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Age dependency in the timing of mitral annular motion in relation to ventricular filling in healthy subjects: Umeå General Population Heart Study

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Aims Peak left ventricular (LV) relaxation normally precedes peak filling (E), which supports the hypothesis that LV suction contributes to early-diastolic filling. The significance of similar temporal discordance in late diastole has previously not been studied. We describe the time relationships between mitral annular motion and LV filling in early and late diastole and examine the effect of normal ageing on these time intervals.

Methods and results A total of 128 healthy subjects aged 25–88 years were studied. Transmitral and pulmonary venous flow reversals (Ar) were recorded by Doppler echocardiography. Mitral annular diastolic displacement—early (E_m) and late (A_m)—were recorded by Doppler tissue imaging. With reference to electrocardiographic R and P-waves, the following measurements were made: R to peak E-wave (R-E) and E_m (R-E_m); onset P to peak A-wave (P-pA), A_m (P-pA_m), and Ar (P-pAr). The differences between [(R-E) and (R-E_m)] for early-diastolic temporal discordance (EDTD) and [(P-A) and (P-A_m)] for late-diastolic temporal discordance (LDTD) were calculated. Isovolumic relaxation time (IVRT) was also measured. Early-diastolic temporal discordance was ~26 ms in all age groups. Late-diastolic temporal discordance, however, was inversely related to age ($r = -0.35$, $P < 0.001$) and IVRT ($r = -0.34$, $P < 0.001$) and therefore decreased in the elderly vs. young (13 ± 10 vs. 23 ± 10 ms; $P < 0.001$). In multivariate analysis, age failed to predict LDTD in the presence of IVRT. A, A_m, and Ar were simultaneous at onset, and peak A_m coincided with peak Ar in all age groups ($r = 0.97$, $P < 0.001$). No significant differences were noted in the RR intervals.

Conclusions Sequential prolongation of IVRT with ageing reduces LDTD, thus converging the peaks of A_m, A, and Ar (atrial mechanical alignment)—a potential novel method to identify subjects at increased dependency on atrial contraction for late-diastolic filling.

Introduction

Left ventricular (LV) filling in early diastole results from a cascade of well-synchronized mechanical events that begin in the systolic phase of the cardiac cycle. During ejection period, the LV undergoes counterclockwise torsion, and clockwise recoil of torsion or untwisting before mitral valve opening, especially during isovolumic relaxation period.[1,2] This recoil is associated with release of restoring forces that had been accumulated during systole and is thought to contribute to diastolic suction and hence LV filling.[2,3] Since early-diastolic annular motion is a potential marker of LV recoil,[4,5] peak annular velocity (E_m) should precede peak mitral flow velocity (E). Indeed this phenomenon has been demonstrated by temporal discordance between these two events using Doppler tissue imaging (DTI) combined with Doppler echocardiography[4–6] and is altered or lost in patients with LV hypertrophy (LVH) and diastolic dysfunction.[5]

Although peak annular velocity in late diastole (A_m) may be a robust marker of left atrial (LA) systolic function, its relationship with peak A-wave (A) of the transmitral flow (TMF) has not been fully investigated. Some studies, however, have shown that despite A_m being load dependent,[7] it begins simultaneously with the A-wave.[8] By examining a large sample of healthy subjects, we sought to investigate the clinical significance of the temporal relationship between atrial contraction and ventricular filling in late diastole and to determine the effect of ageing on temporal discordance in early and late diastole.

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Methods

Study subjects

One hundred and twenty-eight subjects (mean age 54.0 ± 18.4 years, range 25–88 years, 62 women) were studied and arbitrarily classified into three groups: Y (young), M (middle age), and E (elderly). Group Y (25–44 years) consisted of 44 subjects, and Group M (45–64 years) and E (≥65 years) each consisted of 42 subjects. All study subjects were part of the Umeå General Population Heart Study, which consists of a cohort of 300 healthy volunteers aged 20–90 years; equal gender distribution in every age-decade, and all recruited from the Umeå General Population Register. All the 128 participants had: (i) a normal clinical cardiovascular history and were not on any cardioactive medication, (ii) normal findings on physical examination and 12-lead electrocardiogram (ECG), and (iii) sinus rhythm and clear P-waves on ECG superimposed on echo images were mandatory inclusion criteria for this particular study. Each participant gave informed consent and the Ethics Committee of Umeå University approved the study protocol.

Echocardiography

Immediately after physical examination and recording of a 12-lead ECG at rest, a complete M-mode, two-dimensional, and Doppler examination was performed in each subject while lying in a left lateral decubitus position. Commercially available ultrasound system (Acuson Sequoia, Mountain View, CA, USA) equipped with multi-frequency (2–3.5 MHz) imaging transducer was used. All studies were performed according to the recommendations of the American Society of Echocardiography using conventional views and measurements.[9] To minimize cardiac movements resulting from respiration, all echocardiographic data were obtained at end-expiration. M-mode and Doppler recordings were all made with superimposed lead II of the ECG and phonocardiogram (PCG) at sweep speeds of 50 and 100 mm/s. All data were recorded on magneto optical disks (Maxell Corp., NJ, USA) and later analysed offline using the same ultrasound machine.

The TMF pattern was recorded using pulsed-wave Doppler, with the sample volume positioned at the tip of the mitral valve leaflets on the LV four-chamber view. Peak early-diastolic velocity (E), late-diastolic velocity (A), and the E-to-A ratio were also determined offline. Pulmonary venous flow (PVF) was obtained from the same view, with the sample volume placed in the right superior pulmonary vein proximal to the LA guided by colour flow Doppler.

Pulsed-wave DTI was performed with the sample volume set at the endocardial portion of the base of the LV lateral wall from the apical four-chamber view. Left ventricular lateral wall myocardial velocity patterns were recorded and expressed as systolic wave (S_m), early-diastolic wave (E_m), and late-diastolic wave (A_m) (*Figure 1*).

Measurements and calculations

The following measurements were made from at least three different cardiac cycles on the following echocardiograpic images.

Doppler transmitral and pulmonary venous flow:

- The time interval from the onset of P-wave on the ECG to the onset, and then to the peak of: A-wave on the TMF, (P-A) and (P-pA), respectively. Ar-wave on the PVF, (P-Ar) and (P-pAr), respectively.
- Isovolumic relaxation time (IVRT) as the time interval from A_2 (aortic component of the second heart sound on the PCG) to the onset of transmitral E-wave.
- Duration from peak R on the ECG to peak transmitral E-wave (R-E) (*Figure 1*).

Doppler tissue imaging:

- Duration from peak R on the ECG to peak E_m (R-E_m). Thus, early-diastolic temporal discordance (EDTD) was computed as the difference between (R-E) and (R-E_m).

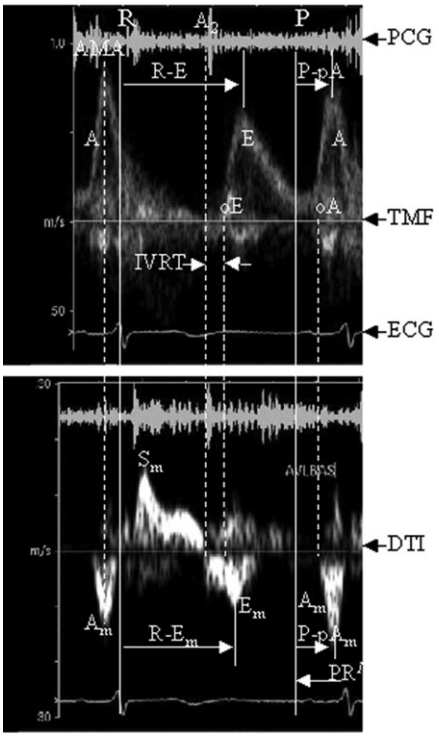

Figure 1 Relationship between Doppler transmitral flow (TMF) (upper panel) and Doppler tissue imaging (DTI) of the LV basal free wall motion (lower panel) in an 84-year-old healthy man. Vertical lines R and P refer to electrocardiographic peak of R and the onset of P, used as reference points for measurements of early-diastolic temporal discordance and late-diastolic temporal discordance, respectively. Mitral in-flow is biphasic, early diastolic (E), and atrial contraction (A). Doppler tissue imaging wall motion profile is triphasic—systolic (S_m), early diastolic (E_m), and atrial contraction (A_m). E and E_m began simultaneously (oE) as did A and A_m (oA). R to peak E (R-E) was longer than R to peak E_m (R-E_m). Peak A coincided with peak A_m (AMA)—atrial mechanical alignment. Isovolumic relaxation time (IVRT) was determined from aortic valve closure (A_2) on the phonocardiogram (PCG) to the onset of E (global) and E_m (regional). PR′ refers to the interval from the peak of R to the onset of P of the preceding cycle. In this particular case, early-diastolic temporal discordance was 14 ms while late-diastolic temporal discordance was zero.

- The time interval from the onset of the P-wave of the ECG to the onset, and the peak of A_m-wave on the LV lateral base: (P-A_m) and (P-pA_m), respectively.
- Late-diastolic temporal discordance (LDTD) was calculated as the difference between the time intervals (P-pA) and (P-pA_m).
- Peak A_m and E_m velocities and the E_m-to-A_m ratio was calculated.

Two-dimensional apical two and four chambers:

- Left ventricular end-diastolic and end-systolic volumes were determined using modified Simpson's formula, and the LV ejection fraction was derived from these volumes using the standard formula.

Left ventricular end-diastolic and end-systolic dimensions and LA dimension were all measured from standard transverse M-mode echocardiograms. RR intervals and heart rate (HR) were measured from every image examined. Effort was made to compare cardiac cycles with similar HRs, particularly in measuring temporal discordance in early diastole.

The onset of P-wave on ECG was derived first by manually measuring the PR interval on the standard 12-lead ECG, using a digital calliper. To maintain the same PR interval in all the measurements performed on every subject, individual measurements were made in reference to R-wave of the ECG, which is a more reproducible landmark. Hence, the distance from the peak of R-wave to the onset of the preceeding P-wave (PR′) was determined and used throughout all measurements on each individual subject (*Figure 1*). This ensured a universal onset point of the P-wave on every set of images studied, thus eliminating possible errors associated with determination of the nadir point of the P-waves.

Reproducibility of measurements

Intra-observer and inter-observer variabilities were tested in 22 subjects selected randomly from the three groups. Measurements, particularly timings upon which our conclusions are based, were repeated by one investigator and independently by a second at different times to determine both intra- and inter-observer variability. Results were analysed using the method of agreement as described by Bland and Altman[10] and presented as the coefficient of variation.

Statistical analysis

All values are expressed as mean ± standard deviation. Comparison between groups was carried out by one-way analysis of variance (ANOVA) and correlation between variables by simple linear regression analysis. Multivariate analysis was performed to identify the factors affecting LDTD, such as age, PR interval, and IVRT. Student's *t*-tests for paired data were used where appropriate. Data analysis and calculations were performed using SPSS program (version 11.0, SPSS Inc., Chicago, IL, USA), and the *P*-value was considered to be statistically significant when it was <0.05.

Results

General and echocardiographic data are presented in *Table 1*. Ventricular systolic function assessed by ejection fraction was normal across all age groups. However, early abnormal relaxation pattern characterized by E-to-A ratio <1 was present in Group E compared with Y ($P < 0.001$). In addition, the LA anteroposterior diameter was larger ($P < 0.001$) and the PR interval longer ($P < 0.001$) in the elderly compared with the young. Otherwise, there were no significant differences between all groups with regard to HR, RR interval, diastolic blood pressure (BP), and LV end-diastolic cavity size.

Early-diastolic temporal discordance

The onset of E_m coincided with the onset of TMF E (*Figure 1*). However, the time interval (R-E_m) was longer in Group E ($P = 0.01$) as was (R-E) ($P = 0.01$), both compared with Group Y. Isovolumic relaxation time was longer in Group E with respect to Group Y ($P < 0.001$). Peak E_m preceded peak E in all age groups by ~26 ms (*Table 2*). After correcting this time interval as a ratio of the RR interval expressed as a percentage, there were still no significant differences between the groups. The corrected EDTD (EDTDc) accounted for ~3% of the cardiac cycle. Furthermore, in univariate analysis, this ratio correlated poorly with factors associated with diastolic dysfunction: age ($r = 0.05$), mitral EDT ($r = -0.1$), E-to-A ratio ($r = -0.19$), and corrected IVRT (IVRTc) ($r = 0.13$) (*Figure 2*).

Late-diastolic temporal discordance

Unlike the temporal discordance in early diastole, the corresponding discordance in late diastole had very distinct

Table 1 General and echocardiographic characteristics (mean ± SD)

	Group Y ($n = 44$)	Group M ($n = 42$)	Group E ($n = 42$)
General			
Age (years)	33.4 ± 5.8	54.0 ± 7.2	75.2 ± 5.5
Sex (male:female)	19:25	28:14	19:23
Systolic BP (mmHg)	116 ± 11	127 ± 13‡	142 ± 12‡
Diastolic BP (mmHg)	73 ± 9	76 ± 10	76 ± 8
HR (bpm)	66 ± 12	66 ± 8	68 ± 11
RR interval (ms)	939 ± 175	929 ± 113	904 ± 152
PR interval (ms)	161 ± 16	174 ± 20‡	173 ± 15‡
Echocardiographic			
LA dimension (mm)	32.9 ± 3.6	36.3 ± 4.3†	37.7 ± 4.7‡
LV end-diastolic dimension (mm)	47.6 ± 5.4	48.8 ± 4.2	47.2 ± 5.0
LV end-systolic dimension (mm)	28.3 ± 4.2	28.7 ± 3.7	25.4 ± 4.2†
LV ejection fraction (%)	65.1 ± 5.6	62.8 ± 4.8	63.8 ± 5.7
E velocity (cm/s)	71.0 ± 13.7	62.9 ± 16.6*	58.3 ± 15.0†
A velocity (cm/s)	43.7 ± 11.9	52.6 ± 13.8†	75.4 ± 14.2‡
E-to-A ratio	1.74 ± 0.58	1.24 ± 0.34‡	0.79 ± 0.17‡
IVRT (ms)	56 ± 13	72 ± 11‡	83 ± 18‡
EDT (ms)	168 ± 37	192 ± 36*	228 ± 50‡
E_m velocity (cm/s)	18.9 ± 4.1	15.3 ± 3.6‡	10.7 ± 2.3‡
A_m velocity (cm/s)	10.8 ± 3.0	14.0 ± 3.1‡	15.5 ± 2.5‡
E_m-to-A_m ratio	1.87 ± 0.64	1.15 ± 0.39‡	0.70 ± 0.15‡

A, late-diastolic flow; A_m, atrial contraction using Doppler tissue imaging; BP, blood pressure; EDT, mitral E-wave deceleration time; E, early-diastolic flow; IVRT, isovolumic relaxation time; E_m, velocity of basal LV motion in early diastole using Doppler tissue imaging; LA, left atrial; LV, left ventricular.
*$P < 0.05$, †$P < 0.01$, and ‡$P < 0.001$ vs. Group Y.

Table 2 Timing of LV lateral basal motion in relation to Doppler transmitral and pulmonary venous flow reversal (mean ± SD)

Variable	Group Y ($n = 44$)	Group M ($n = 42$)	Group E ($n = 42$)
Early diastole			
(R-E) (ms)	509 ± 33	521 ± 37	534 ± 47*
(R-E_m) (ms)	481 ± 37	498 ± 35	507 ± 49*
[(R-E)−(R-E_m)] (ms)	28 ± 19	23 ± 21	28 ± 26
EDTD corrected (% of RR)	3.1 ± 1.1	2.5 ± 2.2	3.2 ± 3.2
Late diastole			
(P-pA) (ms)	152 ± 12	158 ± 15	160 ± 14*
(P-pA_m) (ms)	129 ± 14	139 ± 14*	147 ± 18†
[(P-pA)−(P-pA_m)] (ms)	23 ± 10	19 ± 12	13 ± 10†
LDTDc (% of RR)	2.5 ± 1.1	2.1 ± 1.2	1.5 ± 1.1†
(P-pAr) (ms)	129 ± 14	138 ± 14*	145 ± 18†

All measurements were made with reference to the peak of R and the onset of P on the ECG. (R-E), interval from peak R to peak mitral E-wave; (R-E_m), interval from peak R to peak Doppler tissue early-diastolic E_m-wave; [(R-E)−(R-E_m)], early-diastolic temporal discordance between the time intervals above. A and A_m, transmitral A-wave and Doppler tissue A_m waves, respectively; (P-pA) and (P-pA_m), time intervals to the respective peaks of A and A_m; [(P-pA)−(P-pA_m)], the late-diastolic temporal discordance; (P-pAr), time interval from onset of P to the peak of pulmonary flow reversal (Ar); RR, electrocardiographic R-R interval.

*$P < 0.05$ and †$P < 0.001$ vs. Group Y.

characteristics on univariate analysis. First, it correlated inversely with age ($r = -0.35$, $P < 0.001$) and with IVRT ($r = -0.34$, $P < 0.001$) (*Figure 2*). Secondly, peak A_m coincided with peak Ar ($r = 0.97$, $P < 0.001$) and generally preceded peak A in all age groups. Therefore, progressive prolongation of (P-pA_m) with ageing diminished the time difference between the peaks of A_m and A. In this respect, LDTD decreased from 23 ± 10 ms in the young to 13 ± 10 ms in the elderly ($P < 0.001$) (*Table 2*). Moreover, 24 (18.8%) subjects (1 young, 8 middle-aged, and 15 elderly) had an LDTD approximating zero (≤7 ms), implying that peak A_m coincided with peak A. At this point of coincidence, all the peaks of A, A_m, and Ar would be aligned. Thus, we describe this point of convergence as atrial mechanical alignment (AMA) (*Figure 1*). Finally, LDTD corrected for RR interval (LDTDc) accounted for ∼2.5% of the cardiac cycle in the young and progressively declined to ∼1.5% in the elderly ($P < 0.001$). Conversely, IVRTc increased with age ($P < 0.001$), whereas EDTDc remained unchanged (P = NS) (*Figure 3*).

Multivariate analysis: late-diastolic temporal discordance as dependent variable

Multiple linear regression analysis was performed to weigh the independent associations between LDTD and other variables, particularly those conventionally used to define diastolic dysfunction (age, E-to-A ratio, mitral EDT, and IVRT). By this model, after adjusting for potential determinants such as sex, HR, PR interval, LA dimensions, and systolic BP, the independent inverse correlation between LDTD with age ($P = 0.01$) and with IVRT ($P = 0.03$) was confirmed. However, age lost its ability to predict LDTD in the presence of IVRT.

Reproducibility

Inter-observer and intra-observer reproducibility for all time intervals used to calculate EDTD and LDTD are presented in *Table 3*. No consistent differences were found between duplicate measurements for any variable.

Discussion

Importance of early and late-diastolic temporal discordances

Recent developments in echocardiographic techniques have not only enhanced the ability to study myocardial function non-invasively but also relate diastolic filling to concomitant ventricular wall motion. By comparing myocardial DTI and conventional transmitral inflow Doppler profiles, previous studies[4–6] have demonstrated characteristic temporal relationships between early LV filling (E) and mitral annular motion,[4,5] where normally peak annular velocity consistently precedes peak mitral flow. Thus, temporal discordance between LV relaxation and filling has provided additional evidence that LV suction plays a role in early-diastolic filling. Similar temporal relationships have not been conclusively described in late diastole, although some studies have examined LA mechanical behaviour,[11] amplitudes and timings of myocardial velocities,[12] and the relationship between mitral ring motion and TMF.[8] Furthermore, the temporal relationship between LA contraction and the resultant forward flow (A-wave) and retrograde flow into the pulmonary veins (Ar) has not been previously studied. This study sought to define this relationship and its potential clinical application.

Study findings

Our results show that in late diastole, peak LA contraction (A_m) precedes peak A-wave by ∼20 ms in the young and half that time in the elderly, and these mechanical events consistently follow the P-wave of the ECG. We have further demonstrated that peak A_m strikingly coincides with peak Ar, a relationship that is maintained across all age groups. This coincidence supports the hypothesis that Ar is entirely dependent on LA contraction. Further, this study describes AMA, a physiological state in which the peaks of A, A_m, and Ar coincide at LA contraction. Thus, demonstrating AMA provides additional evidence that forward flow (A-wave) becomes increasingly dependent on LA contraction not only with increased age but also with

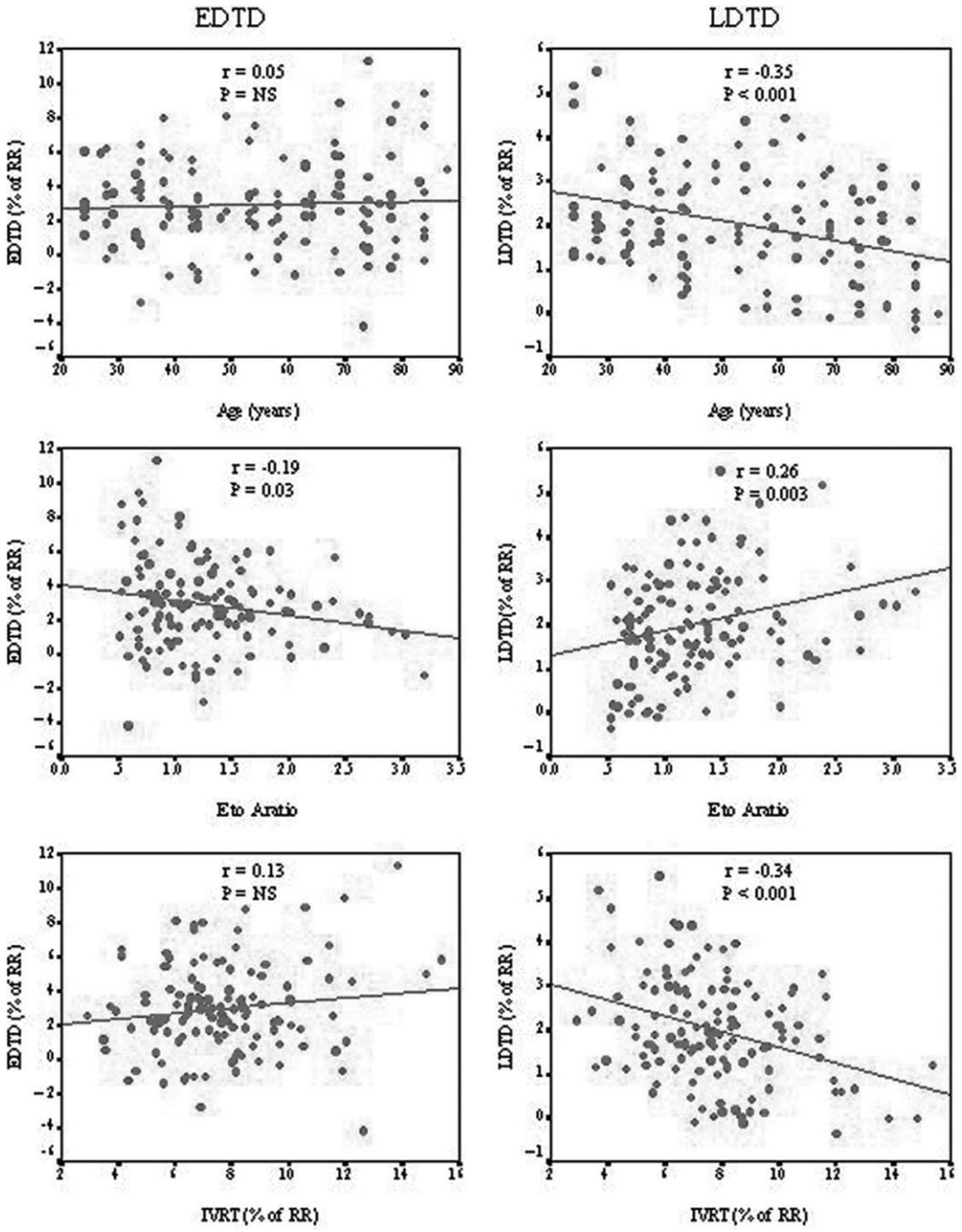

Figure 2 Scatter plots comparing correlations between early-diastolic temporal discordance (EDTD) and late-diastolic temporal discordance (LDTD) against age, E-to-A ratio, and corrected isovolumic relaxation time (IVRTc). Compared with late-diastolic temporal discordance, early-diastolic temporal discordance has a poor relationship with age and some selected factors that define diastolic performance ($n = 128$, for all the plots).

sequential prolongation of IVRT as evident from the multivariate analysis.

In contrast, a temporal discordance demonstrated in early diastole was ~26 ms in all age groups, an observation that is partly in agreement with a previous study.[4] Our findings also show that alterations in late-diastolic timings are more pronounced than those in early diastole, suggesting that these changes may be as a result of completely different mechanisms.

Mechanisms

With LA contraction, there is simultaneous bi-directional flow towards the LV and pulmonary veins. Our observation that peak Ar consistently coincides with peak A_m confirms that pulmonary flow reversal is entirely dependent on LA contraction. Indeed it has previously been shown that atrial flow reversal is absent in patients with atrial fibrillation.[13,14] In contrast, with regard to forward flow, peak A_m precedes peak A-wave, suggesting that other factors in

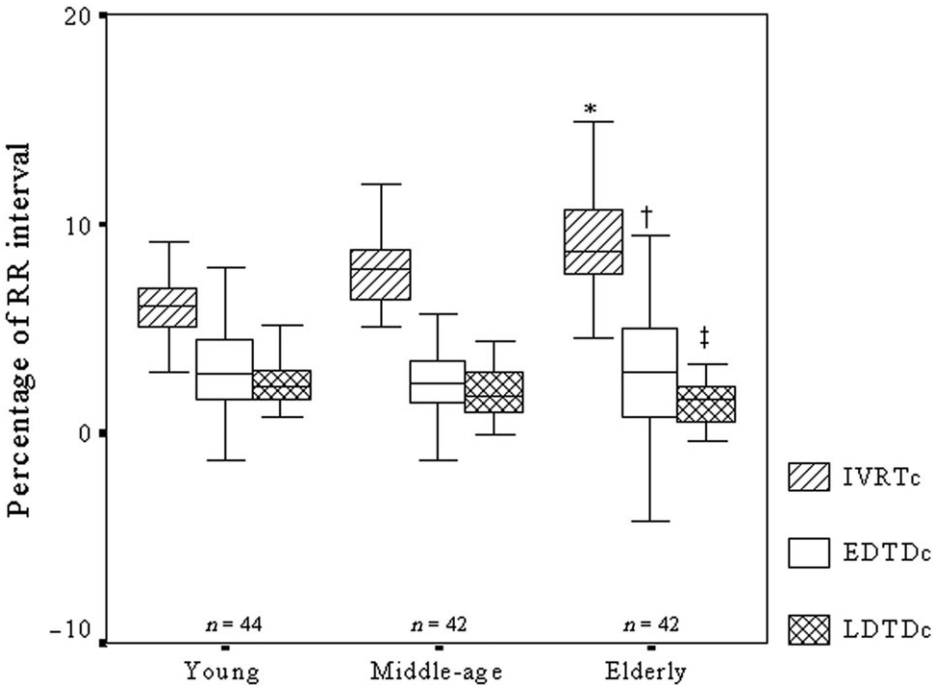

Figure 3 Box plots showing the pattern of change in corrected isovolumic relaxation time (IVRTc), corrected early-diastolic temporal discordance (EDTDc), and corrected late-diastolic temporal discordance (LDTDc) with increasing age. In the young vs. the elderly, there is an increase in corrected isovolumic relaxation time ($^{*}P < 0.001$) and a decrease in late-diastolic temporal discordance ($^{\ddagger}P < 0.001$), whereas early-diastolic temporal discordance remains unchanged ($^{\dagger}P =$ NS). The lowest, second lowest, middle, second highest, and highest box points represent the minimum, 25th percentile, median, 75th percentile, and the maximum, respectively.

Table 3 Reproducibility of measurement of time intervals

	Inter-observer				Intra-observer			
	Mean	SD	Limits	CV (%)	Mean	SD	Limits	CV (%)
Peak R to peak E-wave (ms)	−0.6	6	−12.6 to 11.4	1.1	−1.5	7	−15.5 to 12.5	1.4
Peak R to peak E_m (ms)	0.4	7	−13.6 to 14.4	1.4	−0.3	4	−8.3 to 7.7	1.0
Onset P to peak A (ms)	−1.6	7	−15.6 to 12.4	4.3	−0.2	5	−10.2 to 9.8	3.3
Onset P to peak A_m (ms)	0.1	4	−7.9 to 8.1	2.7	3.1	4	−4.9 to 11.1	2.2

CV, coefficient of variation; Limits, 95% confidence interval; P and R, electrocardiographic P and R, respectively.

addition to LA contraction influence this phase of flow. These include LV elastic properties that account for LA systolic afterload[7] and flow propagation initiated in early diastole. From our results we can postulate that LA contraction occurs before the cessation of flow initiated by LV suction in early diastole, thus providing a 'turbo effect' to this phase of flow by re-accelerating its velocity. Consequently, peak A-wave occurs after peak A_m.

However, when flow downstream is reduced, for instance, by impairment of LV relaxation, LV filling is maintained by augmented LA contraction usually reflected as increased atriogenic velocities as we have shown previously.[15] This scenario is characteristic of advancing age in which LV compliance decreases and impedance to forward flow increases. This physiological remodelling process makes forward flow more dependent on LA contraction in the elderly people, and our demonstration that LDTD progressively narrows with ageing attests to this fact. More importantly, however, although PR interval is known to influence LV diastolic filling, particularly in the elderly,[16] it appears that age exerts its effects on LDTD through changes in the IVRT and not the PR interval. Thus, suggesting that conditions that prolong IVRT will most likely display AMA.

Overall, LV remodelling in the elderly mimics similar changes that occur in pathological conditions such as hypertension.[17] Rodriguez *et al.*[5] showed that in patients with LVH secondary to hypertension and aortic stenosis, there was reversal in timings with peak E preceding peak E_m. Although our study participants were not selected on the basis of these criteria, we did not show a similar reversal in timings particularly among the elderly group. It may be true, as suggested by the same authors that peak early velocity and the time to peak relaxation reflect different phenomena: ventricular filling and restoring forces or elastic recoil. More importantly, however, according to our results, EDTD, which is dependent on elastic recoil, is age independent, suggesting that suction properties of the LV are preserved in healthy hearts despite ageing. This observation supports earlier invasive studies by Yamakado *et al.*,[18] which demonstrated that negative dP/dt, a

measure of LV relaxation, was preserved in healthy people from the age of 20 to 70 years, suggesting that other factors may be responsible for altered filling seen with ageing.

Although in our study comparisons have been made between timings in early and late diastole, events in these two periods of the same diastolic phase are dependent on different mechanisms. Early diastole is mainly dependent on ventricular function and late diastole on atrial function. The LV twisting motion that occurs in early diastole has been proposed to be an energy-economizing mechanism by which wall stress and oxygen demand are minimized.[19] This early ventricular mechanism is complemented in the late atrial phase by LA contraction, which secures maintenance of the required LV filling. These two interdependent mechanisms may perhaps explain why alterations in timings in late diastole are more pronounced relative to those in the early phase. Thus, by looking at time alterations, we may begin to have a better insight into this complex phase of the cardiac cycle.

Clinical implication

Abnormal relaxation pattern on transmitral Doppler is characterized by a prolonged deceleration time of early diastole, with reduced early filling and dominant atrial velocities. This is usually associated with normal or near-normal LV end-diastolic pressure[20] and is a pattern recognized in the elderly. With progressive impairment of LV relaxation, augmented LA contraction may be insufficient. Thus, maintenance of LV filling requires an increase in LA pressures, which consequently leads to pulmonary congestion[21] and dyspnoea. Demonstrating AMA in healthy subjects, especially the elderly, in our study highlights the overall increased cardiac functional dependence on LA systolic performance in the absence of overt ventricular disease. Therefore, loss of atrial mechanical function in this group carries a risk of significant haemodynamic disturbances. In addition to traditional measures of abnormal LV relaxation and LA function in healthy elderly people with or without dyspnoea, it may be useful to determine critical atrial timings that identify those absolutely dependent on atrial contraction for late-diastolic filling. Similar temporal alterations in the LV short and long-axis motion have been described and are known to precede changes usually detected by the traditional measures of systolic function.[22] Certainly, further research is needed to clearly define diastolic time intervals, especially in different loading conditions.

Study limitations

LV diastolic function is complex, and diastolic filling as measured by Doppler echocardiography is influenced by many factors, among them: an increase in preload (volume loading) or afterload (increased BP), HR, and degree of mitral regurgitation. The subjects in our study, however, were healthy volunteers with normal cardiovascular parameters who were studied at rest minimizing changes in preload or afterload. Moreover, HR was consistently similar in all recordings.

Conclusions

In healthy subjects, EDTD, which reflects ventricular restoring forces (suction), is age independent. A similar temporal discordance can be demonstrated between late-diastolic filling and LA contraction, and this suggests that suction effects initiated in early diastole still contribute to late LV filling concomitantly with LA contraction. With advancing age, however, IVRT prolongs and the timing of peak LA contraction and that of late-diastolic flow (A-wave) progressively converge (AMA), providing a novel method to identify healthy persons at increased dependency on LA contraction for late-diastolic filling.

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