REVIEW
ARTICLE

Introduction of Tissue Doppler Imaging Echocardiography—Based on Pulsed-wave Mode

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Noninvasive evaluation of global left ventricular (LV) myocardial contractile function using echocardiography has depended on M-mode and two-dimensional measurement of the LV dimension and area changes between diastolic and systolic phases, which provide an estimation of volume changes between diastole and systole, to calculate the ejection fraction as an index of LV contractile function. The LV ejection fraction represents a contractile function in summary of several LV myocardial segments. Noninvasive evaluation by echocardiography for regional myocardial contractile function depends mainly on visual assessment of the segmental myocardial motion velocity, especially the endocardial inward motion velocity. Human visual assessment is subjective and, hence, has a certain degree of intraobserver and interobserver variability. Tissue Doppler imaging (TDI) echocardiography, a technique which can have a frame rate of up to 200 frames per second (fps), is far beyond the capability of human vision (30 fps). TDI can detect the high-intensity, low-velocity motion of regional myocardium, mainly on the LV longitudinal axis using three apical views. The myocardium of the LV basal segments moves towards the apex during systole; hence, the systolic motion velocity is highest in the basal segments, middle in the LV mid-segments, and lowest in apical segments. The strain (S) image calculates regional myocardial deformation and is defined as the change in length divided by the original length, (L1–L0)/L0. The S is expressed as the percentage change, that is, the degree of regional deformation. A negative S represents a regional myocardial shortening, and a positive S represents a regional myocardial lengthening. The rate at which the S change occurs is called the strain rate (SR) image. The SR is expressed as 1/second and a negative value represents a regional rate of change in deformation during systolic shortening. A total displacement (D) at end-systole of a certain segment can also represent a regional myocardial contractile function. A segmental mean D can be acquired quickly and coded in colors to represent a semi-quantitative regional myocardial contractile function index display using a color bar. Recently, a tissue synchronization image mode has been developed for a more convenient quantification of time-to-peak velocity on several myocardial segments. In this context, examples on each mode acquired from normal and diseased

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regional myocardium will be shown. Thus, TDI will hopefully be more easily and widely accepted by echocardiographers and in clinical applications.

KEY WORDS — strain and strain rate, tissue Doppler image, tissue synchronization image

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Introduction

Conventional evaluation of global and regional myocardial contractile function using noninvasive echocardiography mainly depends on visual assessment of the degree of myocardial thickening and endocardial inward motion, as well as M-mode and two-dimensional echocardiographic measurements of left ventricular (LV) ejection fraction (LVEF) [1]. Visual assessment is known to be very subjective and, hence, has a high degree of intraobserver and interobserver variability. A certain degree of disagreement has also been noted for LVEF measurements made by echocardiography [2–4]. Tissue Doppler imaging (TDI) echocardiography has been used for several decades; however, its clinical application has been controversial.

In contrast to conventional Doppler color ultrasound, TDI can detect low-velocity, high-intensity myocardial tissue motion to depict low-intensity, high-velocity blood flow, mainly red blood cell flow motion velocity. TDI has a frame rate of 90–200 frames per second (fps), thus has the advantages of high temporal resolution up to 5 milliseconds and high spatial resolution up to 1 mm. This high spatial and temporal resolution is far beyond the capabilities of human vision but has the disadvantage of invisibility, and thus limits its clinical applicability [5–9].

Tissue Doppler Imaging (TDI)

The digitized data sets acquired by various TDI modes, defined by various names, and by different echo instrument companies, have mostly emphasized the convenience of data retrieval and its off-line analysis capability using various analytical software [8,9]. However, the data acquired by those TDI modes are the mean myocardial motion velocities [10,11]. A tiny variation in the sample volume placement during off-line analysis can result in a big difference in the velocity-time integral (VTI) expression, which then causes further variation in the VTI-derived parametric data. The parametric data includes strain (S), and strain rate (SR) which are derived from the TDI examination [12–20].

Hence, the introduction of various modes of TDI and its derived parametric images in the present study will be based on the pulsed-wave TDI (PWTDI) mode [10].

TDI examination can detect LV myocardial motion velocity in its longitudinal axis. Therefore, a TDI examination is usually performed via an apical approach using three apical views. The LV myocardium is divided into 16 segments according to the coronary artery supply, as recommended by the American Society of Echocardiography [1]. A segmental longest time-to-peak velocity (TpV) of the basal septal and mid-septal segments can be detected on the medial side myocardium by an apical four-chamber view, along with basal and mid-lateral segments on the left lateral side myocardium by an apical four-chamber view. The basal, middle segmental TpV of the inferior and anterior segmental TpV can be detected by an apical two-chamber view. Likewise, the TpV of the basal, middle posterior segments and anteroseptal segments of the LV myocardium can be detected on an apical long-axis view (Figs. 1 and 2). The transducer should be aligned to the myocardial region of interest as parallel as possible to obtain an optimal