Left Ventricular Deformation and Two-Dimensional Echocardiography: Temporal and Other Parameter Values in Normal Subjects

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Segmental contractility can be assessed quantitatively by analyzing deformation, or strain, and the rate of deformation, or the strain rate. This type of analysis can be performed using either tissue Doppler imaging or, more recently, two-dimensional speckle-tracking echocardiography. The aim of this study was to determine typical parameter values in healthy subjects and their reproducibility. The study involved 105 healthy individuals, including 55 women (52.45%). Their mean age was 38.8 (9.5) years (range, 20-59 years). All underwent speckle-tracking echocardiography with velocity vector imaging. Mean values for the strain and strain rate for each segment as well as for the time-to-peak normalized by the length of the cycle (TPN) were obtained. The resulting mean values were: circumferential strain, 22.2 (4.81)% with a TPN of 0.39 (0.06); longitudinal strain, 19.84 (4.59)% with a TPN of 0.42 (0.06); circumferential strain rate, 1.64 (0.48) 1/s with a TPN of 0.23 (0.06); and longitudinal strain rate, 1.3 (0.49) 1/s with a TPN of 0.21 (0.09). Intra- and inter-observer variability were moderate in magnitude.

Key words: *Left ventricle. Echocardiography. Physiology.*

Deformación ventricular izquierda en ecocardiografía bidimensional: valores y tiempos en sujetos normales

El análisis de la deformación o *strain* y la tasa de deformación o *strain rate* podrían valorar cuantitativamente la contractilidad segmentaria. Esto es factible con Doppler tisular y, más recientemente, también con ecografía bidimensional mediante el rastreo de señales miocárdicas *(speckle tracking).* Este trabajo se diseñó para conocer el valor de estos parámetros en sujetos sanos y su reproducibilidad. Se estudió a 105 sujetos sanos —55 mujeres (52,45%); edad, 38,8 ± 9,5 (20-59) años— mediante *speckle tracking* con la aplicación Vector Velocity Imaging. Se obtuvieron los valores medios de *strain* y *strain rate* de cada segmento, así como el tiempo hasta el pico máximo, normalizado con la longitud del ciclo (TpN). Los valores medios fueron: *strain* circunferencial, 22,2 ± 4,81% con TpN 0,39 ± 0,06; *strain* longitudinal, 19,84 ± 4,59% con TpN 0,42 ± 0,06; *strain rate* circunferencial, 1,64 ± 0,48 1/s con TpN 0,23 ± 0,06; *strain rate* longitudinal, 1,3 ± 0,49 1/s con TpN 0,21 ± 0,09. Las variabilidades del observador y entre observadores fueron moderadas.

Palabras clave: *Ventrículo izquierdo. Ecocardiografía. Fisiología.*

INTRODUCTION

Left ventricular function is of prognostic value in many heart diseases. Traditionally, global systolic function is assessed using the ejection fraction. However, to date, a parameter has not been available to quantify regional systolic function. Currently, methodologies based on the movement of myocardial fibers are available that can measure deformation or strain (S) and the rate of deformation or strain rate (SR).[1] Among them, 2-dimensional speckle-tracking echocardiography identifies speckles on the myocardial fibers and tracks their movements frame by frame. Thus, S is determined by the displacement of some myocardium speckles relative to others[2,3] and SR is deformation over time.

Recently, a method called Vector Velocity Imaging (VVI) has been developed that uses speckle tracking. This has been used in several clinical settings[4,5] and has recently been validated in situations involving ischemia.[6-9] However, to date, the S and SR values calculated with this method in a healthy population have not been described.

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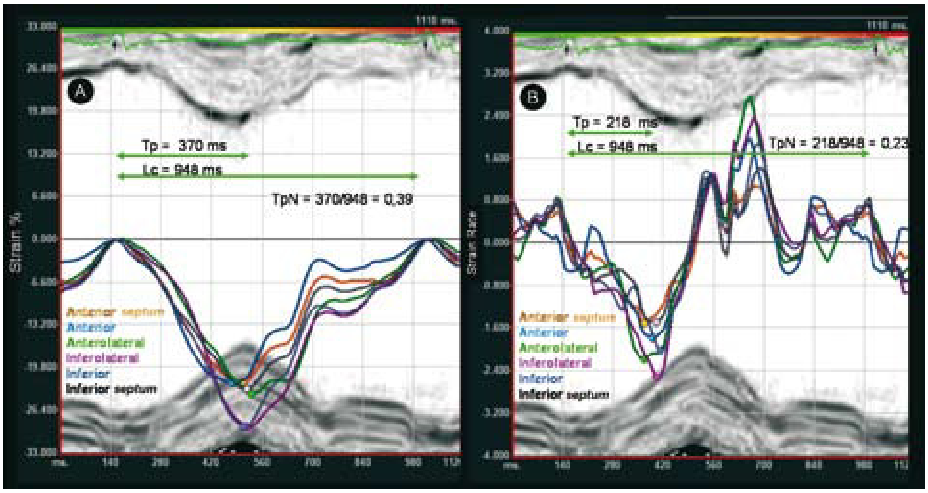

Figure 1. Circumferential strain (A) and strain rate (B) values of the 6 segments analyzed in the transverse plane. Lc indicates length of the cycle; Tp, time-to-peak; TPN, time-to-peak normalized calculated as Tp/Lc.

This study was designed to determine these parameter values in healthy subjects, time-to-peak normalized by the length of the cycle (TPN) and their reproducibility.

METHODS

A total of 116 healthy volunteers were included who were recruited from hospital staff who wanted a cardiovascular health examination and agreed to participate. The study was approved by the hospital ethics committee.

The study only included asymptomatic subjects not under treatment, with no history of heart disease, and with normal physical examination, blood pressure (BP), ECG and Echocardiogram-Doppler ultrasound values. Three subjects were excluded due to BP ≥140/80 mmHg and 8 subjects due to poor echocardiographic image quality.

Echocardiographic Study

The echocardiographic study was performed using a Siemens Sequoia C-512 (Siemens Medical Solutions, Mountain View, Calif., USA) equipped with a 2.5 MHz-4 MHz transducer. Images were obtained in the transverse plane at the level of the papillary muscles and apical 4-chamber view with second harmonic, high temporal resolution imaging (60-100 images/s) and a high-quality ECG signal. The images were stored in digital format for subsequent offline analysis.

Analysis Using Vector Velocity Imaging

The echocardiographic images were processed using Syngo VVI software (Siemens Medical Solutions). The peak systolic values of S and SR for each segment were analyzed. The time from QRS onset to peak was measured (Figure 1). The time-to-peak/length of the cycle relationship was called time-to-peak normalized (TPN). The mean value of the 6 segments was considered to be the global value of the ventricle.

Variability Study

Using VVI, the ventricles of 20 subjects were assessed by 2 expert echocardiologists blinded to the results of each other. One of the experts repeated the assessment 3 weeks later. Data of all the segments were included.

Statistical Analysis

The quantitative variables are expressed as mean (standard deviation). The Shapiro-Wilk test was used to determine the normality of the distribution. The Student *t* test (normal distribution) was used to analyze differences between 2 independent samples or the Mann-Whitney-Wilcoxon *U* test otherwise. The coefficient of variability was used to study intra-observer and inter-observer variability. This was calculated as the standard deviation expressed as a percentage of the mean value of 2 sets of paired observations. A *P*-value <.05 was used as cutoff for statistical significance. The statistical calculations were performed using the SPSS.12 statistical package (SPSS, Chicago, Ill., USA).

RESULTS

The demographic and echocardiographic characteristics of the 105 subjects are shown in Table 1.

TABLE 1. **Demographic and Echocardiographic Characteristics of the Study Population**

Patients, n	105
Age, y	38.8 (9.5)
Women, n (%)	55 (52.4)
Weight, kg	71 (12.88)
Height, cm	169 (9.33)
Body surface area, m2	1.81 (0.2)
Body mass index	24.7 (3.25)
Systolic blood pressure, mmHg	117 (12)
Diastolic blood pressure, mmHg	73 (7.9)
LVDD, cm	4.74 (0.53)
Posterior wall, cm	0.83 (0.12)
Relative wall thickness	0.36 (0.05)
Left ventricular mass index, g/m2	74 (15.39)
Shortening fraction	0.38 (0.04)
Mesocardial shortening fraction	22 (3)
EF (Simpson's rule)	67 (7)
Cardiac output, L/min	5.38 (1.25)

EF indicates ejection fraction; LVDD, left ventricular diastolic diameter.

Strain

The values were obtained by examining the images of a complete cardiac cycle. The circumferential S value was obtained from images acquired in the transverse plane and the longitudinal S value from images acquired in the apical view. The mean peak values of each segment and of the global value of the ventricle, as well as the time-to-peak and its relation to the duration of the cycle are shown in Table 2.

The mean circumferential S values were greater than the longitudinal S values (22.20 [4.81] vs 19.84 [4.59]; P=.004). Furthermore, the circumferential S values of the lower segments was greater than those of the anterior segments (23.92 [7.04] vs 20.49 [6.69]; P<.0001).

Strain Rate

The values obtained are shown in Table 2. The mean circumferential SR values were greater than those of the mean longitudinal SR (1.64 [0.48] vs 1.30 [0.49]; P<.0001) (Figure 2). The inferior segments had greater circumferential SR values than those of the anterior segments (1.73 [0.62] vs 1.57 [0.58]; P=.007).

There were no differences between sexes in any of the parameters studied.

Reliability of the Method

Intra-observer and inter-observer variability were as follows: circumferential S, 13.42% and 15.5%; longitudinal S, 15.96% and 15.79%; circumferential SR, 14.78% and 13.47%; and longitudinal SR, 17.9% and 15.02%.

TABLE 2. **Peak Systolic Strain and Strain Rate Values With Their Respective Time-to-Peak and Time-to-Peak Normalized by the Length of the Cycle**

	Strain	Tp, ms	TPN	Strain rate, 1/s	Tp, ms	TPN
Circumferential						
Anterior septum	20.71 (6.59)	342 (63)	0.38 (0.08)	1.54 (0.56)	182 (53)	0.21 (0.08)
Anterior	20.49 (6.69)[a]	348 (65)	0.39 (0.08)	1.57 (0.58)[b,c]	201 (64)	0.23 (0.08)
Lateral	22.48 (6.96)	361 (53)	0.41 (0.07)	1.65 (0.63)	204 (54)	0.23 (0.08)
Posterior	23.01 (7.97)	356 (63)	0.40 (0.07)	1.73 (0.64)[c]	203 (46)	0.23 (0.08)
Inferior	23.92 (7.04)	351 (49)	0.39 (0.06)	1.73 (0.62)[b]	208 (61)	0.23 (0.08)
Inferior septum	22.57 (6.08)[a]	349 (51)	0.39 (0.07)	1.60 (0.59)	196 (60)	0.22 (0.08)
Global LV	22.20 (4.81)[d]	351 (43)	0.39 (0.06)	1.64 (0.48)[e]	199 (40)	0.23 (0.06)
Longitudinal						
Basal septum	18.97 (7.89)	385 (67)	0.43 (0.09)	1.43 (0.93)	206 (76)	0.23 (0.08)
Mid-septum	19.36 (5.71)	375 (62)	0.42 (0.08)	1.25 (0.62)	185 (72)	0.21 (0.09)
Apical septum	20.27 (9.01)	369 (60)	0.42 (0.08)	1.25 (0.48)	176 (66)	0.20 (0.08)
Lateral basal	20.76 (5.63)	377 (61)	0.42 (0.08)	1.41 (0.71)	194 (75)	0.22 (0.09)
Mid-lateral	19.67 (4.66)	370 (55)	0.42 (0.07)	1.23 (0.47)	184 (64)	0.21 (0.08)
Lateral apical	19.99 (5.39)	378 (55)	0.43 (0.08)	1.21 (0.41)	178 (69)	0.20 (0.08)
Global LV	19.84 (4.59)[d]	375 (97)	0.42 (0.06)	1.30 (0.49)[e]	187 (53)	0.21 (0.09)

LV indicates left ventricle; Tp, time-to- peak; TPN, time-to-peak normalized.
[a]P<001; Student's t; circumferential strain inferior segment versus anterior.
[b]P<.01; Wilcoxon test; circumferential strain rate in inferior segment versus anterior.
[c]P<.05; Wilcoxon test; circumferential strain rate in posterior segment versus anterior.
[d]P<.05; Wilcoxon test; global circumferential strain versus longitudinal.
[e]P<.001; Wilcoxon test; global circumferential strain rate versus longitudinal.
Values are expressed as mean (standard deviation).

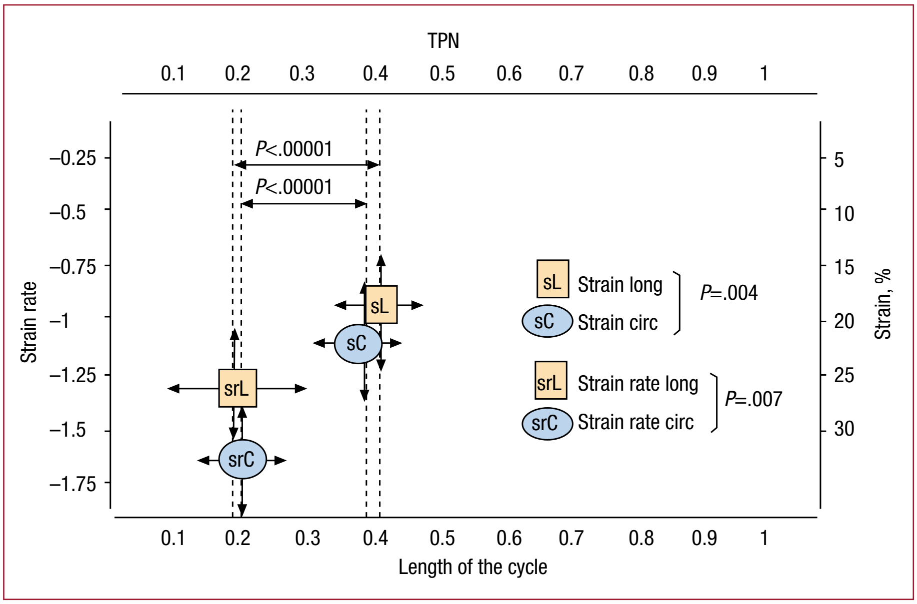

Figure 2. Strain and strain rate values and their corresponding time-to-peak normalized in a population of 105 healthy subjects. It can seen that the time-to-peak normalized values of the strain rate are significantly shorter than those of strain. sC indicates circumferential strain; sL, longitudinal strain; srL, longitudinal strain rate; srC, circumferential strain rate; TPN, time-to-peak normalized.

DISCUSSION

The S and SR values could be useful to quantify regional ventricular function. This study provides normalized data quantified as spatial and temporal values. The addition of the variable time to TPN could be useful to characterize various pathologies such as myocardial ischemia.

Experimental studies[10-12] and clinical studies[13,14] have demonstrated that ischemia induces reductions and delays in deformation in ischemic segments. Thus, a parameter such as TPN, whose normal values are reported in this study, could be useful to define late strain in a simple, noninvasive and easily reproducible manner. Future studies should assess its real potential. In addition, there were no differences between sexes in any of the parameters studied. Reproducibility was moderate. Future improvements in image definition and the algorithms that delineate the myocardium-blood interface could improve reproducibility.

Limitations

In total, 8 subjects were excluded from the study due to poor echocardiographic image quality (7%), and thus 93% completed the study. Subject age ranged between 18 years and 60 years, and so the data cannot be extrapolated to subjects younger or older than these ages, respectively.

In conclusion, we provide time-to-peak values normalized for S and SR that could serve as a reference to define late contraction as marker of ischemia. No differences were observed between sexes. Intra-observer and inter-observer variability were moderate and remain open to improvement.

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