of dilated cardiomyopathy, though LV cavity dimensions may be normal. Echocardiogram is used to monitor the effectiveness of treatment. In one study of PPCM recovery of LV function was reported in 54% of study population [55]. This was more likely to happen in women with EF of > 30% at diagnosis [55]. However, even in those with recovery of resting LV function by echo, contractile reserve on dobutamine echo is reduced [56].The condition is likely to recur during subsequent pregnancy even following recovery of LV function. The condition is associated with a worse prognosis where recovery of LV function is incomplete or did not occur after the index pregnancy [57]. Patients with LVEF of < 25% at diagnosis or in whom LV function has not normalized should be counseled against subsequent pregnancy [58]. Early and serial echocardiogram may be considered during subsequent pregnancies in all patients with prior history of PPCM.

### 5.4. Tachycardia Induced Cardiomyopathy (TIC)

There are no diagnostic features of TIC on echocardiogram. Non-specific dilated cardiomyopathy may ensue from chronic tachyarrhythmia of either supraventricular or ventricular origin [59-60]. Treatment of tachyarrhythmia is associated with recovery of LV systolic function, though some degree of adverse LV remodeling may persist [61]. Diastolic dysfunction by echo is encountered which may not reverse after normalization of LV systolic function [62].

### 5.5. Ischemic cardiomyopathy

On standard echocardiogram findings that constitute ischemic cardiomyopathy include regional wall motion abnormalities, wall thinning with aneurysmal dilatation of the infarcted myocardial segment, left ventricular (LV) cavity dilatation and decline in LV systolic performance that is out of proportion to the degree of underlying CAD (Figure-9).

Beyond recognition of an underlying ischemic process, an issue that frequently merits clarification is that of hibernating viable myocardium and non-viable infarcted myocardium [63]. This is particularly difficult to distinguish when infarcted myocardial segments have normal or relatively normal thickness or when global LV contractile dysfunction as that seen in DCM is encountered. For this low-dose dobutamine echocardiography test is useful. Augmented contractility with dobutamine typically seen as a biphasic response is noted with hibernating myocardium. Newer methods of assessing longitudinal fiber contraction during dobutamine echo by long axis pulsed wave Doppler and M-mode is considered to be superior, particularly in patients with LBBB [64].

### 5.6. Valvular cardiomyopathy

It is defined as ventricular dysfunction that is out of proportion to the abnormal loading conditions of the heart [11]. Left ventricle is affected by regurgitant lesions of the mitral and

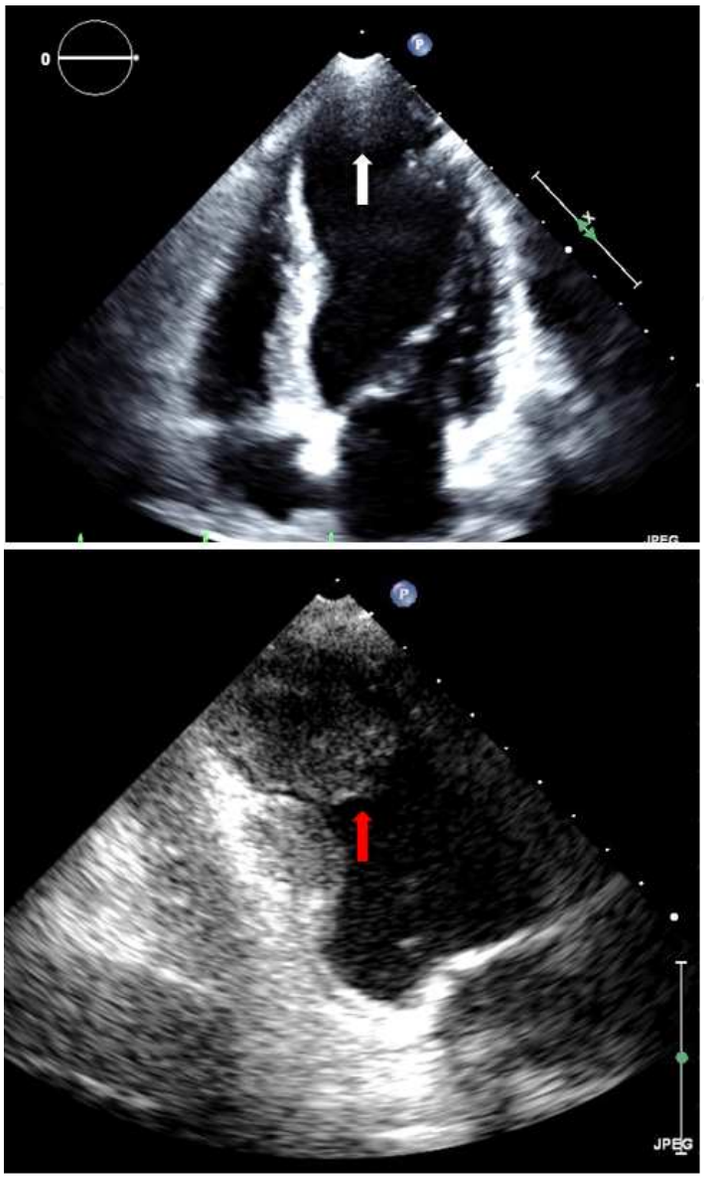


**Figure 9.** Apical LV aneurysm (white arrow) is seen in a patient with ischemic cardiomyopathy. In another patient apical LV aneurysm is associated with a large LV mural thrombus (red arrow).

aortic valves and by increased afterload of aortic stenosis. Primary valve abnormality can be readily identified though findings can be blunted in the failing heart.

*5.6.1. Aortic stenosis*

Increased afterload of aortic stenosis results in concentric left ventricular (LV) hypertrophy. LV cavity size is normal and systolic function preserved. With progressive disease LV dilatation and impaired systolic function ensues. In patients with severe systolic dysfunction assessment of aortic stenosis by Doppler can be challenging due to low flow velocity. Inotropic augmentation of contractility and flow with dobutamine can be used in such cases [65].

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*5.6.2. Aortic regurgitation*

LV cavity enlargement is present, which can be marked. Systolic function is initially preserved but declines with advanced disease. Increase in LV end-diastolic pressure may blunt the color Doppler signal of aortic regurgitation. Serial estimation of LV cavity dimension and volume is necessary for aortic valve replacement prior to irreversible contractile dysfunction. LVEF of ≤ 50%, LV end-diastolic dimension of ≥ 70 mm and LV end-systolic dimension of ≥ 50 mm are echo criteria for surgical intervention in asymptomatic individuals [66]. Abnormal longitudinal and circumferential strain is noted in the preclinical phase [67]. Incremental value of these strain parameters for therapeutic intervention is not well established.

*5.6.3. Mitral regurgitation*

LV volume overload is well tolerated with preserved LV systolic function early in the disease. Progressive decline in LV systolic function can be underestimated when using LV ejection fraction as a marker of systolic performance. Left atrial enlargement is followed by LV cavity enlargement. Progressive increase in left atrial pressure may decrease the color Doppler signal of mitral regurgitation in advanced cases. LV end-systolic dimension of ≥ 45 mm or LVEF of ≤ 60% is used to time surgical intervention [68].

**5.7. Hypertensive heart disease and cardiomyopathy**

There is an increase in LV mass consequent to concentric hypertrophy of LV. Systolic function is preserved. Variable degree of diastolic function is noted. In patients with severe LV hypertrophy echocardiographic differentiation from other disease states with LV hypertrophy is challenging. Restrictive filling pattern is seen in severe disease. Progressive disease is associated with LV cavity dilatation and decline in LV systolic function similar to that seen in dilated cardiomyopathy.

**5.8. Metabolic cardiomyopathy**

*5.8.1. Amyloid heart disease*

Cardiac amyloidosis is an infiltrative disorder of the heart which on echo is seen as thick-walled left and right ventricles with normal left ventricular cavity dimension and systolic function. Advanced disease is associated with decline in left ventricular systolic function. Increased echogenicity from thickening of heart valves, biatrial enlargement and thickened interatrial septum are other morphologic features of established disease. Pericardial effusion is seen in more than half of patients [69] (Figure-10). Increased granular appearance of the heart in earlier description of cardiac amyloidosis is not distinct on modern echo hardware and image processing [70]. Assessment of transmitral flow and mitral annular velocities by Doppler reveals impaired diastolic function. Restrictive diastolic filling pattern is noted in advanced cases. Unlike in restrictive filling pattern, reduced mitral A- velocity may be seen with normal mitral E-deceleration time. This finding suggests atrial myopathy and reduced contractility from amyloid infiltration [71]. Some overlapping clinical and echocardiographic features of

hypertrophic cardiomyopathy are seen in 5% of cases. In contrast to a hypertrophied ventricle, low voltage in precordial leads is seen on ECG, and systolic anterior motion of mitral valve which is a frequent observation in hypertrophic cardiomyopathy on echo, is uncommon in patients with cardiac amyloidosis. By novel echo techniques longitudinal strain and strain rate show systolic dysfunction despite preserved radial contraction as determined by fractional shortening. The value of strain parameters in early diagnosis and in prognosis is being evaluated [72]. Furthermore, strain measurement by 2D speckle tracking shows variation in longitudinal strain from base to apex with relative preservation of apical strain. This finding can be helpful in distinguishing cardiac amyloidosis from hypertrophic cardiomyopathy and hypertrophy associated with increased afterload state of aortic stenosis [73].

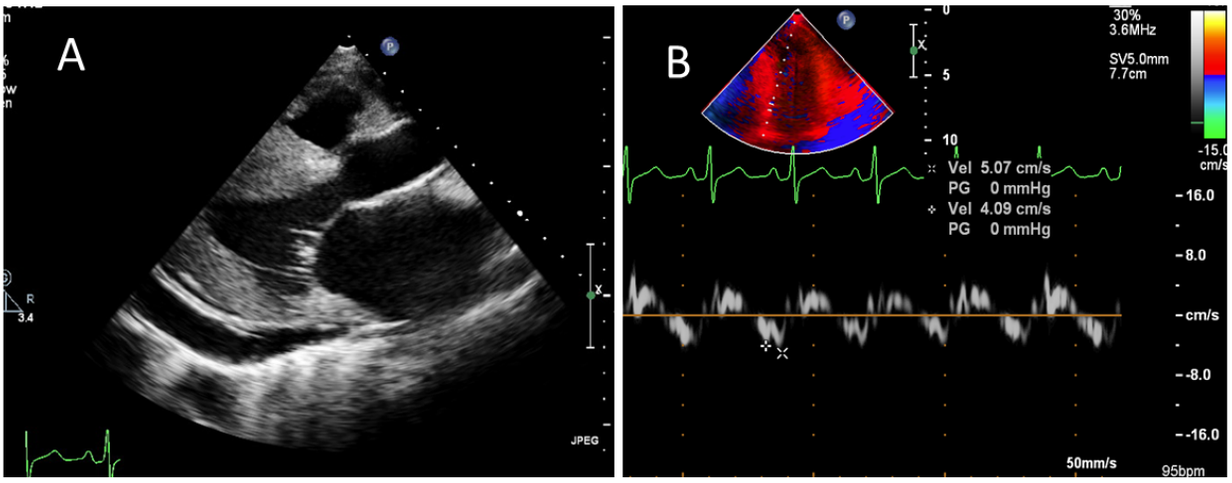


**Figure 10.** Severe concentric left ventricular wall thickening and small pericardial effusion is present in this patient with cardiac amyloidosis (panel A). Impaired mitral annular velocity is indicative of abnormal diastolic function (reduced mitral annular velocities with reversal of E′ to A′ ratio) (panel B).

### *5.8.2. Hemochromatosis*

There are no specific morphologic features on echocardiogram. Dilated cardiomyopathy is seen in advanced stages of hemochromatosis [74]. Non-invasive diagnosis of cardiac involvement is dependent on demonstration of myocardial iron deposit on cardiac MRI [75]. In cases with established cardiac involvement, assessment of myocardial kinetics by Doppler and tissue strain may reveal functional impairment prior to development of overt cardiomyopathy. The value of these new techniques in determining prognosis and in serial follow up of patients following therapeutic intervention has been the subject of recent studies.

## 5.9. Toxic cardiomyopathy: Alcohol and anthracyclines

Echo findings are non-specific. Dilated cardiomyopathy from cardiotoxicity of alcohol cannot be distinguished from idiopathic dilated cardiomyopathy. Impairment of left ventricle systolic function is a concern for both anthracycline and some non-anthracycline based chemothera-

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peutic regimens. Dose dependent cardiotoxicity from anthracyclines is reversible if detected early and upon institution of effective heart failure therapy [76]. Serial assessment of left ventricle systolic function, preferably by echo, is routine in such cases. Impaired tissue kinetics by measures of myocardial strain and strain rate is noted prior to gross impairment of left ventricle systolic function. This may have a role in influencing management [77].

## 6. Conclusion

Value of echocardiography in the diagnosis, prognosis and monitoring of therapy in patients with cardiomyopathy is discussed in the preceding review. 3DE, Doppler and speckle strain and left ventricular torsion may have a role in preclinical disease states. Incorporation of these diagnostic methods in routine clinical assessment of patients with cardiomyopathy is dependent on emerging data on the usefulness and reproducibility of these techniques.

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