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Diastolic Heart Failure

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1. Introduction

The mortality, hospitalization, and prevalence rates of heart failure (HF) are increasing, in spite of decrease in coronary artery and cerebrovascular disease mortality.[1] Importantly, heart failure with normal ejection fraction (HFNEF) currently accounts for more than 50% of all heart failure patients and as the prevalence of HFNEF in the heart failure population rises by 1% a year.[2]

Approximately half of patients with a diagnosis of heart failure have a normal left ventricular (LV) ejection fraction (EF) without valve disease which is defined as diastolic heart failure (DHF), because it is attributed to LV diastolic dysfunction.[3] The prevalence of DHF increase even more dramatically with age more than HF with a reduced EF and is much more common in women than in men at any age. Studies examining prevalence of diastolic heart failure in hospitalized patients or in patients undergoing outpatient diagnostic screening and prospective community based studies have shown that the prevalence of diastolic heart failure approaches 50%.[4-6] Although HF patients with preserved systolic function has a slightly better prognosis than HF patients with abnormal systolic function, there is a fourfold higher mortality risk compared with subjects free of HF.[7]

2. The mechanism of DHF

Heart failure is a clinical syndrome characterized by symptoms and signs of increased tissue water and decreased tissue perfusion. Definition of the mechanisms that cause this clinical syndrome requires measurement of both systolic and diastolic function. When heart failure is accompanied by a predominant or isolated abnormality in diastolic function, this clinical syndrome is called diastolic heart failure. The pathophysiology is attributed to LV diastolic dysfunction, in which LV diastolic chamber size is normal or reduced despite elevated filling pressures resulting in decreased cardiac output. DHF occurs when the ventricular chamber is unable to accept an adequate volume of blood during diastole, because of a decrease in ventricular relaxation and/or an increase in ventricular stiffness,[3] and increased circulating blood volume is present. Hypertension, ischemia, aging and diabetes mellitus are the major risk factor of a decrease in ventricular relaxation and/or an increase in ventricular stiffness. Endocardial biopsies from HF patients without coronary artery

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disease (CAD) showed structural and functional differences in cardiomyocytes from patients with diastolic HF compared to cardiomyocytes from patients with abnormal systolic ejection fraction.[8] Myocytes from patients with diastolic HF had increased diameter and higher myofibrillar density and developed greater passive force and had greater calcium sensitivity. Myocardial collagen volume fraction was equally elevated.

2.1 Characteristics of medical examination

Patients with DHF were shown to have similar pathophysiological characteristics, compared with HF patients with a reduced EF including reduced exercise capacity and impaired quality of life. The Framingham criteria for diagnosis of HF is the following. Major criteria are 1) paroxysmal nocturnal dyspnea or orthopnea, 2) jugular venous distention (or central venous pressure is more than 16 mmHg), 3) hearing rale or acute pulmonary edema, 4) cardiomegaly, 5) hepatojuglar reflex, and 6) response to diuretics (weight loss is more than 4.5 kg per 5 days). Minor criteria are 1) ankle edema, 2) nocturnal cough, 3) exertional dyspnea, 4) pleural effusion, 5) vital capacity lower less than two thirds of normal condition, 6) hepatomegaly, and 7) tachycardia (more than 120 beats/minute. With diastolic HF, fourth heart sounds may be present but third heart sounds are seldom present. Chest radiography will show pulmonary congestion during acute exacerbations and for some time following an episode, cardiomegaly will be present in systolic HF but may or may not be present in HF with preserved ejection fraction. When it is difficult with diagnosing HF, it is important to use echocardiography. [9,10]

2.2 The diagnosis of DHF

The diagnosis of heart failure with normal left ventricular (LV) ejection fraction (HFNEF) requires the following conditions to be satisfied: (1) signs or symptoms of heart failure; (2) normal or mildly abnormal systolic LV function; (3) evidence of diastolic LV dysfunction. Normal or mildly abnormal systolic LV function implies both an LVEF > 50% and an LV end-diastolic volume index (LVEDVI) < 97 mL/m^2. Diagnostic evidence of diastolic LV dysfunction can be obtained invasively (LV end-diastolic pressure >16 mmHg or mean pulmonary capillary wedge pressure >12 mmHg) or non-invasively by tissue Doppler (TD) (E/E' >15) with an echocardiography. If TD yields an E/E' ratio suggestive of diastolic LV dysfunction (8 < E/E' < 15), additional non-invasive investigations are required for diagnostic evidence of diastolic LV dysfunction. These can consist of blood flow Doppler of mitral valve or pulmonary veins, echocardiographic measures of LV mass index or left atrial volume index, electrocardiographic evidence of atrial fibrillation, or plasma levels of natriuretic peptides. If plasma BNP is more than 200 pg/mL, diagnostic evidence of diastolic LV dysfunction also requires additional non-invasive investigations (Fig. 1).

LVEDVI: left ventricular end-diastolic volume index, mPCW: mean pulmonary capillary wedge pressure, LVEDP: left ventricular end-diastolic pressure, TD: tissue Doppler, E: early mitral valve flow velocity, E': early TD lengthening velocity, BNP: brain natriuretic peptide, E/A: ratio of early (E) to late (A) mitral valve flow velocity, Dct: deceleration time, LVMI: left ventricular mass index; LAVI: left atrial volume index, Ard: duration of reverse pulmonary vein atrial systole flow, Ad: duration of mitral valve atrial wave flow.

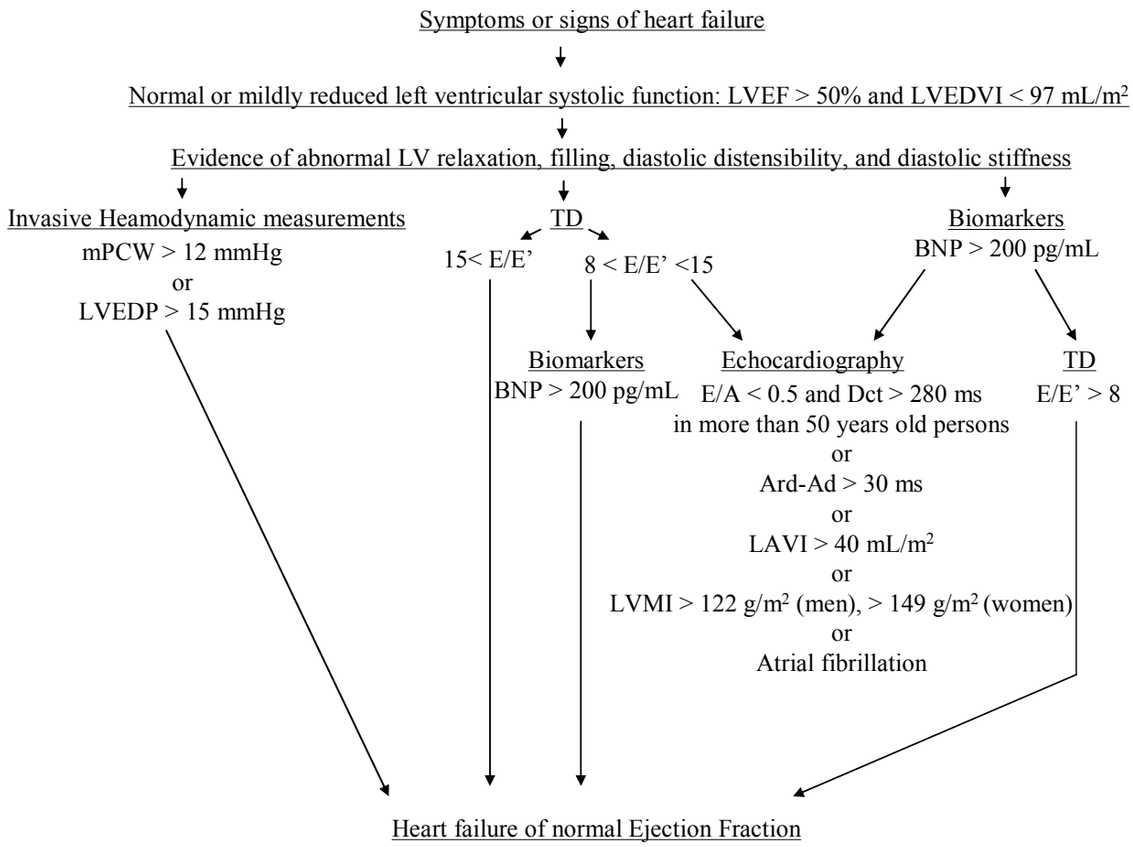

Fig. 1. How to diagnose HFNEF: Diagnostic flow chart in a patient suspected of HFNEF.

A similar strategy with focus on a high negative predictive value of successive investigations is proposed for the exclusion of HFNEF in patients with breathlessness and no signs of congestion. If a patient with breathlessness and no signs of fluid overload has a BNP of less than 100 pg/mL, any form of heart failure is virtually ruled out because of the high negative predictive value of the natriuretic peptides, and pulmonary disease becomes the most likely cause of breathlessness (Fig. 2). [11,12]

As far as diastolic dysfunctuion, in decompensated patients with advanced systolic heart failure (LVEF≦30%, New York Heart Association class Ⅲ to Ⅳ symptoms), tissue Doppler-derived with E/E′ ratio may not be as reliable in predicting intracardiac filling pressures, particularly in those with larger LV volumes, more impaired cardiac indices, and the presence of cardiac resynchronization therapy. [13]

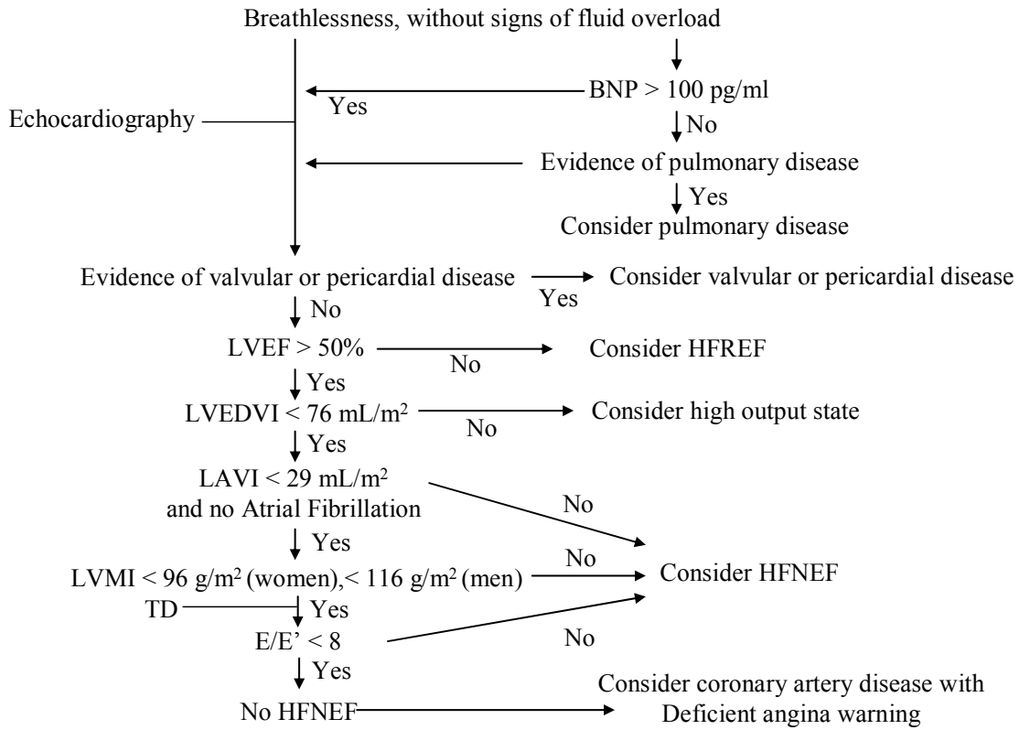

Fig. 2. How to exclude HFNEF: Diagnostic flow chart in a patient presenting with breathlessness and no signs of fluid overload.

2.3 Echocardiography in diastolic heart failure

2.3.1 Doppler echocardiographic assessment of diastolic function and filling pressures

Comprehensive Doppler echocardiography is invaluable in the evaluation of HF patients as the 2.1. characteristics of medical examination section. Assessment of diastolic function begins with the transmitral flow velocity profile. Decreases in the ratio of early to late diastolic filling (E/A), increases in the deceleration time, increases in the isovolumic relaxation time, or increases in tissue Doppler imagings (E/E') indicate impaired relaxation. However, in the presence of impaired relaxation, increases in filling pressure progressively modify the transmitral gradient and mitral inflow pattern. A comprehensive Doppler assessment must be used to determine diastolic function from filling pressures and tissue Doppler imagings. [12] Patients studied at various times during their presentation will display a spectrum of filling patterns, including abnormal relaxation and psuedonormal or restrictive patterns. Such a spectrum has also been reported in patients with HF with a depressed EF and reflects the potent effect of filling pressures and blood pressure and their interaction with underlying diastolic dysfunction on the Doppler patterns. Thus, depending on their level of compensation and their filling pressures and whether they have exertional or rest symptoms, patients with HF preserved EF may display any of the filling patterns.[14]

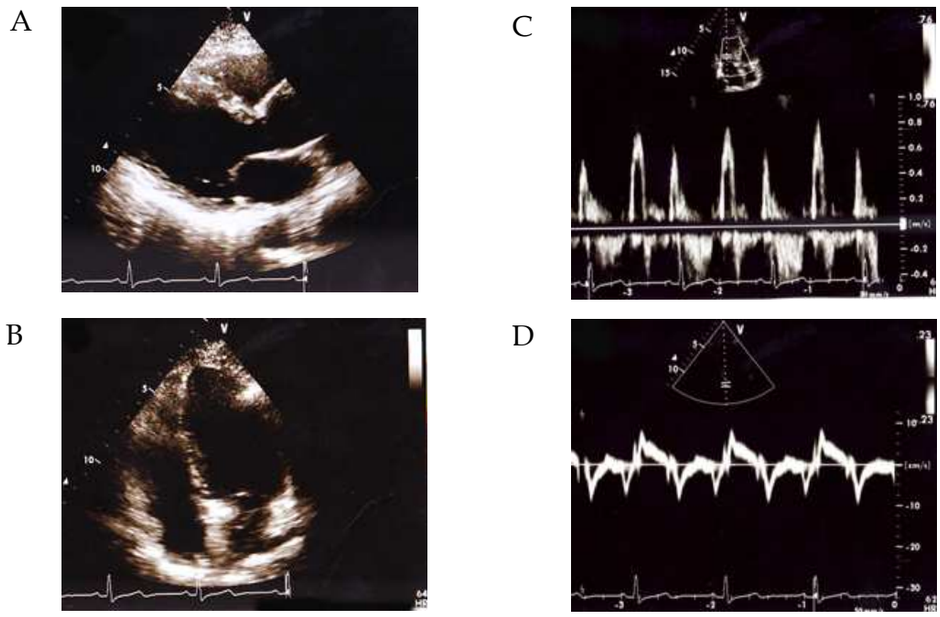

Fig. 3. Normal pattern in LV inflow: Panel A shows long axis view. Panel B shows 4 chamber view. Panel C shows LV inflow. Panel D shows tissue Doppler imaging.

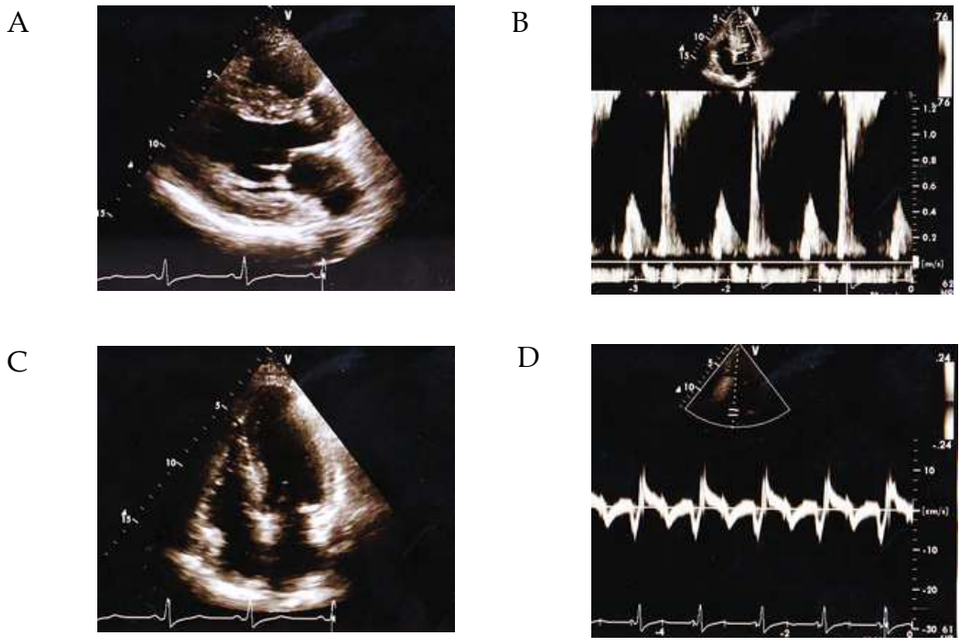

Fig. 4. Abnormal relaxation pattern in LV inflow: Panel A shows long axis view. Panel B shows 4 chamber view. Panel C shows LV inflow. Panel D shows tissue Doppler imaging.

2.3.2 Left ventricle in diastolic heart failure

Most patients with HF preserved EF have normal chamber dimensions, although a small subset may have variable degrees of LV enlargement.

Although HF preserved EF has been thought to occur primarily inpatients with LVH, studies that have carefully quantified LV mass report that echocardiographic criteria for LVH are met in less than 50% of patients. [15-18]

2.3.3 Left atrium in diastolic heart failure

Increases in the left atrial dimension or volume are commonly present in patients with HF preserved EF. [19-21]

2.3.4 Pulmonary hypertension in diastolic heart failure

Just as chronic pulmonary venous hypertension leads to pulmonary arterial hypertension in HF with reduced EF, the same can occur in HF preserved EF, and an elevated tricuspid regurgitant velocity indicative of pulmonary hypertension is extremely common in HF preserved EF.[19, 22]

2.3.5 Other echocardiographic findings in diastolic heart failure

Regional wall motion abnormalities with preserved EF and right ventricular dilatation, either from ischemic disease or secondary to chronic pressure overload from chronic pulmonary venous hypertension, can also be present at echocardiography in patients with HF preserved EF. Additional negative findings at echocardiography include the absence of valvular disease, pericardial tamponade, pericardial constriction, the presence of congenital heart diseases such as atrial septal defect, other more extensive structural abnormalities are important enough to cause the HF symptoms.

2.4 The treatment of DHF

Almost randomized, double-blind studies of therapy for HF are studies of systolic dysfunction. Guidelines for the management of patients with chronic HF have been published by several organizations. The management of patients with DHF is not different from that of HF patients with a reduced EF. They include daily monitoring of weight, attention to patient education, and close medical follow-up. The role of cardiac rehabilitation in patients with DHF has also been explored.[23]

The treatment of diastolic heart failure can be demonstrated the following 3 strategies. First, treatment should target symptom reduction by decreasing pulmonary venous pressure at rest and during exertion. Second, treatment should target the pathological disease that caused the diastolic heart failure. For example, coronary artery disease, hypertensive heart disease and diabetes mellitus provide relatively specific therapeutic targets, such as lowering of blood pressure, induction of hypertrophy regression, blood sugar control and treatment of ischemia by increasing myocardial blood flow and reducing myocardial oxygen demand. Third, treatment should target the underlying mechanisms that are altered by the disease processes.

Diuretics are advised for therapy of diastolic HF in the ACC/AHA Guidelines for Evaluation and Management of Heart Failure. The use of diuretics may improve breathlessness in patients with diastolic HF, because circulating blood volume is a major

determinant of ventricular filling pressure. In spite of chronic data are lacking on nitrates, they are effective on the diastolic HF in the acute phase, because of deceasing central blood volume by vasodilating. In spite of chronic data are also lacking on human atrial natriuretic peptides, they are effective on the diastolic HF in the acute phase, because of deceasing central blood volume by natriuretic and vasodilating effect. Digoxin was reported to yield symptomatic improvement and decreased hospitalizations without mortality benefit in the DIG study in patients with DHF.[24]

We treat with angiotensin converting enzyme (ACE) inhibitors, angiotensin receptor blockers (ARBs) and aldosterone antagonists in the chronic systolic heart failure patients, because the rennin-angiotensin- aldosterone system (RAAS) plays the pivotal roles on the left ventricular remodeling in HF patients.[25] Recent studies of HF patients with preserved LV function suggest that ACE inhibitors or ARBs may improve functional class, exercise duration, ejection fraction, diastolic filling and LV hypertrophy. In the large randomized trial of perindopril (an ACE inhibitor) for patients older than 70 years with chronic HF and normal or near-normal EF, event rates were lower than anticipated. Some trends toward benefit, primarily driven by reduction in HF-related hospitalizations, were observed at 1 year (PEP-CHF trial).[26] In the CHARM-Preserved Trial, [27] HF patients with an EF higher than 40% were randomized to candesartan (an angiotensin receptor antagonist) or placebo in addition to standard therapy. Fewer patients in the candesartan group than in the placebo group reached the primary endpoint of cardiovascular death or HF hospitalization, a finding that reached statistical significance only after adjustment for nonsignificant differences in baseline characteristics. Then, irbesartan (an ARB) did not improve the outcomes of DHF patients (I-PRESERVE).[28] Although candesartan and irbesartan are angiotensin receptor blockers, the results of the trials are different. These pleiotropic effects may be different. The trial of aldosterone antagonists for DHF patients is going on in DHF patients (TOPCAT trial). Beta blocker has been shown to improve morbidity with diastolic and systolic HF. [29,30] Although calcium channel antagonists can improve measures of diastolic function during short-term use, definitive data with chronic administration for diastolic HF are not available. Recent reports show statins reduce the number of cardiovascular hospitalizations in patients with systolic heart failure, although they did not reduce the primary outcome which is the composite of death from cardiovascular causes, non fatal myocardial infarction and nonfatal stroke.[31,32] A few trials of statins have shown to improve the mortality in patients with DHF [33]. Further investigations are needed.

3. Conclusions

Heart failure with normal left ventricular ejection fraction (HFNEF) currently accounts for more than 50% of all heart failure patients. The updated strategies for the diagnosis and exclusion of HFNEF are useful not only for individual patient management but also for patient recruitment in future clinical trials exploring therapies for HFNEF.

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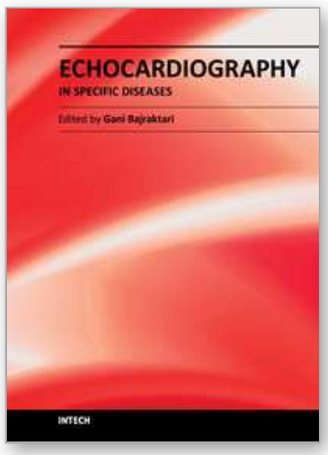

Echocardiography - In Specific Diseases

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The book "Echocardiography - In Specific Diseases" brings together contributions from well- known researchers from around the world, some of them specialized in imaging science in their clinical orientation, but also representatives from academic medical centers. Each chapter is structured and written to be accessible to those with a basic knowledge of echocardiography but also to be stimulating and informative to experts and researchers in the field of echocardiography. This book is primarily aimed at cardiology fellows during their basic echocardiography rotation, fellows of internal medicine, radiology and emergency medicine, but also experts in echocardiography. During the past few decades technological advancements in echocardiography have been developing rapidly, leading to improved echocardiographic imaging using new techniques. The authors of this book tried to explain the role of echocardiography in several special pathologies, which the readers may find in different chapters of the book.

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