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Original article

Normal Left Ventricular Mechanics by Two-dimensional Speckle-tracking Echocardiography. Reference Values in Healthy Adults

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ABSTRACT

Introduction and objectives: Two-dimensional speckle-tracking echocardiography is a novel tool to assess myocardial function. The purpose of this study was to evaluate left ventricular myocardial strain and rotation parameters by two-dimensional speckle-tracking echocardiography in a large group of healthy adults across a wide age range to establish their reference values and to assess the influence of age, sex, and hemodynamic factors.

Methods: Transthoracic echocardiograms were acquired in 247 healthy volunteers (139 women, 44 years [standard deviation, 16 years old] (range, 18-80 years). We measured longitudinal, circumferential, and radial peak systolic strain values, and left ventricular rotation and twist.

Results: Average values of global longitudinal, radial, and circumferential strain were –21.5% (standard deviation, 2.0%), 40.1% (standard deviation, 11.8%) and –22.2% (standard deviation, 3.4%), respectively. Longitudinal strain was significantly more negative in women, whereas radial and circumferential strain and rotational parameters were similar in both sexes. Accordingly, lower limits of normality for the strain components were –16.9% in men and –18.5% in women for longitudinal strain, and –15.4% for circumferential and 24.6% for radial strain, irrespective of sex. Longitudinal strain values were more negative at the base than at apical segments. Mean rotational values were –6.9° (standard deviation, 3.5°) for the base, 13.0° (standard deviation, 6.5°) for apical rotation, and 20.0° (standard deviation, 7.3°) for net twist.

Conclusions: We report the comprehensive assessment of normal myocardial deformation and rotational mechanics in a large cohort of healthy volunteers. We found that women have more negative longitudinal strain, accounting for their higher left ventricular ejection fraction. Availability of reference values for these parameters may foster their implementation in the clinical routine.

Mecánica ventricular izquierda normal mediante ecocardiografía *speckle tracking* bidimensional. Valores de referencia para adultos sanos

Palabras clave:
Ecocardiografía *speckle tracking*
Strain bidimensional
Giro
Valores de referencia
Individuos sanos
Ventrículo izquierdo
Deformación miocárdica
Individuos normales

RESUMEN

Introducción y objetivos: La ecocardiografía con *speckle tracking* bidimensional es un nuevo instrumento para evaluar la función del miocardio. El objetivo de este estudio fue evaluar los parámetros de rotación y *strain* del ventrículo izquierdo mediante la ecocardiografía con *speckle tracking* bidimensional en un gran grupo de adultos sanos de una amplia gama de edades, con objeto de establecer los valores de referencia de dichos parámetros y determinar la influencia de la edad, el sexo y los factores hemodinámicos.

Métodos: Se realizaron ecocardiografías transtorácicas a 247 voluntarios sanos (139 mujeres; media de edad, 44 ± 16 [intervalo, 18-80] años). Efectuamos determinaciones de los valores de *strain* sistólico máximo longitudinal, circunferencial y radial, así como de la rotación y el giro del ventrículo izquierdo.

Resultados: Los valores medios de *strain* total longitudinal, radial y circunferencial fueron –21,5 ± 2,0%, 40,1 ± 11,8% y –22,2 ± 3,4%, respectivamente. El *strain* longitudinal fue significativamente más negativo en las mujeres, mientras que el *strain* radial y el circunferencial y los parámetros rotacionales fueron similares en ambos sexos. En consecuencia, los límites inferiores de la normalidad para los componentes del *strain* fueron –16,9% en los varones y –18,5% en las mujeres para el *strain* longitudinal, –15,4% para el *strain* circunferencial y 24,6% para el *strain* radial, con independencia del sexo. Los valores de *strain* longitudinal fueron más negativos en la base que en los segmentos apicales. Los valores medios de la rotación fueron -6,9 ± 3,5° en la base, 13,0 ± 6,5° para la rotación apical y 20,0 ± 7,3° para el giro neto.

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Conclusiones: Presentamos una evaluación detallada de la deformación normal del miocardio y la mecánica rotacional en una cohorte amplia de voluntarios sanos. Observamos que las mujeres presentan un *strain* longitudinal más negativo, lo cual explica su mayor fracción de eyección del ventrículo izquierdo. La disponibilidad de valores de referencia de esos parámetros puede facilitar su aplicación en la práctica clínica habitual.

Abbreviations

BP: blood pressure
Cε: circumferential strain
LVEF: left ventricular ejection fraction
Lε: longitudinal strain
LV: left ventricular
Rε: radial strain

INTRODUCTION

Left ventricular (LV) systolic function has been reported to be a powerful predictor of long-term survival in patients affected by a wide spectrum of cardiac diseases.[1–3] The most widely used echocardiographic parameter to quantify LV systolic function has been LV ejection fraction (LVEF). While LVEF is a strong predictor of mortality and is used to select patients for device implantation[4] surgical procedures[5] and pharmacological treatments,[6] it is extremely load-dependent, its measurement with echocardiography depends critically on operator expertise, and it is affected by significant intraobserver and interobserver variability.[1]

Global LV function is the result of the contraction and relaxation of a complex myocardial fiber architecture as a transmural continuum between 2 helical fiber geometries, where right-handed helical geometry in the subendocardial layer of myocardial wall gradually changes into left-handed geometry in the subepicardial layer.[7,8] Myocardial fiber contraction determines changes of LV size and shape that are the result of concomitant longitudinal shortening, circumferential rotation, and radial thickening of the myocardium. The LVEF provides a global index of LV chamber function, ignoring the relative role of the different components of myocardial function (deformation in various directions and rotation), which may be affected to a different extent in different cardiac diseases even when LVEF is still in the normal range.[9]

Two-dimensional speckle-tracking echocardiography has recently emerged as a novel technique for objective and quantitative evaluation of global and regional myocardial function, independent of the angle of myocardial insonation.[10–12] The myocardial deformation data (strain, ε) are obtained by frame-by-frame automatic measurement of the distance between 2 points of each LV segment during the cardiac cycle along 3 dimensions (radial, Rε; circumferential, Cε, and longitudinal, Lε).

In addition, 2-dimensional speckle-tracking echocardiography can be used to assess LV rotational mechanics. LV rotation can be measured on 2-dimensional short-axis views acquired at base and apical levels to allow computation of twist and untwist. Several studies have related the dynamics of cardiac twist to systolic function of the LV.[13,14]

However, to be clinically useful, all these new parameters of myocardial and LV function need reference values that can be compared with data obtained from patients with suspected myocardial diseases. To date, reference values for deformation and rotational parameters are limited, heterogeneous, and sometimes inconsistent.[15–18]

Accordingly, we designed this prospective, observational study to use 2-dimensional speckle-tracking echocardiography in healthy volunteers to obtain the reference values for Lε, Cε, and Rε as well as rotation and twist of the LV and to assess their relationship with sex and age.

METHODS

Study Population

A cohort of 260 healthy Caucasian volunteers were prospectively recruited at a single tertiary center among hospital employees, fellows in training, their relatives, and individuals who underwent medical visits for driving or working licenses and met the inclusion criteria. Prospective criteria for recruitment included age >17 years, no history of cardiovascular or lung disease, no symptoms, absence of cardiovascular risk factors (ie, hypertension, smoking, diabetes, dyslipidemia), no cardioactive or vasoactive treatment, and normal results on electrocardiography and physical examination. Exclusion criteria were athletic training, pregnancy, and body mass index > 30 kg/m^2. Blood pressure (BP) was measured in all participants immediately before the echocardiographic examination. Height and weight were measured using a calibrated stadiometer and scale, and body surface area was calculated according to the Dubois and Dubois formula.[19] Body mass index was calculated by dividing weight in kilograms by height in meters squared (kg/m^2).

The study was approved by the University of Padova Ethics Committee (protocol number 2380 P, approved on October 6, 2011) and written informed consent was obtained from all volunteers before screening for study eligibility.

Echocardiography

Study participants underwent a transthoracic echocardiographic examination in the left lateral recumbent position using a commercial ultrasound scanner (Vivid E9, GE Vingmed; Norway) equipped with a 2.5 MHz transducer. Two-dimensional (grayscale) views were obtained from the apical (4-, 2-chamber, and long-axis views) and parasternal (short-axis views at mitral valve, papillary muscle, and apical levels) approaches. Three consecutive cardiac cycles of each view were acquired during a breath hold at end-expiration. Special care was taken to obtain correct apical and short-axis images using standard anatomic landmarks and checking for foreshortening.[10] To obtain the apical short-axis view, the transducer was placed on the chest wall at the level of the apical impulse and then moved one intercostal space upward and properly angulated in order to obtain a circular short-axis view of the LV with the smallest right ventricular area.[20] All the images were obtained at a frame rate of 50 frames to 80 frames per second. Timing of aortic valve closure was assessed looking at the aortic valve motion in the long-axis apical view. All studies were digitally recorded and transferred to a dedicated workstation for further analysis.