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CME

Echocardiography

A Novel Noninvasive Method to Assess Left Ventricular −dP/dt Using Diastolic Blood Pressure and Isovolumic Relaxation Time

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Background: Left ventricular Doppler-derived −dP/dt determined from the continuous-wave Doppler spectrum of the mitral regurgitation (MR) jet has been shown to be a valuable marker of diastolic function, but requires the presence of MR for its assessment. We sought to determine if a novel method of determining −dP/dt using the diastolic blood pressure and isovolumic relaxation time (DBP-IVRT method) correlates with Doppler-derived −dP/dt using the MR method (Doppler-MR method). Methods: Thirty-three patients with less than severe MR were enrolled. −dP/dt was determined using the Doppler-MR method from the continuous-wave Doppler spectrum of the MR jet (32 mmHg/time from 3 to 1 m/sec). −dP/dt was also determined using the DBP-IVRT method using the following equation: −dP/dt = (DBP − LVEDP)/IVRT, where left ventricular end-diastolic pressure (LVEDP) was estimated based on tissue Doppler and mitral inflow patterns. Results: Twenty-five patients had adequate Doppler waveforms for analysis. The average amount of MR was mild-to-moderate severity. The mean −dP/dt was 680 ± 201 mmHg by the Doppler-MR method and 681 ± 237 mmHg by the DBP-IVRT method. There was a significant correlation between the 2 methods of determining −dP/dt (Pearson r = 0.574, P = 0.003). The Bland–Altman plot revealed almost no bias between the 2 methods; the difference in −dP/dt between the 2 techniques was noted to be greater for patients with higher −dP/dt, however. Conclusion: Diastolic blood pressure and isovolumic relaxation time may be used to noninvasively assess diastolic function in patients who do not have MR, especially in those with reduced diastolic function. (Echocardiography 2013;30:267-270)

Key words: echocardiography, Doppler echocardiography, diastolic function

One of the ways in which cardiac function has been evaluated has been to measure peak dP/dt, the maximal rate of pressure rise during left ventricular contraction.[1] Peak dP/dt is sensitive to changes in myocardial contractility, but less affected by changes in afterload due to the fact that maximum rise in pressure occurs before opening of the aortic valve, and is only slightly affected by preload. This measure is also indifferent to wall-motion abnormalities and variants in ventricular anatomy/morphology.[2]

Traditionally, the measurement of dP/dt has required invasive measures, such as the use of a high-fidelity micromanometer-tipped catheter, limiting its use in clinical cardiology. Noninvasive measures have been developed to derive dP/dt and −dP/dt using continuous-wave Doppler echocardiography, but they require the presence of mitral regurgitation (MR) to allow calculation of left ventricular pressure increase using the MR velocity curve and modified Bernoulli equation.[3,4] dP/dt and −dP/dt derived using this approach have been shown to predict outcome in patients with heart failure[4] and in patients undergoing mitral valve surgery.[5]

A limitation of the Doppler-derived method described above is that it is not applicable to patients without MR. An alternative technique was evaluated by Rhodes et al.[6] and by Yilmaz et al.[7] that uses noninvasive diastolic blood pressure (DBP) and isovolumic contraction time (IVCT) derived by Doppler echocardiography to calculate dP/dt. Yilmaz et al. compared this new method to dP/dt derived by the continuous-wave Doppler MR method in 36 patients, and found a close correlation between the 2 methods. To our knowledge, however, no one has used the DBP and isovolumic relaxation time (IVRT) to determine the −dP/dt of the left ventri-

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cle. The purpose of this study is to compare a novel method of determining −dP/dt (the DBP-IVRT method) to the Doppler MR method for evaluation of diastolic function.

Methods:

Patients (n = 33) with at least minimal, but less than severe MR who were already undergoing a clinically indicated transthoracic echocardiogram (Siemens Acuson Sequoia, Siemens Ultrasound, Mountain View, CA, U.S.A.; Philips iE33, Philips Healthcare, Andover, MA, U.S.A.) were enrolled in the study in December 2009. Patients were excluded if they were not in sinus rhythm. The study was approved by the Institutional Review Board of the University of Michigan, and all patients provided informed consent to undergo additional imaging per a written protocol.

−dP/dt was determined using the Doppler-MR method from the continuous-wave Doppler spectrum of the MR jet in the apical four-chamber view at a sweep speed of 150 mm/sec (Fig. 1); the scale and baseline were optimized to maximize the spectrum (0–4 m/sec scale). Three different MR spectra were captured, and −dP/dt (32 mmHg/time from 3 to 1 m/sec) was measured in each, and then averaged. In addition, pulse-wave Doppler of the mitral inflow was performed in the apical four-chamber view with the sample volume placed at the tips of the mitral valve leaflets. Three different pulse-wave spectra were captured at a sweep speed of 150 mm/sec, and the time of onset of QRS to beginning of E wave, as well as E/A ratio, was measured in each and averaged. Next, continuous-wave Doppler of aortic outflow was measured in the apical 5-chamber view at a sweep speed of 150 mm/sec, so that time from onset of QRS to end of aortic outflow could be measured from 3 different spectra, and averaged. Tissue doppler was used to measure E′ (average of lateral and septal measurements) when possible. Each patient also underwent manual measurement of blood pressure using a standard cuff.

−dP/dt was determined using the DBP-IVRT method using the following method:

$$-dP/dt = (DBP - LVEDP)/IVRT,$$

where LVEDP was estimated at 10 mmHg if tissue Doppler-derived E/E′ was ≤ 15, and 20 mmHg if E/E′ was >15.

If no adequate tissue Doppler waveforms were available, then the LVEDP was estimated based on the mitral inflow E/A: LVEDP = 10 mmHg if E/A $\leq$ 1.6, and 20 mmHg if E/A $>$ 1.6. (See Fig. 2.)

Statistical Analysis:

All data are expressed as mean ± SD or as a percent. The 2 methods to measure −dP/dt were compared using Pearson correlation analysis, as well as Bland–Altman analysis.[8] Statistical calculations were performed using SPSS v.17 (SPSS Inc., Chicago, IL, USA).

Results:

Twenty-five patients had adequate Doppler waveforms for analysis. Seven patients were excluded because of an inadequate Doppler spectrum of the MR jet, and 1 was excluded because of an inadequate pulse-wave Doppler spectrum to measure IVRT. Patient characteristics are shown in Table I. The average amount of MR was mild-to-moderate severity. The mean −dP/dt was 680 ± 201 mmHg by the Doppler-MR

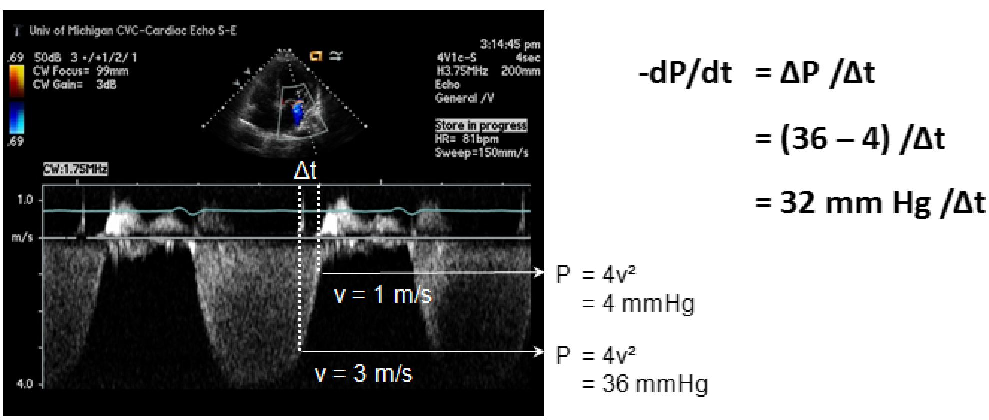
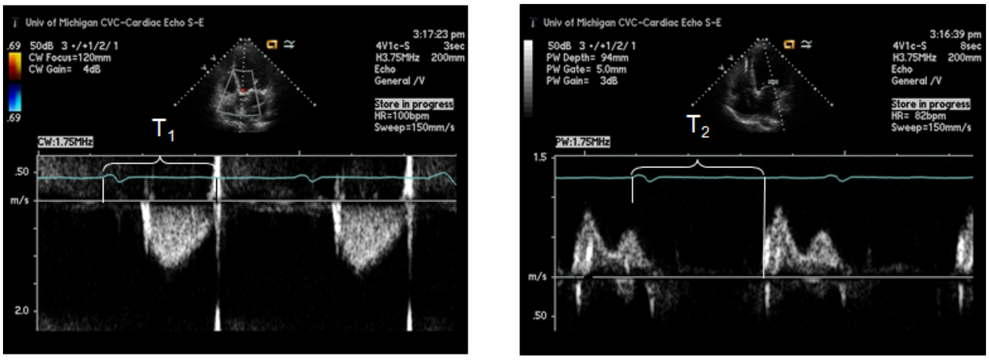


Figure 1. −dP/dt was determined using the Doppler-mitral regurgitation method from the continuous-wave Doppler spectrum of the mitral regurgitation jet (Δpressure from 3 to 1 m/sec divided by the time from 3 to 1 m/sec). P = pressure; t = time; v = velocity.[4]



$$\text{IVRT} = T_2 - T_1$$

Figure 2. The isovolumic relaxation time is calculated by subtracting T1 (time from onset of the QRS to end of aortic flow) from T2 (time of onset of the QRS to onset of mitral inflow).

TABLE I

Patient Characteristics

Age (years)	69 ± 11
Sex (%)	72% male
Mean EF (%)	40 ± 21
Average amount of mitral regurgitation (MR)	Mild-to-moderate
Mean SBP (mmHg)	117 ± 20
Mean DBP (mmHg)	67 ± 11
Mean −dP/dt by Doppler-MR method (mmHg)	680 ± 201
Mean −dP/dt by DBP-IVRT method (mmHg)	681 ± 237

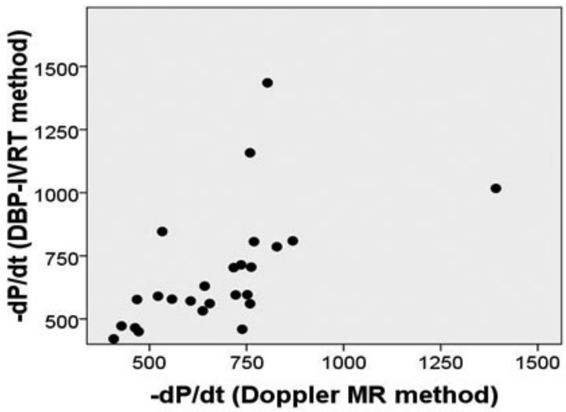


Figure 3. Bivariate correlation analysis revealed a significant correlation between the 2 methods of determining −dP/dt (Pearson r = 0.574, P = 0.003).

method and 681 ± 237 mmHg by the DBP-IVRT method. Bivariate correlation analysis revealed a significant correlation between the 2 methods of determining −dP/dt (Pearson r = 0.574, P = 0.003) (Fig. 3). A Bland–Altman plot was also used to assess the agreement between the 2 methods (Fig. 4), and revealed that there was almost no bias between the 2 methods. The difference in −dP/dt between the 2 techniques was noted to be greater for patients with higher −dP/dt.

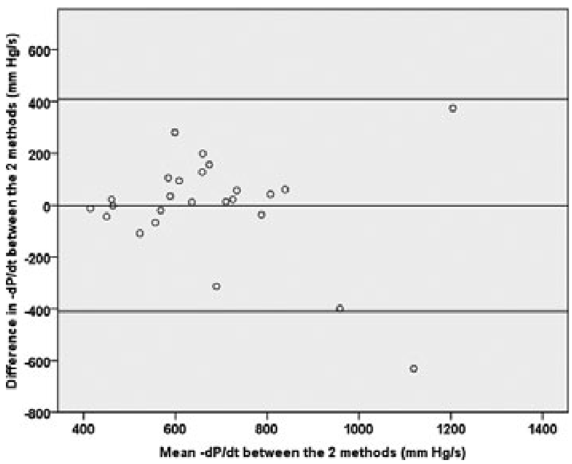


Figure 4. Bland–Altman plot of the 2 methods used to calculate −dP/dt. The line of bias (center horizontal line) reveals there is almost no bias between the 2 methods. The upper and lower horizontal lines reveal the 95% limits of agreement (mean ± 2 standard deviations).

Discussion:

Noninvasive assessment of the diastolic function parameter −dP/dt has traditionally required continuous-wave Doppler echocardiography of the MR jet to derive −dp/dt. However, this depends on the presence of MR to allow calculation of left ventricular pressure increase using the MR velocity curve and modified Bernoulli equation.[3,4] Our study found that diastolic blood pressure and isovolumic relaxation time may be used as an alternative method to noninvasively assess −dp/dt without requiring the presence of mitral insufficiency. As such, this method has potential to achieve more widespread application in patients who do not have mitral insufficiency.

Although there was a significant correlation between the 2 methods, Bland–Altman analysis revealed that as the −dP/dt increased, there was less agreement between the 2 methods. The 3 participants who had a −dP/dt > 1000 as determined by the DBP-IVRT method had the least agreement between the 2 methods. This suggests that the DBP-IVRT method of assessing −dP/dt may be most useful in patients with reduced diastolic function. A potential application of this new technique may be that it can provide a simplified way to monitor the effectiveness of heart-failure therapy. Larger studies will need to be done to see whether this is an appropriate use of this technique.

One limitation of the study was the small number of patients. Also, 7 of the 33 patients did not have adequate MR Doppler spectra to allow calculation of −dP/dt using the Doppler MR method, and thus were excluded from analysis. Another limitation of the study is that calculation of −dP/dt is dependent on the quality of the MR Doppler signal which can vary from patient to patient, as well as from one echocardiography machine to another. Even a small error in determining the points on the MR spectrum used to correspond with 1 and 3 m/sec could result in miscalculation of −dP/dt. We attempted to minimize this by averaging 3 MR spectra; the same investigator also performed all the calculations to minimize variability in how the measurements were obtained. This study also depends on the accuracy of filling pressures as measured by echocardiography, which may be another limitation. Most of these limitations are related to the older Doppler-MR technique used for comparison, however, as opposed to the new DBP-IVRT technique, and they highlight both the need and the potential for a new technique that does not require assessment of MR.

Finally, almost all of the blood pressures used in the calculations were obtained while patients were lying down and undergoing echocardiography. However, in 4 cases, the blood pressures used were obtained afterward instead. Correlation analysis was also performed without these 4 subjects, and was not found to alter the results significantly.

In conclusion, this study demonstrates that left ventricular −dP/dt can be measured non invasively using diastolic blood pressure and isovolumic relaxation time. Unlike the Doppler-MR method used in prior studies to determine −dP/dt, this novel method can be applied to patients in the absence of MR, and works especially well in those with reduced diastolic function. As such, this method may be helpful to assess response to heart-failure therapy, although further studies will be required to evaluate this.

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