Global Advanced Research Journal of Medicine and Medical Sciences (ISSN: 2315-5159) Vol. 7(1) pp. 010-016, January, 2018
Available online http://garj.org/garjmms

Review Article

Usefulness of echocardiography in the diagnosis of heart failure

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Accepted 23 January, 2018

Heart failure is a condition with increasing prevalence worldwide and approximately 50% of heart failure patients present with evidence of left ventricular systolic dysfunction. This is manifested as low left ventricular ejection fraction and is also called Heart failure with reduced ejection fraction (HFrEF). Clinical studies have shown that approximately 40% of patients with congestive heart failure have predominantly diastolic left ventricular dysfunction also called Heart failure with preserved ejection fraction (HFpEF). Echocardiography is a non-invasive relatively cheap technique well suited to the evaluation of left ventricular function and represents the gold standard for assessment of left ventricular systolic function. Doppler echocardiography is a simple, noninvasive and safe technique for assessment of diastolic function. With echocardiography, heart failure resulting from varying aetiology can be conveniently diagnosed with out the disadvantage and detrimental health effects of ionizing radiation.

Keywords: Heart failure, systolic dysfunction, diastolic dysfunction, echocardiography.

INTRODUCTION

Heart failure (HF) is a complex, clinical syndrome that arises secondary to abnormalities of cardiac structure and/or function (inherited or acquired) that impair the ability of the ventricle to fill with or eject blood (Braunwald, 2008).

The syndrome of HF is a common manifestation of the later stages of various cardiovascular diseases including hypertensive heart disease, coronary artery disease, valvular heart disease and cardiomyopathies.

The cardinal manifestations HF are dyspnoea, orthopnoea, paroxysmal nocturnal dyspnoea and fatigue, which tends to limit exercise tolerance, and fluid retention, which may lead to pulmonary congestion and peripheral oedema. Both abnormalities can impair the functional capacity or quality of life of affected individuals, but they do not necessarily dominate the clinical picture at the same time. Some patients have exercise intolerance but little evidence of fluid retention, while others complain primarily oedema and report few symptoms of dyspnoea or fatigue (Rathhold, 2002; Remme et al., 2005).

The prevalence of HF is increasing (McMurray et al. 1993); Reitsma et al. 1996) and approximately 50% of HF patients present with evidence of left ventricular systolic dysfunction manifested as a low left ventricular (LV) ejection fraction (American Heart Association, 2005).

Echocardiography is a non-invasive technique well suited to the evaluation of LV function, and most echocardiographic departments find that estimation of LV function occupies an increasing proportion of their work load. The American College of Cardiology/American Heart Association (ACC/AHA)guidelines (Hunt et al., 2005) as well as the European Society of Cardiology (ESC) guidelines (Swedberg et al., 2005) state that

Table 1. Referral for echocardiography

1.	Almost all patients with symptoms and signs of heart failure should be referred for echocardiography
2.	Echocardiography is more accurate than clinical judgement combined with chest-xrays

echocardiography is the single most useful test in the diagnosis of heart failure since structural abnormality, systolic dysfunction, diastolic dysfunction or a combination of these abnormalities are present in patients who present with resting or/and exertional symptoms of HF to establish a definitive diagnosis of heart failure. It is important to demonstrate an objective evidence of structural or functional abnormalities to explain patient's symptoms of heart failure since the symptoms of heart failure are not specific and more than a third of patients with a clinical diagnosis of heart failure may not actually have heart failure (Oh, 2007).

The ESC guidelines (Swedberg et al. 2005) recommend chest x-ray for the evaluation of patients with suspected LV dysfunction because of signs or symptoms. In particular, chest x-ray is useful to detect to detect the presence of cardiac enlargement or pulmonary congestion but not systolic or diastolic dysfunction. Echocardiography represents the 'gold standard' in the assessment of LV systolic dysfunction. It can certainly do better than chest x-ray for cardiac enlargement and may also provide direct imaging of pulmonary congestion. In particular it is important to consider the disadvantage of radiation exposure in situations such as HF when serial assessment is mandatory (Picano, 2004; Picano, 2005). Current protection standards and practices are based on the premise that ionising radiation dose, no matter how small can result in detrimental health effects (European Commission on Radiation Protection, 2004). These include long term development of cancer and genetic damage (International Commission on Radiation Protection, 2001).

The aim of this review is to describe the echocardiographic imaging procedure and point out the usefulness of echocardiography in the diagnosis of heart failure resulting from various heart diseases. Finally it highlights advances in echocardiography. These advances are also essential and applicable in the diagnosis of heart failure resulting from different cardiovascular diseases.

REFERRAL FOR ECHOCARDIOGRAPHY

Almost all patients with symptoms or signs of heart failure, including those post myocardial infarction, should be referred for echocardiographic evaluation as early as possible in their clinical course (table 1) (Colquhoun et al., 1995). There may be few patients that due to frailty or other complex pathology, the investigation would add little to their management. However, many drugs (such as angiotensin converting enzyme (ACE) inhibitors, digoxin and potent diuretics) used in the treatment of heart failure can have serious consequences when inappropriately used. Echocardiography helps to determine the specific cardiovascular disease to enable appropriate use of heart failure drugs. Breathlessness is frequently multifactorial especially in the elderly and echocardiography helps in identifying the contribution of the heart to the total symptom load.

Left ventricular systolic function may be found to be worse than expected from clinical and chest x-ray parameters after echocardiography. Conversely in some patients, LV contraction at rest is shown to be unexpectedly good (Soufer et al., 1985) prompting a search for evidence of diastolic dysfunction or reconsideration of the diagnosis.

IMAGING PROCEDURE

The heart should be imaged from parasternal long axis, parasternal short axis and apical 'windows' routinely. If no satisfactory images are obtained a subcostal view often helps. Aortic root and left atrial dimension should be obtained. Left ventricular cavity dimension and global and regional systolic function should be assessed. Right ventricular size and function, valve morphology and function, pulmonary artery pressure and left ventricular diastolic function should be assessed.

Aortic root and left atrial dimension

This is imaged from the parasternal view. The aortic root is dilated in long standing hypertension, severe aortic regurgitation, post stenotic dilatation and Marfan's syndrome. The left atrium is dilated in mitral stenosis, mitral regurgitation and dilated cardiomyopathy. It is also possible to see intra-atrial masses such as left atrial thrombus or myxoma.

Left ventricular dimension and global systolic function

With acceptable parasternal views, LV chamber dimensions can be recorded routinely and wall thickness can be measured (table 2). LV chamber dimensions are increased in dilated cardiomyopathy, severe mitral and aortic regurgitation, LV failure and long standing hypertension. In ischemic heart disease, where wall motion abnormalities may be present, it is not advisable to use M mode estimations of ejection fraction. Major wall

Table 2. Types of data to be collected

1.	Quantitation of global left ventricular function and size
2.	Description of regional wall motion
3.	Echocardiographic and Doppler assessment of valve morphology and valve function
4.	Description of right ventricular function
5.	Left ventricular diastolic function

motion abnormalities should be noted. Provided visualization of the endocardium is good, it is useful to calculate ejection fraction (EF), using any of the well established methods (Schiller et al., 1989). If there are major wall motion abnormalities, measurement of EF should be made in both four chamber and two chamber views. In heart failure with reduced ejection fraction (HRrEF) the ejection fraction is < 40%. This is seen in dilated cardiomyopathy, rheumatic heart disease and ischemic heart disease. EF measurements should not be made if visualization of the endocardium is insufficient; it is better than to describe global ventricular systolic function in more general terms. EF measurements made with echocardiography have been compared to angiographic and isotope methods, and it is clear that there is no ideal method of taking this measurement (Folland et al., 1979; Starling et al., 1981). However prognostic information after myocardial infarction can be obtained from such measurements(Volpi et al., 1993). LV end systolic volume is also of prognostic importance and should be routinely recorded where possible (White et al., 1987).

Left ventricular regional systolic function

Major wall motion abnormalities seen should always be described. Formal wall motion scores are often useful where measured, although they are most frequently used as research measures. Recommendations have been published for recording these findings (Henry et al., 1982).

Right ventricular size and function

A portion of the right ventricle(RV) and right ventricular out flow tract appear as the cavity space above the interventricular septum. The RV is dilated in pulmonary hypertension, tricuspid regurgitation, dilated cardiomyopathy, atrial septal defect, long standing pulmonary stenosis. Normal ranges for right ventricular dimensions have been published (Foale et al., 1986)**.**

Valve morphology and function

Valves should be inspected in all available views for stenosis or regurgitation and calcification. An assessment of the patient's valvular function should be undertaken by a mixture of imaging and Doppler echocardiography. Abnormal valves should be assessed by continuous wave Doppler. Aortic valves should be assessed, if abnormal to determine peak and mean pressure gradients and valve area (Otto et al., 1986). Mitral valve area can be estimated from the rate of diastolic pressure decline (Holen et al., 1977). Mitral stenosis may be further evaluated by direct planimetry of the valve area from short axis view. It is important to appreciate that valve gradients will not reflect the severity of stenosis in patients with low cardiac output. In such situations it is better to calculate the effective valve area using the 'continuity equation' (Zhang et al., 1985) . Colour Doppler ultrasound is extremely sensitive for the detection of regurgitant lesions. Mitral and aortic regurgitation are frequently detected using colour flow mapping or spectral Doppler. A broad jet penetrating deeply into the receiving chamber combined with an intense continuous wave Doppler signal is likely to indicate a haemodynamically significant regurgitant lesion. Mitral regurgitation is very frequently seen in patients with dilated ventricles, and is often more extensive than can be appreciated by auscultation alone.

Pulmonary artery pressure

In the parasternal short axis view at the aortic valve level, the main pulmonary artery is seen distal to the pulmonary valve and bifurcates into two branches (the right and left pulmonary arteries) giving what is called the 'pair of trousers' sign. Pulmonary artery pressure can often be estimated at this level.

Left ventricular diastolic function

Clinical studies have shown that approximately 40% (Vlahovic and Popovic, 1999) of patients with congestive heart failure have predominantly diastolic left ventricular dysfunction. This is called heart failure with preserved ejection fraction (HFpEF) and is seen in conditions like hypertension, hypertrophic cardiomyopathy and pericardial diseases. In this instance the EF is normal. There is interesting literature about the ability of pulsed Doppler to assess diastolic function (Yamamoto et al., 1996). When pulsed Doppler sample volume is placed at the tip of the mitral leaflets, recorded transmitral velocity pattern is composed of two principal deflections: the E

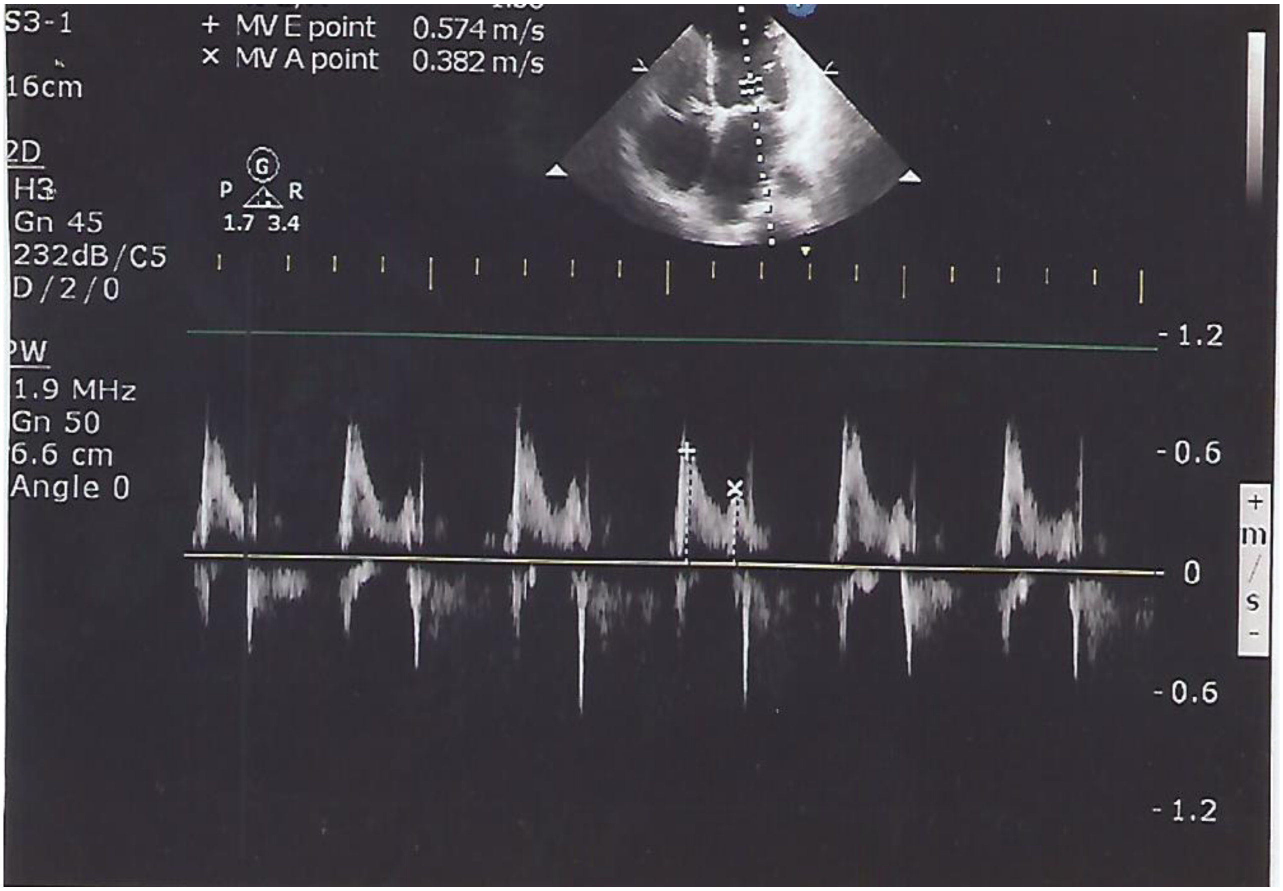

Figure 1. Normal left ventricular diastolic function with E/A ratio greater than 1

wave occurring during the rapid filling phase, and the lower A wave, arising from atrial contraction (figure 1). These two waves are usually separated with relatively low velocity signals during diastasis. Numerous indices derived from this pattern have been proposed as markers of diastolic function such as the peak and integrated velocities of the E and A waves, their ratio, and acceleration and deceleration times. There are three pathologic filling patterns detected by pulsed Doppler based on the E/A ratio namely impaired relaxation pattern (figure 2), pseudonormal pattern and restrictive pattern. However few of these measurements are sufficiently advanced for routine use. In particular the familiar E/A ratio rises with age (Klein et al., 1994) and provides insufficient data from which to draw conclusions about LV global diastolic dysfunction. A short early deceleration time, however, is associated with poorer prognosis, and adds additional prognostic information to that provided by measurements of systolic function (Giannuzzi et al., 1996). This is an area of rapid development; methods such as analysis of LV filling propagation also look promising (Takastuji et al., 1996).

HOW ECHOCARDIGRAPHIC FINDINGS GUIDE MANAGEMENT

Identification of poor global systolic function

Clinical data alone can predict ACE inhibitor benefit in severe heart failure and after myocardial infarction (Acute Infarction Ramipril Efficacy Study Investigators, 1993) , but clinical and chest x-ray findings underestimate the prevalence of LV dysfunction. The studies of the left ventricular dysfunction (SOLVD)(The SOLVD investigators, 1991) and survival and ventricular enlargement (SAVE) (Pfeffer et al., 1992) trials demonstrate significant reductions in mortality and other end points when patients with poor LV function were treated with ACE inhibitors.

Identification of isolated diastolic dysfunction

It has been recognised for more than 10 years that some patients with the clinical syndrome of heart failure appear to have well preserved systolic function on

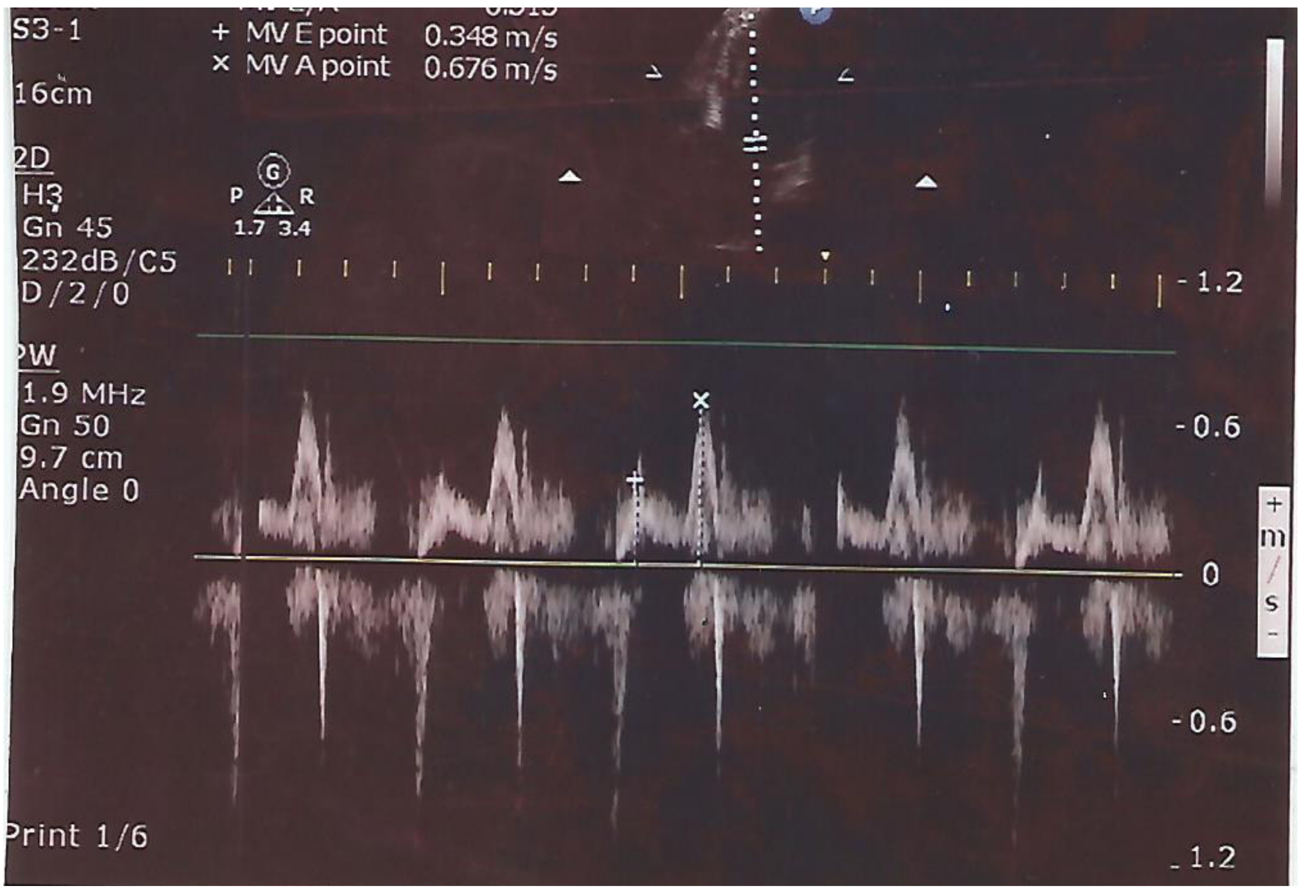

Figure 2. Grade 1 Left ventricular diastolic dysfunction or impaired relaxation with E/A ratio less than 1.

echocardiography. These patients should be evaluated with care and diastolic function assessed with care. Early recognition of diastolic dysfunction may assist in additional risk stratification and subsequently guide the introduction of appropriate pharmacological interventions.

Identification of isolated right heart failure

Some patients will be found to have isolated right heart failure with normal left heart function on echocardiography. Identification of this subgroup is important. Treatment should be directed to the underlying cause such as thromboembolic disease, or alleviation of chronic hypoxia from chronic obstructive airway disease. There is no evidence that such patients benefit significantly from ACE inhibitor therapy.

Valve disease

Significant valvular disease is sometimes missed clinically, particularly mitral stenosis. Aortic stenosis is not always easy to grade accurately particularly in the elderly. Regurgitant lesions may be underestimated or missed clinically, but clear demonstration of their presence and severity may lead to more vigorous afterload reduction or consideration of valve replacement. Criteria for the latter were reviewed (Ross, 1996). Occasionally, intracardiac masses like vegetations, intracardiac shunts and large pericardial effusions are seen.

Embolic risk

Assessment of embolic risk in patients with heart failure, and the resulting consideration of warfarin therapy , may be assisted by echocardiography. Embolic risk can be assessed by a combination of clinical variables and echocardiographic features. Intracardiac thrombi, a large left atrium, poor LV function, increased LV chamber size, and mitral stenosis have all been associated with increased risk (Petersen et al., 1989; Gottdiener et al., 1983; Juggdutt et al., 1989).

ADVANCES IN ECHOCARDIOGRAPHY POTENTIALLY APPLICABLE TO HEART FAILURE

Automated wall detection algorithms (Perez et al., 1992; Stewart et al., 1993) can be used to record rate of change of volume in a graphical way, similar to gated radionuclide ventriculography, and hence aim to provide more precise measurement of EF. They also allow determination of additional diastolic parameters. These methods work satisfactorily on very good quality images.

Transoesophageal echocardiography obtains excellent pictures, even in subjects whose trans thoracic images may be difficult to interpret. It visualises posterior structures such as the left atrial appendage, which cannot normally be seen on routine recordings. Transoesophageal echocardiography should be considered if left atrial masses, bacterial endocarditis, or clots are suspected. However, it is more complex and 'semi-invasive' than transthoracic echocardiography, and cannot be considered a routine investigation in heart failure at this time.

Dobutamine stress echocardiography shows promise in the 'unmasking' of stunned or hibernating myocardium in patients with ischemic heart disease (Peirard et al., 1990). Apparently infracted regions which transiently recover function with low dose dopamine are likely to recover permanently after coronary revascularization (Perrone-Filardi et al., 1995). It is most useful, therefore in patients who might actually undergo if such a hypokinetic area can be seen to recover with inotropes.

Doppler tissue imaging and colour kinesis are technologies which encode movement of myocardium or endocardium in colour thus demonstrating hypokinetic, akinetic, or dyskinetic segments of the cardiac wall (Miyatake et al., 1995). Regional myocardial thickening and ventricular synchrony are readily apparent, and chamber volume measurements may be more accurately defined. Calculation of myocardial velocity gradients is more sensitive than measuring endocardial excursion alone (Sutherland et al., 1995). The addition of myocardial contrast agents and second harmonic imaging (Sutherland et al.,1995) and concurrent use of dobutamine stress (von Bibra et al., 1995) are likely to make these clinically useful technologies.

Three dimensional reconstruction of cardiac chambers and valves shows great promise in the provision of additional information. Chamber dimension can be estimated with greater accuracy than is possible with cross sectional methods (Nosir et al., 1996) and valves can be seen and assessed with great accuracy (Salustri et al., 1996).

CONCLUSION

Although these technological advances are exciting, the priority is to apply current knowledge well, with increased use of transthoracic echocardiographic imaging in the syndrome of heart failure. It is likely that application of cross sectional imaging with Doppler ultrasound enhancement should be wide spread in the evaluation of patients with this very common but highly lethal condition.

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