Refinement on Single-beat Determination of Left Ventricular Systolic Function in Patients with Atrial Fibrillation

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Single-beat determination of left ventricular systolic function at a beat with equal subsequent cardiac cycles has been proposed as an accurate method in atrial fibrillation. However, there has still been substantial variability between the values calculated from beats with equal subsequent cycles. Therefore, some refinement on the single-beat method is needed. In 100 patients with atrial fibrillation, Doppler aortic flow time-velocity integral was determined for at least 20 consecutive cardiac cycles. The values at beats with equal subsequent cardiac cycles were chosen and compared with the average values over all cardiac cycles. The values at beats with cycle lengths shorter than 500 milliseconds were usually far below the average values over all cardiac cycles. Bland-Altman agreement analysis revealed improved accuracy by gradually narrowing the range of the limits of agreement when 2 or 3 beats with equal subsequent cycles and cycle lengths longer than 500 milliseconds were used for evaluation. (J Am Soc Echocardiogr 2005;18:913-918.)

Assessment of left ventricular (LV) performance in atrial fibrillation (AF) has traditionally proven difficult and unreliable because of beat-to-beat variation.[1,2] In clinical practice the standard process for acquiring an accurate assessment of LV function during AF involves averaging an arbitrary number of consecutive cardiac cycles. This process is suboptimal because the averaged value is dependent on a selected window of cardiac cycles. Moreover, the mean number of beats in AF required by the sample period has been approximately 3 times that required in sinus rhythm (3-5 beats) to calculate the LV performance with the same level of variability.[2] It is time-consuming and not realistic in the clinical scenario to analyze more than 10 beats for evaluating LV performance.

Prior studies have established that during AF the LV systolic parameters positively correlate with the ratio of the preceding R-R interval (RR_1) to the pre-preceding R-R interval (RR_2) and the value at $RR_1/RR_2 = 1$ in the regression line is a reasonable estimate of the measured average value over all cardiac cycles.[3-7] Sumida et al[6] extended that work by demonstrating that single-beat determination of Doppler-derived aortic flow parameters using data at the beat with $RR_1 = RR_2$ could be applied for estimating the average LV systolic function during AF. However, in the study of Tabata et al,[5] they analyzed a large sample (> 100) of consecutive cardiac cycles in AF and showed that there was a substantial scattering of data points for each of the measured systolic parameters when $RR_1/RR_2 = 1$. This precludes the use of just any given beat with $RR_1 = RR_2$ for estimating the LV systolic function during AF.

One important question has to do with the limits of cycle lengths in the RR_1/RR_2 ratio, which could be equal to unity either at a very long RR_1 and RR_2, or at a very short RR_1 and RR_2. If the measured parameters deviate markedly away from the measured average value for these situations, some limitations on the cycle lengths in the RR_1/RR_2 ratio are needed. In addition, the method using data at beats with $RR_1 = RR_2$ can be used clinically if the variability of measurement can be decreased to an acceptable level. We postulated that by averaging the values of a few beats with $RR_1 = RR_2$ and cycle-length limits we could decrease the variability to an acceptable level and apply this method for evaluating LV systolic function during AF in clinical practice. The aim of this study was to assess the influence of cycle-length variations on the values of LV systolic parameters at beats with $RR_1 = RR_2$ and to determine how many beats with $RR_1 = RR_2$ were

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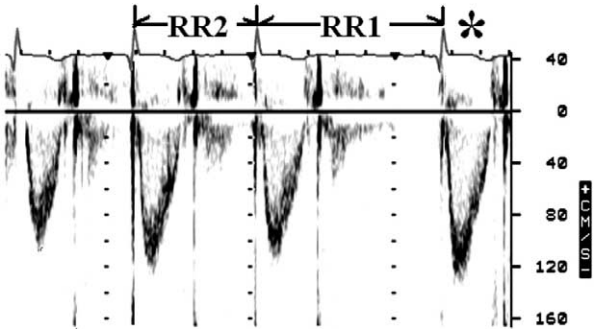

Figure 1 Representative Doppler aortic flow recording for patient with atrial fibrillation. Aortic time-velocity integral at given cardiac beat (*) and ratio of preceding R-R interval (RR_1) to prepreceding R-R interval (RR_2) were evaluated.

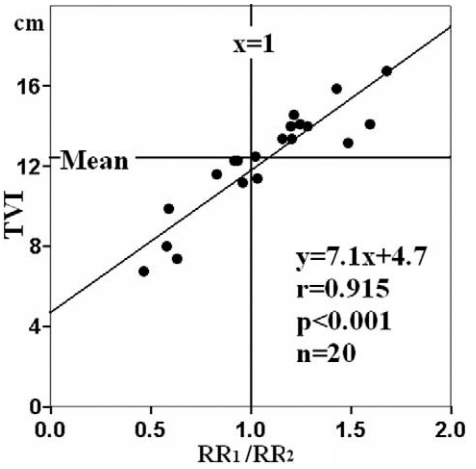

Figure 2 Representative relation between aortic flow time-velocity integral (*TVI*) and ratio of preceding to prepreceding R-R intervals (RR_1/RR_2) was evaluated using linear regression analysis for patient with atrial fibrillation.

required for analysis to get an acceptable level of variability.

METHODS

Study Population

The study population comprised consecutive adult patients who were referred for echocardiographic examinations of AF from November 2003 to August 2004. Patients were excluded if they had poor acoustic window, complete atrioventricular block, aortic stenosis, prosthetic aortic valve, or LV outflow obstruction. None were excluded on the basis of age, sex, or degree of hemodynamic impairment. Informed consent was obtained before the study from all patients and the ethics committee approved the research.

Doppler Echocardiographic Study

Transthoracic echocardiographic examination was performed using a machine (Sonos 7500, Philips Medical System, Andover, Mass). Pulsed Doppler aortic flow velocity spectrum was obtained from the apical 5-chamber view. The sample volume was placed at the LV outflow tract 0.5 to 1.0 cm proximal to the aortic valve. The Doppler signals were recorded during at least 22 consecutive cardiac cycles and analyzed offline. The time-velocity integral (TVI) (proportional to stroke volume) of aortic flow at each given beat was measured 3 times and averaged for analysis for at least 20 consecutive cardiac cycles. Simultaneous electrocardiograms were used to measure the R-R intervals. Figure 1 shows representative Doppler aortic flow velocity profile during AF.

Regression Method

The relation between the TVI at a given cardiac beat and the RR_1/RR_2 ratio was evaluated. The value of TVI at $RR_1/RR_2 = 1$ was calculated from the equation of linear regression in the relation between the TVI and the RR_1/RR_2 ratio. The calculated values at $RR_1/RR_2 = 1$ in the regression line were compared with the measured average values over all cardiac cycles.

Limits of Cycle Lengths in the RR_1/RR_2 Ratio

The values of TVI at a given beat with $RR_1 = RR_2$ were normalized by expressing the values as a ratio of the measured average values over all cardiac cycles. The influence of cycle-length variations on the values of TVI at beats with $RR_1 = RR_2$ was examined from the plot of normalized values against cycle lengths.

Beats with Equal RR_1 and RR_2

The value of TVI at a given beat with $RR_1 = RR_2$ was chosen and compared with the measured average value over all cardiac cycles (single-beat method including all cycle lengths). The RR_1 and RR_2 intervals of the beats were defined as identical if the difference between them was $< 5\%$. To decrease the variability of the measurement by single-beat method, we averaged the values of 1 to 4 beats with $RR_1 = RR_2$ and cycle-length limits, and compared them with the measured average values over all cardiac cycles. Mean percentage difference between the calculated values by each method and the measured average values over all cardiac cycles was also evaluated.

Statistical Analysis

The results are expressed as mean ± SD and $P < .05$ was considered significant. Linear regression analysis was done to analyze the relation between the value of TVI at a given cardiac beat and the RR_1/RR_2 ratio. Bland-Altman[8] analysis was applied to evaluate agreement between the calculated values by different methods and the measured averaged values over all cardiac cycles.