Preload and Incident Angle Independent Index of Left Ventricular Contractility Determined by Continuous Wave Doppler Echocardiography

Satoshi Nakatani, MD; Toshio Imanishi, MD; Izuru Nakasone, BS;
Kenji Sunagawa, MD; Kunio Miyatake, MD

Although left ventricular $dP/dt_{\max}$ can be accurately assessed using Doppler echocardiography, the fact that Doppler-derived $dP/dt_{\max}$ depends both on preload and Doppler incident angle limits its clinical value. We investigated the clinical usefulness of Doppler-derived $(dP/dt_{\max})/IP$ (IP , isovolumic pressure), which is known to be relatively insensitive to preload and theoretically independent of the incident angle in 9 subjects. We conclude that Doppler-derived $(dP/dt_{\max})/IP$ is relatively insensitive to both the incident angle and preload. In addition to its noninvasiveness, these unique features makes it very attractive as a clinical index of ventricular contractility. (*Jpn Circ J* 1998; 62: 469–471)

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The maximal value of the first derivative of left ventricular pressure rise, $dP/dt_{\max}$, is one of the most popular indices of left ventricular contractility¹. However, determinations of $dP/dt_{\max}$ require the invasive high-fidelity pressure recording system employed at cardiac catheterization and are not suitable for repeated assessment. Estimation of $dP/dt_{\max}$ can be made from mitral regurgitation velocity measured by continuous wave Doppler echocardiography, because the instantaneous pressure difference between the left ventricle and atrium during systole can be assessed from the velocity^{2,3}. However, there are some clinical problems with Doppler-determined $dP/dt_{\max}$. Firstly, $dP/dt_{\max}$ per se depends on preload⁴. Secondly, Doppler-derived $dP/dt_{\max}$ is sensitive to the incident angle, this being an inherent problem of velocity measurement by Doppler.

The index $(dP/dt_{\max})/IP$, which is obtained by dividing $dP/dt_{\max}$ by isovolumic developed pressure (IP), is known to be relatively insensitive to preload⁴. Because this index is derived only from information on pressure, it can be determined by Doppler echocardiography using the simplified Bernoulli equation. Moreover, Doppler-derived $(dP/dt_{\max})/IP$ is independent of the incident angle, because the angle related terms in the numerator and the denominator cancel each other as follows. The relationship between true mitral regurgitant velocity (V) and Doppler-derived regurgitant velocity (V') is given as:

$$V \times \cos \alpha = V'$$

where α is the Doppler incident angle. By applying the simplified Bernoulli equation, we get

$$P = 4 V^2 = 4 (1/\cos^2 \alpha) V'^2 = (1/\cos^2 \alpha) P'$$

where P is true left ventriculo-atrial pressure difference during systole, and P' ($= 4 V'^2$) is Doppler-derived pressure difference. Then,

$$dP/dt = (1/\cos^2 \alpha) dP'/dt$$

$$\text{Thus, } dP/dt/P = (1/\cos^2 \alpha) dP'/dt/P'$$

substituting $(1/\cos^2 \alpha) P'$ for P ,

$$dP/dt/P = (1/\cos^2 \alpha) dP'/dt / (1/\cos^2 \alpha) P' = dP'/dt/P'$$

Thus, $(dP/dt_{\max})/IP$ is independent of the incident angle.

The aim of the present study is to investigate the clinical usefulness of Doppler-determined $(dP/dt_{\max})/IP$ by examining its independence of both preload and incident angle in patients.

We studied 9 subjects whose mitral regurgitant velocity profiles recorded by continuous wave Doppler echocardiography were clear enough to be digitized. All were in sinus rhythm. The severity of mitral regurgitation was graded by color Doppler echocardiography as mild in 3, moderate in 4 and severe in 2⁵. They comprised 6 males and 3 females aged 45 to 60 years (mean 52 years). Three patients had rheumatic mitral valve disease, 5 had dilated cardiomyopathy and 1 had mitral valve prolapse.

Continuous wave and color Doppler examinations were performed with a commercially available ultrasound system (SSH-160A, Toshiba Medical Co, Tokyo, Japan) equipped with a 2.5 MHz transducer. Doppler windows used were apical long-axis or 4-chamber views. A continuous wave Doppler beam was oriented parallel to the direction of the mitral regurgitant jet with the aid of color Doppler echocardiography to obtain the highest possible jet velocity of adequate quality. Recordings were made on a strip chart recorder connected to the ultrasound system, at a paper speed of 100 mm/sec.

The velocity profile was manually traced from the onset

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The Cardiology Division of Medicine, National Cardiovascular Center, Osaka, Japan

Mailing address: Satoshi Nakatani, MD, The Cardiology Division of Medicine, National Cardiovascular Center, 5-7-1 Fujishiro-dai, Suita, Osaka 565, Japan

ing the origin and the highest point. An average of 5 consecutive beats was used for analysis. Data are expressed as mean $\pm$ SD. The paired t test was used to compare measurements before and after a change in preload or the incident angle.

To investigate the effect of changes in preload on Doppler measurements, both the subject's legs were passively raised up to 45 degrees, and measurements were done before and about 30 sec after this maneuver in all 9 subjects. An increase was seen in $dP/dt_{\max}$ from 836 ± 156 mmHg/sec to 899 ± 149 mmHg/sec ($p < 0.05$), while $(dP/dt_{\max})/IP$ did not show any significant change (45.4 ± 8.9 vs 46.6 ± 8.3 , $p = \text{ns}$, Fig 2). The effect of the incident angle was investigated by moving the angle correction cursor on the display from 0 to 20 degrees depicting the same mitral regurgitation in 7 subjects. An increase was seen in $dP/dt_{\max}$ from 1083 ± 400 mmHg/sec to 1248 ± 430 mmHg/sec ($p < 0.001$). This was about a 1.15 times increase, close to the expected value of 1.13 ($=1/\cos^2 20^\circ$). On the other hand, $(dP/dt_{\max})/IP$ was almost constant despite the angle correction (43.0 ± 10.5 vs 43.1 ± 10.3 , $p = \text{ns}$, Fig 2).

Although Doppler echocardiography can be used to estimate $dP/dt_{\max}$ noninvasively, parallel projection of the Doppler beam to the center of mitral regurgitation flow is essential for recording of the true velocity and for accurate measurement of $dP/dt_{\max}$. However, it is not always possible to detect the true velocity, especially when the regurgitant flow is eccentric as in mitral valve prolapse. On the other hand, $(dP/dt_{\max})/IP$, theoretically and practically independent of the incident angle as demonstrated in the present study, can be applied without considering the spatial distribution of regurgitant flow. Another problem with $dP/dt_{\max}$ is that this index is load sensitive.⁴ For instance, high $dP/dt_{\max}$ does not always indicate good contractility in the case of a dilated ventricle, because $dP/dt_{\max}$ changes linearly with ventricular end-diastolic volume. It is known that $(dP/dt_{\max})/IP$ is sensitive to ventricular contractile state, and relatively insensitive to loading conditions.⁴ Because this index is derived only from information on pressure, it can be estimated using Doppler echocardiography in an echocardiographic laboratory. Thus, the present study has demonstrated the feasibility of this method to assess systolic function clinically.

As with any other Doppler technique, the accuracy of this method depends on the quality of the mitral regurgitation velocity Doppler signal. In the case of a faint signal, enhancement of the signal with transpulmonary contrast agent may be useful.⁸ Another limitation of the present study may be the small number of subjects in the study. However, the results in the current study were quite consistent among our subjects. Therefore, our conclusion is unlikely to be altered by a larger study population.

We conclude that Doppler-derived $(dP/dt_{\max})/IP$ is relatively insensitive to both the incident angle and preload. In addition to its noninvasiveness, these unique features makes it very attractive as a clinical index of ventricular contractility.

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