Mitral flow derived Doppler indices of left ventricular diastolic function

See page 1376 for the article to which this Editorial refers

Heart failure has been identified as a major health care initiative for the millennium. In the United States alone there are more than 4.9 million people with heart failure and 450 000–700 000 new cases are diagnosed each year\(^1\). Heart failure is currently the most frequent cause of hospital admission for patients over 65 years of age. The concept that heart failure is defined as ventricular systolic contractile dysfunction and inability to meet the metabolic requirements of the body tissues is no longer tenable, because almost one third of all patients with heart failure have normal systolic function but abnormal left ventricular diastolic function\(^2\). Diastolic ventricular relaxation is an energy requiring process involving sequestration of cytosolic calcium by the sarcotubular system and not simply passive elastic recoil. Today’s definition of heart failure needs to embrace diastolic ventricular dysfunction, that is, failure to receive blood at normal intracardiac filling pressures. Normal ventricular filling is a prerequisite for normal ventricular emptying, and the relationship between diastolic filling and contractile function is described by Frank–Starling law.

Perturbations in myocardial perfusion and ventricular hypertrophy induced by chronically increased afterload due to valvular heart disease or hypertension often result in abnormalities of ventricular function which are first manifest in diastole. Thus, there is an important need for techniques to accurately and unequivocally diagnose abnormalities of ventricular diastolic function. Left ventricular diastolic dysfunction was assessed initially in terms of impaired relaxation by measurement of the time constant of left ventricular pressure decay (tau), or altered ventricular compliance, both of which required haemodynamic and/or angiographic measurement at cardiac catheterization to construct pressure decay curves or pressure-volume/dimension relations\(^3\). However, serial evaluation of left ventricular diastolic function by cardiac catheterization has never been a practical proposition. The introduction of echocardiography and subsequently Doppler has provided non-invasive methods of quantitating left ventricular diastolic function in terms of chamber filling dynamics and left atrial pressure.

M-mode echocardiograms of the left ventricular dimension or the two-dimensional echocardiographic left ventricular short axis area with simultaneous left ventricular pressure tracings have been digitized to construct pressure–dimension loops\(^4\), estimate peak filling rates and the duration of the rapid diastolic filling phase\(^5\). However, these measurements can only be utilized when the region of the left ventricle sampled is representative of the whole ventricle, so that their use is precluded in ventricles with regional wall motion abnormalities. In contrast, Doppler techniques enable measurement of blood flow velocities across the mitral valve throughout diastole which reflect global left ventricular filling, and do not require assessment of ventricular size, shape or regional wall motion abnormalities\(^6\). Initial Doppler studies measured peak blood flow velocities during rapid passive filling phase (E wave) and during atrial systolic contraction (A wave) and demonstrated that these measurements describing diastolic left ventricular function changed with age even in normal subjects. The velocity during the passive rapid filling phase peak velocity decreased in amplitude with concomitant prolongation of passive filling. This was accompanied by augmentation of the peak velocity during atrial systole, indicating that a greater proportion of left ventricular diastolic filling volume resulted from atrial systole with increasing age, and this could be expressed as a progressive decline in the ratio of peak velocities E/A or the ratio of their respective velocity time integrals \(E\text{VTI}/A\text{VTI}\).

There followed a burgeoning literature of Doppler studies describing small numbers of patients in whom measurements of E and A wave blood flow velocities were made in a wide spectrum of diseases in which abnormal left ventricular diastolic function was suspected. These studies showed that transmitral E and A blood flow velocities and their ratio (E/A) were sensitive to variations in left ventricular loading conditions, heart rate, body weight, age and gender\(^7,8\). More recently quantitation of the deceleration time of the early (E wave) passive filling velocity transient has been shown to correlate with left atrial pressure. Because interpretation of Doppler measurements of diastolic ventricular function may be complicated by a number of confounding factors, recommendations have been formulated to assist in the diagnosis of left ventricular diastolic function\(^9,10\).

A notable deficiency in the Doppler literature was the...
absence of a large prospective study of a normal population in which measurements of diastolic function (filling dynamics and isovolumic relaxation time) have been made in both sexes from early adulthood to old age and the stability (variability and reproducibility) of these measurements tested prospectively. This deficiency has been rectified by Schirmer and colleagues[11] in the Tromsø Study which was supported by the Norwegian Council on Cardiovascular Diseases and reported in this issue.

The authors assessed left ventricular diastolic function in 3022 subjects using Doppler echocardiography with two specific goals. The first goal was to characterize diastolic left ventricular function by age and gender in 875 normal subjects; the second was to assess the influence of left ventricular mass, ejection fraction and a history of cardiovascular disease on diastolic function in the remaining 2200 patients. The normalcy of the reference population (n=875) was carefully established by history, physical examination (heart rate <100 beats min⁻¹; blood pressure <140/90 mmHg and body weight <20% greater than mean body weight by height) and review of echocardiograms via which patients with left ventricular hypertrophy and ejection fraction <45% were excluded. In addition, the authors examined the interaction of age and gender on E deceleration time and the E/A velocity ratio.

The important findings of this prospective cross-sectional study design were to confirm that continual change in left ventricular diastolic function occurred with advancing age in the normal heart in a well-characterized normal population. These age-related changes in diastolic function consisted of a shift from the high peak E wave velocity with a short deceleration time and low peak A wave velocity, to a reduced E velocity amplitude, prolonged deceleration time and augmentation of the A velocity, such that there is a progressive fall in E/A velocity ratio. Thus the amplitude of blood flow during the early filling phase slows but its duration increases while the peak velocity of blood flow from atrial contraction increases such that atrial contraction contributes a greater proportion to left ventricular end-diastolic volume. These age-related transitional changes in diastolic function were similar in the normal males and females, and also in the whole population surveyed and occurred independent of body weight, hypertension, left ventricular hypertrophy or history of cardiovascular disease.

In characterizing the changes in diastolic ventricular function in the normal heart with age, the authors provide the first large normal database for left ventricular diastolic function which will serve as a new reference template that will undoubtedly prove useful in identifying patients with diastolic dysfunction. However, several years after the Tromsø Study was conceived, several additional measurements are now thought to be useful for a complete description of diastolic function in normal and abnormal hearts[12]. These include isovolumic relaxation time, pulmonary venous velocities, atrial filling fraction, flow propagation velocities by Doppler colour flow M-mode and diastolic myocardial velocities from Doppler tissue imaging[12]. These measurements when adjusted for age and sex will provide a more complete understanding of diastolic function by allowing differentiation between the effects of preload and relaxation on left ventricular filling dynamics[12].

Future aims should focus on constructing a practical algorithm for evaluating left ventricular diastolic dysfunction utilizing the combination of age-adjusted values for the E/A velocity ratio and deceleration time integrated with the newer measures of pulmonary venous flow velocity patterns, propagation velocity and diastolic myocardial velocities especially in older patients (>65 years) in whom diastolic heart failure predominates.

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References


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