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Lateral vs medial mitral annular tissue Doppler in the echocardiographic assessment of diastolic function and filling pressures: which should we use?

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Abstract Tissue Doppler echocardiography (TDE) is used in the assessment of diastolic function, however, it is unclear whether the medial (E' med) or lateral (E' lat) annulus should be used. Our aim was to compare the diagnostic utility of E' med and E' lat. In 232 subjects left ventricular (LV) systolic and diastolic function was assessed via transthoracic echocardiography with TDE measurements obtained from both annuli. LV function was normal in 91 subjects (39%), with diastolic dysfunction found in 141 subjects (61%). TDE velocities decreased with age and progressive diastolic dysfunction for either annulus. E' med recorded significantly lower myocardial velocities than E' lat. Receiver operator curves showed improved area under the curve (AUC) for E' med than E' lat. Furthermore the AUC was significantly improved compared to E/A ratio and deceleration time. For diagnosing diastolic dysfunction, an E' med < 11 cm/s provided a sensitivity of 78%, specificity of 67% and positive predictive value of 70%. Whilst for diagnosing elevated filling pressures an E/E' medial ratio > 8 provided values of 56%, 93% and 91%, respectively. In conclusion, although either annulus can be used, E' med provides better diagnostic utility.

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Background

Diastolic heart failure arising from left ventricular diastolic dysfunction (DD) is a significant cause and predictor of morbidity and mortality.[1,2] Left ventricular diastolic function is determined by left ventricular relaxation and compliance properties, which can be assessed non-invasively via Doppler techniques in the echocardiography laboratory.

Traditional Doppler-derived parameters of diastolic function are obtained from transmitral and pulmonary venous recordings, but are dependent upon loading conditions.[3–6] This results in diastolic parameters exhibiting a U shaped parabolic pattern when progressing from normal to worsening degrees of diastolic dysfunction,[7] which makes determining whether a subject's Doppler pattern corresponds with 'better' or the 'left' side or 'worse' or the 'right' side of the parabola difficult. Newer modalities such as tissue Doppler echocardiography (TDE) have now been developed which exhibit relatively linear properties and are independent of loading conditions. These modalities can be used to complement traditional Doppler methods for the assessment of diastolic function in subjects undergoing transthoracic echocardiographic examination (TTE).[8]

TDE data display myocardial velocities throughout the cardiac cycle. The Doppler signals of the myocardium are of low intensity and high amplitude compared to that of red blood cells, which are of high velocity and low amplitude. Spectral pulsed wave Doppler (PW) provides better temporal and velocity resolution compared to the color method.[9,10] Previous investigators have shown that the ratio of early diastolic mitral inflow (E) to early diastolic mitral annular tissue velocity (E') has a good correlation with left ventricular filling pressure and can be used to diagnose diastolic dysfunction.[11–14] However, a variety of sites have been used to obtain spectral PW TDE data including the medial mitral annulus (E' med) or the lateral mitral annulus (E' lat) or an average sum of both. Consequently, a variety of cutoff values for the diagnosis of diastolic dysfunction and/or high left ventricular filling pressures have been advocated.[9–12,14–16] A study by Sohn et al.[11] found that an E' med < 8.5 cm/s and E'/A' ratio < 1 discriminated a pseudonormal from normal pattern with a sensitivity of 88% and specificity of 67%. For the estimation of filling pressures a study by Nagueh et al.[17] using E' lat found that an E/E' lat ratio > 10 correlated with raised filling pressures. In contrast a study by Ommen et al.[12] using E' med found that an E/E' med ratio > 15 correlated with elevated filling pressures.

Hence, to date there has been no consensus on the most appropriate annulus to be used for TDE assessment of diastolic function and filling pressures. Our aim was to compare both the medial and lateral annuli in consecutive subjects attending a TTE examination to determine which site provides the best diagnostic utility.

Methods

This study was approved by the Austin Health's Human Research Ethics Committee, with written informed consent obtained from all participants. Two hundred and sixty-one consecutive subjects referred for a TTE to assess left ventricular function were enrolled. Exclusion criteria were the presence of significant valvular heart disease, mechanical valvular prosthesis or technically difficult transthoracic imaging. Twenty-nine subjects met these criteria and were excluded from further analysis.

Definitions

Subjects were classified as having normal diastolic function or diastolic dysfunction according to the definitions published by the Canadian consensus on diastolic dysfunction by echocardiography,[7] which was further sub-classified into abnormal relaxation, pseudonormal and restrictive patterns. To distinguish normal subjects from those with pseudonormal diastolic dysfunction, evidence of raised LV filling pressures with a positive Valsalva maneuver was required. A positive test was designated if E/A reversal, DT prolongation and a greater than 25% decrease in E velocity occurred on a strain phase of Valsalva.[18–22]

Echocardiography

TTE examination was performed using a commercially available ultrasound system (Acuson Sequoia, 3.5 MHz transducer) in the left lateral decubitus position. Standard parasternal and apical views were used to assess for left ventricular hypertrophy (LVH), systolic (SD) and diastolic (DD) dysfunction. All recordings and measurements were obtained according to the published recommendations of the American Society of Echocardiography.[23–25]

M-Mode echocardiography was used to measure cardiac dimensions and wall thickness. Fractional shortening was calculated as LV end-diastolic minus end-systolic/end-diastolic dimensions $\times$ 100. LV ejection fraction (EF) was calculated via modified Simpson's rule and M-Mode measurements. Left ventricular mass index (LVMI) was calculated by dividing LV mass by the body surface area (BSA) obtained using the ASE corrected convention.

Parameters of diastolic function measured at the mitral leaflet tips over three consecutive cardiac cycles included mitral *E* and *A* wave (early and late diastolic peak filling velocities), *E*/*A* ratio, mitral *E* wave deceleration time (DT), isovolumic relaxation time (IVRT) and mitral *A* wave duration (*A* dur). Pulmonary venous flow recordings were obtained from the apical four-chamber view with the sample volume placed 1–2 cm into the right upper pulmonary vein. Measurements obtained over three consecutive cardiac cycles were peak systolic pulmonary venous inflow velocity during ventricular systole (S_{max}), peak diastolic pulmonary venous inflow velocity during early phase of atrial diastole (D_{max}), *S*/*D* ratio, peak reversed systolic *A* wave during atrial contraction (AV_{max}) and *A* wave duration (pul *A* dur).

Tissue Doppler echocardiography velocities were obtained using a commercially available software package (Acuson, DTI package), which lowered the Nyquist limit, with low wall filter settings and minimal optical gains. In the apical four-chamber view, a 2 mm pulse wave Doppler sample gate was placed alternately at the medial then lateral mitral annulus to obtain the peak early diastolic (E'), atrial (A') and systolic tissue velocities (S') in three consecutive cardiac cycles for each site (Fig. 1). These values were used to calculate the E/E' ratio.

Subjects were classified as having normal function or diastolic dysfunction according to the definitions published by the Canadian consensus on diastolic dysfunction by echocardiography by two independent, experienced echocardiographers.[7]

Statistical analysis

Continuous data are presented as mean ± SEM unless otherwise specified. Dichotomous variables were expressed as percentages. The unpaired *t* test (2-tailed) was used to assess differences between continuous variables. The chi-square or Fisher exact test was used to compare categoric variables between groups. One way repeated analysis of variance (ANOVA) was used for multivariate analysis. Statistical analyses were performed using Stata (StataCorp, Texas, 1997) and StatView (SAS Institute, Cary, 1998). A value of $p < 0.05$ was considered statistically significant.

Results

Ninety-one subjects had a normal TTE examination, whilst 141 had diastolic dysfunction, classified into abnormal relaxation ($n = 57$), pseudonormal ($n = 83$) or restrictive ($n = 1$) patterns. Thirty subjects with diastolic dysfunction also had systolic dysfunction. The data from the restrictive group was excluded from further analysis.

Clinical characteristics

The clinical characteristics of the groups are shown in Table 1. Subjects in the normal group were younger than the diastolic dysfunction groups. Subjects with abnormal relaxation were the oldest and reflect the relationship between impaired left ventricular compliance and ageing. In contrast the pseudonormal group were significantly older than the normals but significantly younger than the abnormal relaxation group. The majority of subjects were male with normal systolic function as reflected by LVEF measurements. Subjects with diastolic dysfunction were more likely to have had a previous cardiac event and be hypertensive, as reflected by significantly increased LVMI. Left atrial area (LAA) increased significantly with worsening diastolic function.

Traditional Doppler measurements

Traditional Doppler measurements for the groups are given in Table 2 and exhibit the expected U shaped parabolic curve from normal to worsening diastolic dysfunction. Peak *E* velocity decreased significantly in the abnormal relaxation group, but was unchanged from normal in the pseudonormal group. The *E*/*A* ratio, IVRT and DT exhibited similar parabolic patterns.

Pulmonary venous Doppler recordings were only obtainable in 72% of TTE examinations performed (Table 2). The *S*/*D* ratio exhibited a bimodal pattern with the highest ratio in the abnormal relaxation group. There was no statistically significant difference detected in the pulmonary AV_{max} velocities across all groups with a trend towards higher velocities in the pseudonormal group.

Tissue Doppler echocardiography measurements

TDE measurements obtained at E' med were lower than E' lat in all cases (E' med 13 ± 1 cm/s vs E' lat 15 ± 1 cm/s, $p < 0.001$, A' med 15 ± 1 cm/s vs A' lat 19 ± 1 cm/s, $p < 0.001$). Furthermore age

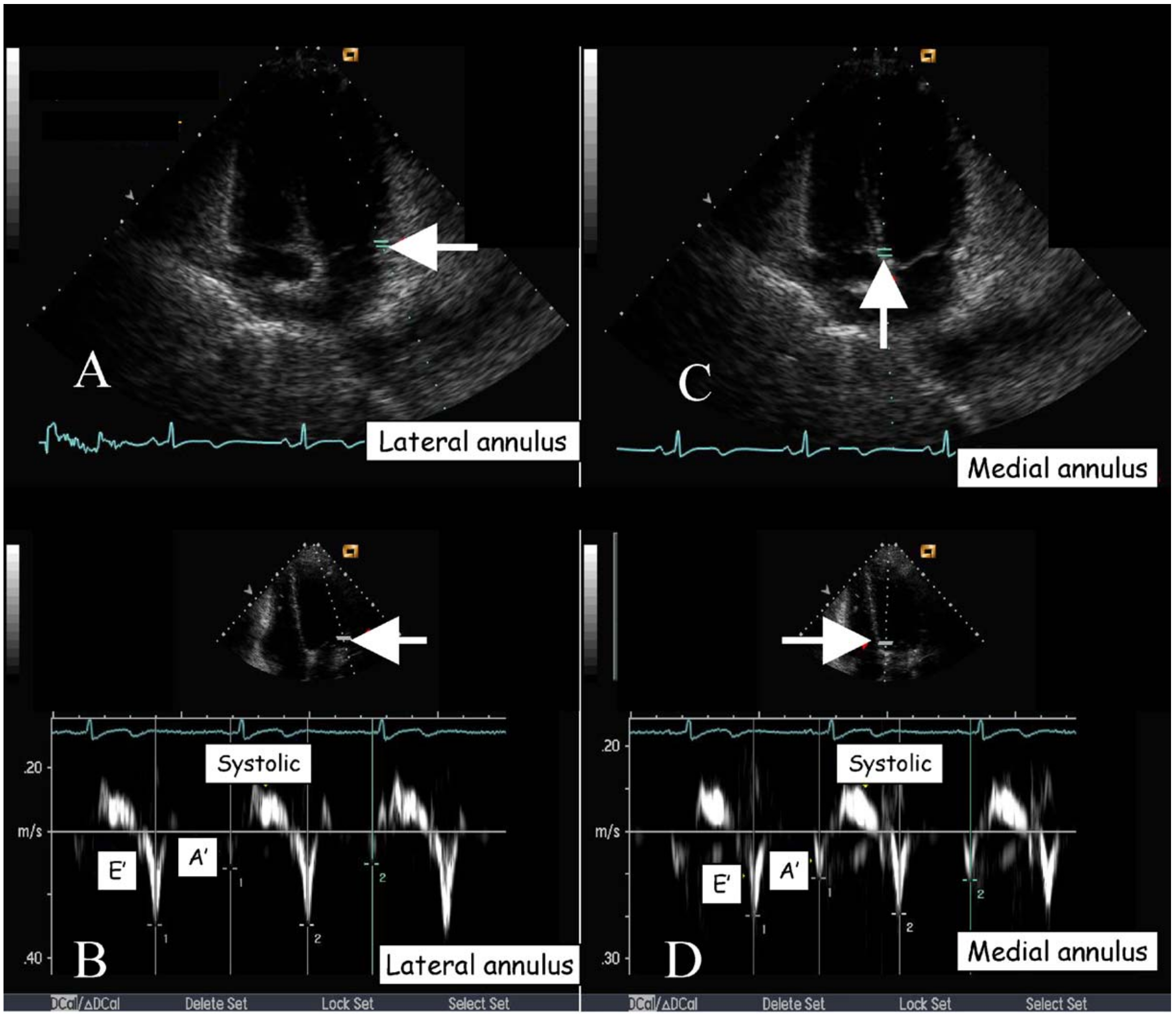

Figure 1 A. Lateral mitral annular cursor placement for TDE data. Transthoracic apical four-chamber view showing cursor placement for TDE measurement of lateral myocardial tissue velocity. B. TDE measurements from lateral mitral annulus. Tissue Doppler myocardial velocities obtained at lateral mitral annulus. E' = peak early diastolic myocardial tissue velocity, A' = peak late (atrial contraction) diastolic myocardial tissue velocity, systolic = peak systolic myocardial tissue velocity. C. Medial mitral annular cursor placement for TDE data. Transthoracic apical four-chamber view showing cursor placement for TDE measurement of medial myocardial tissue velocity (arrow). D. TDE measurements from medial mitral annulus. Tissue Doppler myocardial velocities obtained at medial mitral annulus. E' = peak early diastolic myocardial tissue velocity, A' = peak late (atrial contraction) diastolic myocardial tissue velocity, systolic = peak systolic myocardial tissue velocity.

Table 1 Clinical characteristics of subjects according to left ventricular diastolic function

Cardiac function	Normal	Diastolic dysfunction	Abnormal relaxation	Pseudonormal
	$N = 91$	$N = 141$	$N = 57$	$N = 83$
Age (yrs)	51 ± 1	64 ± 1*	67 ± 1**	$63 \pm 1^{*\dagger}$
Male (%)	58%	58%	61%	56%
LA area (cm^2)	19.0 ± 0.4	23.4 ± 0.5*	22.7 ± 0.7*	23.9 ± 0.6*
LVEF (%)	60 ± 1	56 ± 1	57 ± 2	56 ± 2
Phx cardiac event	18	28*	24*	32*
LVMI (g/m^2)	88 ± 3	116 ± 3*	117 ± 5*	115 ± 4*
Hypertensive (%)	49	84*	85*	83*

LA area = left atrial area, LVEF = left ventricular ejection fraction, LVMI = left ventricular mass index. *$p < 0.001$ vs normal cardiac function. $^{\dagger}p < 0.001$ vs abnormal relaxation group.

Table 2 Traditional mitral and pulmonary Doppler measurements of subjects according to diastolic function

Cardiac function	Normal	Diastolic dysfunction	Abnormal relaxation	Pseudonormal
	$N = 91$	$N = 141$	$N = 57$	$N = 83$
Transmitral				
E (m/s)	0.79 ± 0.02	0.78 ± 0.02	0.68 ± 0.02*	$0.83 \pm 0.02^{\ddagger}$
A (m/s)	0.71 ± 0.02	0.92 ± 0.02*	0.94 ± 0.03*	0.90 ± 0.02*
E/A ratio	1.15 ± 0.06	0.89 ± 0.03*	0.75 ± 0.05*	$0.94 \pm 0.03^{\ddagger}$*
IVRT (ms)	85 ± 2	94 ± 2*	96 ± 2*	$92 \pm 2^{\dagger}$
DT (ms)	184 ± 3	229 ± 5*	271 ± 7*	$203 \pm 4^{\ddagger}$*
Pulmonary				
S_{max} (m/s)	0.59 ± 0.02	0.62 ± 0.01	0.61 ± 0.02	0.62 ± 0.02
D_{max} (m/s)	0.48 ± 0.01	0.47 ± 0.01	$0.41 \pm 0.01^{\dagger}$	$0.50 \pm 0.02^{\ddagger}$
S/D ratio	1.29 ± 0.04	1.4 ± 0.04	$1.54 \pm 0.07^{\dagger}$	1.32 ± 0.06
AV_{max} (m/s)	0.31 ± 0.01	0.32 ± 0.01	0.32 ± 0.01	0.34 ± 0.01

E = early diastolic transmitral filling velocity, A = late/atrial contraction transmitral velocity, E/A ratio = early to late transmitral filling ratio, IVRT = isovolumic relaxation time, DT = early diastolic transmitral filling deceleration time, S = pulmonary venous systolic velocity, D = pulmonary venous diastolic velocity, S/D ratio = systolic to diastolic pulmonary venous ratio, AV_{max} = pulmonary venous atrial reversal maximal velocity. $^{\dagger}p < 0.01$, *$p < 0.001$ vs normal group. $^{\ddagger}p < 0.001$ vs abnormal relaxation group.

($\geq$ 60 yrs) significantly decreased TDE measurements at E' lat and E' med. After adjustment for age, sex and hypertension the difference in E (lat) and E (med) between subjects with normal and diastolic dysfunction remained highly significant ($p < 0.001$) (Fig. 2).

TDE velocities showed a significant linear decrease with progressive diastolic dysfunction for both annulli (Table 3). Similarly, the systolic TDE velocities (S') were significantly reduced in the pseudonormal group for both medial and lateral annuli compared to the normal group. A significant ($p < 0.001$) reduction for S' at the medial annulus was also found between abnormal relaxation and pseudormal groups. The E/E' ratios correlating with left ventricular filling pressure showed a statistically significant linear increase for either annuli with worsening diastolic dysfunction (Table 3). Conversely A' velocities showed a parabolic pattern and were significantly higher in the abnormal relaxation group for both annuli and significantly reduced for the pseudonormal group at the medial annulus. This is a similar parabolic pattern to that seen with transmitral peak A velocities (Fig. 3). The E'/A' ratios also exhibited a parabolic pattern at either annulus with the lowest ratio in the abnormal relaxation group and subsequent increase in the pseudonormal group (Table 3).

Diagnostic utility of tissue Doppler echocardiography

Receiver operated curves (ROC) were generated for E' (lat) and E' (med) ratios for the diagnosis of any diastolic dysfunction (Fig. 4) with similar area under curves (AUC) of 76%, however, the medial annulus provided improved sensitivity and specificity for the diagnosis of diastolic dysfunction compared to E' (lat) at a cutoff of 11.4 cm/s. For

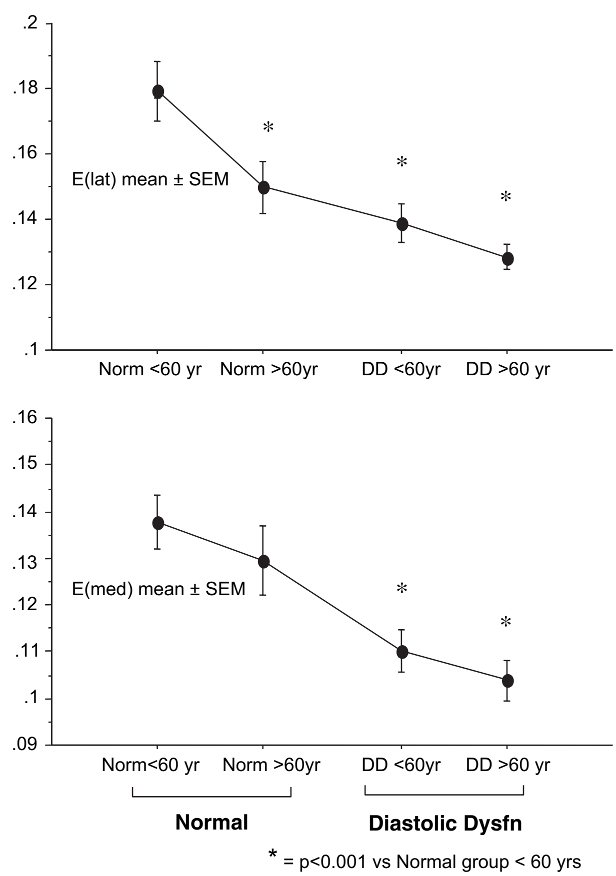

Figure 2 Effects of age on myocardial tissue Doppler velocities in subjects with normal and diastolic dysfunction.

Table 3 Tissue Doppler velocities at medial and lateral mitral annuli according to diastolic function

Cardiac function	Normal	Diastolic dysfunction	Abnormal relaxation	Pseudonormal
	$N = 91$	$N = 141$	$N = 57$	$N = 83$
E' lateral (cm/s)	17.3 ± 0.5	13.3 ± 0.3*	12.8 ± 0.4*	13.2 ± 10.4*
E' medial (cm/s)	13.9 ± 0.4	10.7 ± 0.3*	11.0 ± 0.5*	10.6 ± 0.3*
A' lateral (cm/s)	17.0 ± 0.6	18.7 ± 0.5†	20.8 ± 0.9*	17.9 ± 0.7
A' medial (cm/s)	14.1 ± 0.4	15.5 ± 0.4†	17.8 ± 0.9*	14.8 ± 0.7$^{\mu}$
S' lateral (cm/s)	14.0 ± 0.4	12.1 ± 0.3‡	12.8 ± 0.6*	11.9 ± 0.4‡
S' medial (cm/s)	11.1 ± 0.3	10.5 ± 0.2	10.9 ± 0.5	10.3 ± 0.2$^{\dagger\mu}$
E/E' lateral	4.7 ± 1.4	6.2 ± 0.2*	5.7 ± 0.3†	6.5 ± 0.2*$^{\mu}$
E/E' medial	5.9 ± 0.2	7.8 ± 0.3*	6.4 ± 0.4	8.5 ± 0.4*$^{\mu}$
E'/A' lateral	1.10 ± 0.04	0.73 ± 0.02*	0.64 ± 0.03*	0.79 ± 0.03*
E'/A' medial	1.010 ± 0.04	0.73 ± 0.03*	0.65 ± 0.02*	0.77 ± 0.04*

E' lateral = lateral mitral annular early diastolic myocardial velocity, E' medial = medial mitral annular early diastolic myocardial velocity, A' lateral = lateral mitral annular atrial contraction diastolic myocardial velocity, A' medial = medial mitral annular atrial contraction diastolic myocardial velocity, S' lateral = lateral mitral annular systolic myocardial velocity, S' medial = medial mitral annular systolic myocardial velocity. $^{\ddagger}p < 0.05$, $^{\dagger}p < 0.01$, $^{*}p < 0.001$ vs normal group. $^{\mu}p < 0.001$ vs abnormal relaxation group.

E/E' (lat) and E/E' (med) the AUC was 68% and 70%, respectively (Fig. 5).

ROC curves were also constructed for E/E' (lat) and E/E' (med) for the diagnosis of diastolic dysfunction and elevated filling pressures with improved AUC for the medial annulus (77% vs 79%, respectively). When compared to traditional Doppler measurements of E/A ratio and DT the AUC for TDE measurements were significantly improved. Indeed, when correcting for subjects aged over 60 yrs tissue Doppler measurements maintained AUC, whilst the AUC for E/A, E'/A' (lateral) ratio and DT reduced, indicating reduced diagnostic utility of these measurements in this age group (Table 4).

In the diagnosis of diastolic dysfunction, an E' lat velocity of <12 cm/s provided a sensitivity of 90%, specificity of 37% and positive predictive value (PPV) of 59%. For an E' lat of <13 cm/s the values were 80%, 52% and 63%, respectively. In comparison, an E' med < 10 cm/s provided a sensitivity of 89%, specificity of 52% and PPV of 65%, for an E' med < 11 cm/s these values were 78%, 67% and 70%, respectively (Table 5).

In the assessment of left ventricular filling pressures and differentiation between a normal and pseudonormal diastolic filling pattern at the lateral annulus, an E/E' ratio > 6 provides a sensitivity of 56%, specificity of 83% and PPV of 77%. An E/E' ratio > 7 provides values of 33%, 92% and 81%, respectively. In comparison at the medial mitral annulus an E/E' ratio > 7 provided a sensitivity of 69%, specificity of 72% and PPV of 75%. An E/E' ratio > 8 provided values of 56%, 93% and 91%, respectively (Table 5).

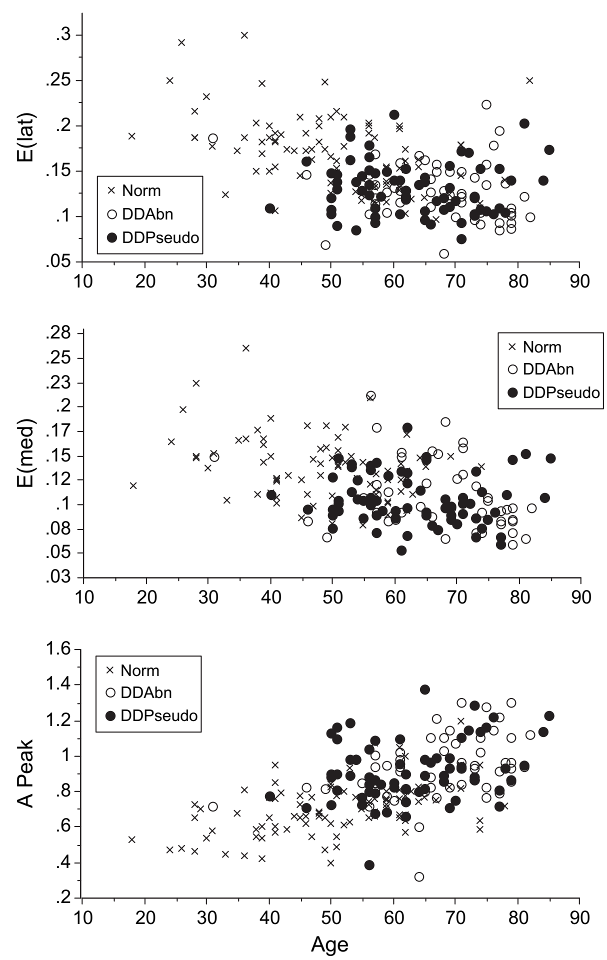

Figure 3 E' (lateral), E' (medial) and A peak vs age and diastolic function.

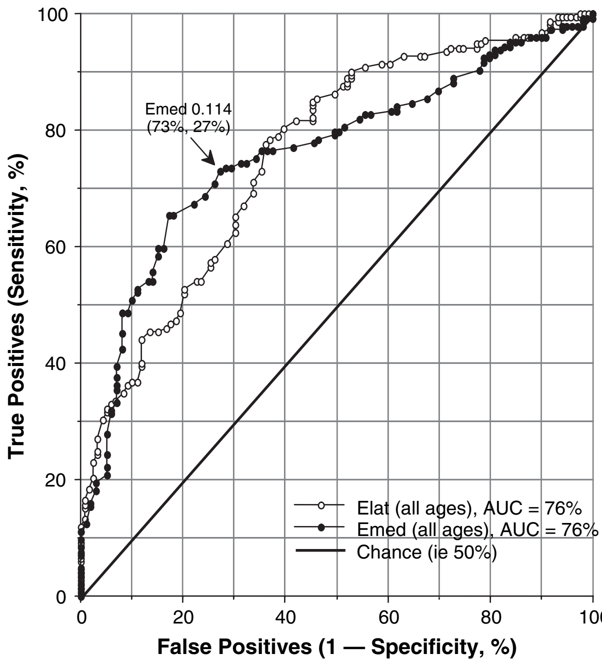

Figure 4 Receiver operated curve for *E* (lateral) and *E* (medial) for the diagnosis of diastolic dysfunction.

Discussion

The classification of diastolic function on echocardiographic criteria can be difficult, with the differentiation of normal from pseudonormal diastolic dysfunction most problematic. Hence, a variety of measurements for the diagnosis of diastolic dysfunction have been used and include transmitral and pulmonary venous profiles along with hemodynamic maneuvers. However, obtaining adequate pulmonary venous profiles and/or a hemodynamic maneuver to unmask a pseudonormal filling pattern may be difficult to achieve in all subjects. Indeed, traditional Doppler and 2D assessments of diastolic function, such as the Canadian consensus are known to be semiquantitative with poor concordance and requiring refinement, yet continue to be applicable to studying large numbers of subjects.[26,27] Such refinement has been advocated with a combined approach with the inclusion of age related criteria and newer modalities of color M Mode and TDE, with traditional Doppler.[28,29]

In contrast to traditional Doppler methods, TDE has the advantage that data is easily obtainable in the majority of subjects and does not require patient and sonographer education in hemodynamic maneuvers. Previous studies with TDE have recommended a variety of criteria and values for the diagnosis of diastolic dysfunction including

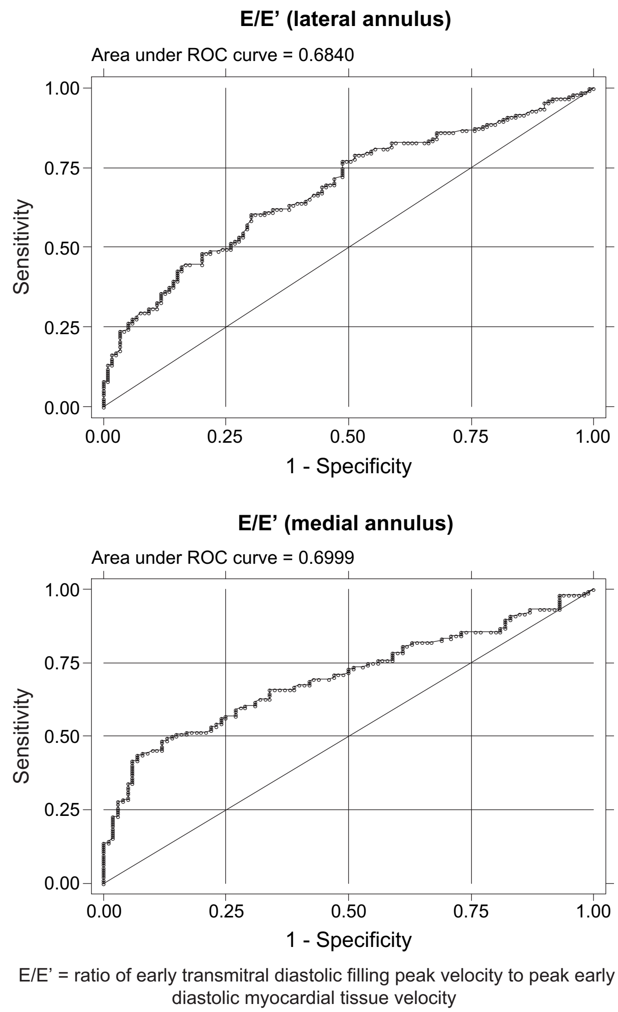

Figure 5 Receiver operated curves for E/E' (lateral) and E/E' (medial) for the diagnosis of diastolic dysfunction.

Table 4 Area under curve measurements from receiver operated curves for traditional and tissue Doppler measurements for the differentiation of normal and pseudonormal diastolic dysfunction

TTE measure	AUC all subjects (%)	AUC subjects age > 60 (%)
E' (lateral)	77	69
E' (medial)	80	78
E/E' (lateral)	77	72
E/E' (medial)	79	82
E'/A' (lateral)	74	52
E'/A' (medial)	80	77
E/A ratio	74	67
Deceleration time	68	60

AUC = area under curve, E' lateral = lateral mitral annular early diastolic myocardial velocity, E' medial = medial mitral annular early diastolic myocardial velocity, E/A ratio = early to late transmitral filling ratio.

Table 5 Diagnostic utility of tissue Doppler echocardiography in the diagnosis of diastolic dysfunction

	Lateral		Medial	
	$E' < 12$ cm/s	$E' < 13$ cm/s	$E' < 10$ cm/s	$E' < 11$ cm/s
(i) Tissue Doppler E' velocity in the diagnosis of diastolic dysfunction				
Sensitivity (%)	90	80	89	78
Specificity (%)	37	52	52	67
PPV (%)	59	63	65	70
	$E/E' > 6$ cm/s	$E/E' > 7$ cm/s	$E/E' > 7$ cm/s	$E/E' > 8$ cm/s
(ii) E/E' ratio in the assessment of filling pressures (normal vs pseudonormal)				
Sensitivity (%)	56	33	69	56
Specificity (%)	83	92	72	93
PPV (%)	77	81	75	91

E' = early diastolic myocardial tissue velocity, E/E' = ratio of early transmitral diastolic filling peak velocity to peak early diastolic myocardial tissue velocity.

taking an average or sum of multiple sites. Alternatively cutoff values have been suggested according to the site sampled i.e. E' med $< 8-10$ cm/s, with some investigators including the E'/A' ratio in the diagnosis of diastolic dysfunction to improve sensitivity and specificity. The initial validation studies correlating invasive hemodynamic measurement of filling pressure with TTE findings found lower TDE velocities across all groupings (normal and diastolic dysfunction) for both sites when compared to our results.[11,16,17] They also found a correlation between high filling pressures, diastolic dysfunction and an E/E' ratio $> 10-15$.

In this study, TDE velocities were measurable in all subjects assessed. We found that TDE myocardial velocities were significantly reduced with ageing and worsening grades of diastolic dysfunction. However, after adjustment for age the differences in TDE velocities between subjects with normal and those with diastolic dysfunction remained highly significant ($p < 0.001$) for either annulus. Furthermore TDE velocities exhibited a unimodal, linear pattern compared to the parabolic pattern of traditional Doppler methods. Our data also shows that when comparing E' med and E' lat, the former has lower TDE velocities and provides better diagnostic utility for the diagnosis of diastolic dysfunction at the medial annulus using E' velocities and E'/A' ratio. In the differentiation of normal from elevated filling pressure curves the medial annulus provides better utility as assessed by AUC from ROC. This is likely to be due to the fact that E' med is less affected by translational movement of the heart due to the apex being relatively fixed throughout the cardiac cycle. In addition, Doppler beam angle errors are less likely to occur since the motion of the base of the heart is in an axial plane and parallel to the Doppler cursor when compared to sampling for the lateral annulus. E' lat myocardial velocities may also be affected by myocardial ischaemia and/or infarction, which is less likely to occur at E' med. Indeed, a recent invasive hemodynamic study in normal healthy volunteers showed that E' med TDE velocities in subjects with preserved LV systolic function have a good correlation with LV filling pressure, whilst E' lat do not.[30]

Our results show that high filling pressures were detectable at a lower E/E' ratio than previously published reports. The likely cause for this discrepancy is almost entirely due to the higher TDE velocities measured resulting in lower E/E' ratios. For example, in our study a subject with normal diastolic function and a subject with pseudonormal diastolic dysfunction had a mean E' med of 14 cm/s and 11 cm/s, respectively. In the study by Sohn et al.[11] using E' med, these velocities were found to be 10 cm/s and 8.5 cm/s, respectively. The higher TDE velocities recorded in our study may result from a variety of reasons. Firstly, the initial validation studies of TDE were performed upon symptomatic patients with known cardiac disease undergoing invasive cardiac procedures in the supine rather than lateral decubitus position.[11,17] In addition, a large percentage of subjects with diastolic dysfunction in these studies also had reduced systolic function, which is known to reduce myocardial velocities.[13] However, in our cohort only 20% of subjects had systolic dysfunction, which is likely to be a realistic representation of referral patterns to echocardiography labs. Indeed, previous studies have shown that subjects with combined LV systolic and diastolic dysfunction have a better correlation between LV filling pressures and E/E' ratios than those with preserved systolic function.[12] In contrast our group of subjects had predominantly normal LV systolic function without known cardiac disease and studies were performed in the left lateral decubitus position. Other reasons for this discrepancy in velocities measured may include technical factors relating sample gate size and positioning of PW gate i.e. myocardium vs true annulus. Recently published studies have documented myocardial tissue velocities with values similar to that obtained in this study in subjects with normal LV systolic function.[8,9,31]

In patients with diastolic and systolic heart failure it is known that in the longitudinal left ventricular axis systolic TDE velocities are decreased.[32,33] In our cohort we found a trend to lower systolic velocities at the medial annulus with worsening diastolic function and a statistically significant reduction in velocities at the lateral annulus. This is consistent with previous studies in subjects with isolated diastolic dysfunction and not diastolic heart failure.[32]

Clinical applications

To date, there have been limited studies on the use of TDE in subjects with normal systolic function, and this study is a large series showing its utility in the non-invasive assessment of LV filling pressures and diastolic function. In the echocardiographic assessment of diastolic function the currently recommended approach involves traditional 2D, Doppler and Valsalva methods combined with newer modalities of tissue Doppler and color M Mode.[28,29] Our results provide important information on the relative use of E' med and E' lat in TDE measurements. Whilst the E' lat may be used, we suggest that E' med provides better diagnostic utility. In addition, with increasing age and worsening LV systolic function it may be prudent to lower the diagnostic range for TDE velocity with a subsequent increase in the diagnostic range for the E/E' ratio.

Study limitations

In this study, diastolic function was classified according to established echocardiographic criteria but no invasive hemodynamic measurements were performed. However, the effect of loading conditions was assessed by the Valsalva maneuvre, which has been shown to be an effective non-invasive means of determining LV filling pressure.[18,20,22] Furthermore other investigators have shown a strong correlation between TDE measurements and invasively assessed LV filling pressures.[7,10]

Conclusion

Myocardial velocities obtained with TDE in conjunction with traditional Doppler methods provide an important non-invasive means of assessing diastolic function and filling pressures in man. Myocardial velocities are reduced with increasing age, diastolic and systolic dysfunction. These measurements are easily obtained with pulse wave Doppler techniques compared to pulmonary venous profiles. Either annulus may be used, but the medial mitral annulus provides better diagnostic utility.

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