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Efficiency of quantitative longitudinal peak systolic strain values using automated function imaging on transthoracic echocardiogram for evaluating left ventricular wall motion: New diagnostic criteria and agreement with naked eye evaluation by experienced cardiologist

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ABSTRACT

Purpose: To evaluate the efficiency of automated function imaging (AFI) on transthoracic echocardiogram (TTE) for detecting left ventricular (LV) wall motion (LVWM) abnormalities, we compared longitudinal peak systolic strain (LPSS) measurements using AFI with naked eye TTE evaluations by experienced cardiologists and non-experienced residents.

Materials and methods: A total of 352 segments of LV myocardium from 22 consecutive subjects with LVWM abnormalities based on American Heart Association classifications (11 male, mean age 58 ± 14 years) on previous TTE (Vivid-7, GE) were evaluated. LPSS was measured using stored AFI data. Naked eye evaluation of LVWM was performed by 2 experienced cardiologists and 2 non-experienced residents.

Results: AFI successfully tracked 342 (97%) of all segments (mean LPSS −14.8 ± 8.1%). A significant strong negative correlation was observed between LV ejection fraction using method of disks and global LPSS (R = −0.8974). Temporary AFI criteria of LPSS were normal <−12; hypokinesis −12-2; and akinesis >2. Of 342 segments, 239, 87, and 16 segments were diagnosed as normal, hypokinesis, and akinesis, respectively. Level of agreement and kappa coefficients between qualitative evaluation of LVWM by AFI temporary criteria and qualitative evaluation of LVWM by experienced cardiologist 2 (0.784 and 0.479, respectively) were inferior to those comparing experienced cardiologists (0.845 and 0.595) but superior comparing experienced cardiologist with non-experienced resident (0.696 and 0.323), and between the 2 non-experienced-residents (0.682 and 0.347).

Conclusion: Qualitative evaluation of LVWM using temporary AFI criteria had a 97% success rate and agreed well with findings of an experienced cardiologist. AFI can be a useful tool for training residents.

1. Introduction

The accurate and reproducible determination of left ventricular (LV) function is one of the most important elements of clinical diagnosis, disease stratification, therapeutic guidance, follow up, and prognosis in patients with cardiovascular diseases [1,2].

Traditionally, 2-dimensional (2D) transthoracic echocardiography (TTE) has been most widely used for evaluating LV systolic function by the estimation of LV ejection fraction (LVEF) using the modified Simpson method. However, qualitative naked eye evaluation of regional LV wall motion (LVWM) on TTE is usually based on visual impression; therefore, it is subjective and dependent upon experience and skills of assessors [3].

Recently, the technique of TTE strain rate imaging by speckle tracking was developed to resolve this problem [4–8]. Speckle tracking is used for evaluation of global and regional LV function based on pure 2D grayscale ultrasound acquisition allowing calculation of segmental strains and estimation of longitudinal peak systolic train (LPSS), by tracing of the automatically detected myocardial speckles. This technique overcomes many traditional problems associated with the angle dependence of tissue Doppler imaging, and can be applied to all segments, including the apical region [9]. Furthermore, speckle tracking has been integrated into the most recent echocardiographic systems for quick, automated evaluation of LV function and a new operator-independent stain method for assessing LV function named "Automated Function Imaging, (AFI)".

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The AFI algorithm noninvasively tracks and analyzes LPSS based on speckle segmental wall strain [9,10]. AFI is likely to become a useful tool to support clinical decision making, by assessing LV function semi-automatically with a simplified operational procedure and high reproducibility [11], independent of the skills of assessors.

In this study, to evaluate the efficiency of AFI on TTE for detecting LVWM abnormalities, we measured LPSS using AFI in patients with regional LVWM abnormalities on previous TTE caused by various heart diseases and compared the results with qualitative naked eye TTE evaluation by analyzers with varying degrees of experience (experienced cardiologists and non experienced residents). We verified whether the scored AFI criteria were consistent with the evaluation of experienced cardiologists. The results suggest an important role for AFI in analysis of LVWM, independent of the skill and experience of the assessors.

2. Materials and methods

Twenty two consecutive patients (11 male, mean age 58 ± 14 years) who were diagnosed with regional LVWM abnormalities on previous TTE caused by various heart diseases were entered in the study.

The main background cardiac diseases of the 22 patients were as follows: 11 patients had ischemic heart disease, 4 patients had dilated cardiomyopathy or post myocarditis, 2 patients had cardiac sarcoidosis, 1 patient had cardiac amyloidosis, 1 patient had sick sinus syndrome, 1 patient had sick sinus syndrome and post-aortic valve replacement, 1 patient had post aortic valve replacement, and 1 patient had complete atrio-ventricular block (Table 1).

Patients underwent 2D TTE imaging using a 1.7/3.4 MHz transducer and a commercial ultrasound system (Vivid 7, GE Health Medical, Milwaukee, WI, USA). All images were stored digitally for playback and analysis by experienced cardiologist 1 (K.L.) who had 10 years of experience as a cardiologist. LVEF was calculated using the modified Simpson's method and LPSS using AFI was automatically calculated from the saved data.

Stored images were qualitatively subjectively evaluated with the naked eye for regional LVWM and interpreted according to the American Heart Association criteria with a 16-segment model (a total of 352 segments from all 22 patients) using apical 4-, 3-, and 2-chamber view images by 2 experienced cardiologists (1 = K.L. and 2 = M.T. who had 6 years of experience as a cardiologist) and 2 non experienced beginner residents (1 = N.H. and 2 = Y.I.) without knowledge of the clinical information and evaluated qualitatively scored as 3 categories: normal, hypokinesis, and akinesis. Segments with dyskinesis were included in the akinesis segments.

2.1. AFI

The AFI study involved off-line analysis of 3 digitally stored apical 2D images (apical 4-, 3-, and 2-chamber views) with high frame rate (60 or more Hz) using commercial imaging analysis software (EchoPAC, GE Health Medical). This method assesses myocardial deformation based on grayscale images, and is semi-automatic and angle-independent. As with 2D strain, AFI analyzes LVWM by tracking features (natural acoustic tags) in the 2D TTE. The AFI algorithm estimates the percent of wall lengthening and shortening in a set of 3 longitudinal 2D image planes, apical 4-, 3-, and 2-chamber views. It then combines the results of all 3 planes in a single bull's-eye summary as LPSS along with segmental and global peak strain values (Fig. 1). The LPSS values in a 16-segment LV model were used in the present study. Values of the LPSS from the apical 4-, 3-, and 2-chamber views were obtained automatically by AFI software. The average of the 3 values was regarded as global LV LPSS.

Table 1
Description of the background diseases of the patient population. The main background cardiac diseases of the 22 patients were as follows: 11 patients had ischemic heart disease, 4 patients had dilated cardiomyopathy or post myocarditis, 2 patients had cardiac sarcoidosis, 1 patient had cardiac amyloidosis, 1 patient had sick sinus syndrome, 1 patient had sick sinus syndrome and post-aortic valve replacement, 1 patient had post-aortic valve replacement, and 1 patient had complete atrio-ventricular block.

	Number of patients
Ischemic heart disease	11
Dilated cardiomyopathy or post myocarditis	4
Cardiac sarcoidosis	2
Cardiac amyloidosis	1
Sick sinus syndrome	1
Sick sinus syndrome and post-aortic valve replacement	1
Post-aortic valve replacement	1
Complete atrio-ventricular block	1

2.2. Statistics

Comparison of distribution of percentage of segments scored as normal, hypokinesis, and akinesis in a total of 342 evaluated segments in naked eye evaluation of LVWM among 4 different assessors was assessed using chi square tests.

Cohen's and Fleiss' kappa coefficients were used as statistical measures for assessing the reliability of agreement between 2 (Cohen) and all 4 (Fleiss) assessors for the 3 classifications (normal, hypokinesis, and akinesis) for evaluation of LVWM. Values of the kappa coefficient were habitually regarded as follows: <0 indicated no agreement, 0–0.20 slight agreement, 0.21–0.40 fair, 0.41–0.60 moderate, 0.61–0.80 substantial, and 0.81–1 almost perfect agreement.

3. Results

Among the 352-segments analyzed by AFI, 10 segments were excluded for technical reason such as image artifacts, dropout or misalignment, or angulations that would affect analysis. The remaining total of 342 segments (97%) was successfully tracked with mean LPSS −14.8 ± 8.1%.

3.1. Relationship between global LV LPSS (%) and echocardiographic LVEF by method of disk (MOD) (%) by experienced cardiologist

Global LV LPSS using AFI were automatically calculated for each patient with selection and markings of images by experienced cardiologist 1 independently, before qualitative subjective naked eye evaluation of LVWM by the same assessor. A significant strong negative correlation was observed between LVEF values using MOD and global LV LPSS ($R = -0.8974$) both assessed by experienced cardiologist 1 (Fig. 2).

3.2. LPSS value (%) using AFI for the 3 classifications (normal, hypokinesis, and akinesis) of segments for naked eye evaluation of LVWM by experienced cardiologist 1

The average LPSS values obtained using automated AFI calculation (data were acquired by experienced cardiologist 1 for the 3 classifications using naked eye evaluation of LVWM by the same assessor) rated as normal, hypokinesis, and akinesis were −17.4 ± 6.3, −7.7 ± 6.6, and 0.9 ± 6.1%, respectively. Evaluations were performed independently after measurement of LPSS. LPSS was significantly lower in normal segments than segments with hypokinesis and those with akinesis (both $P<0.01$). Furthermore, LPSS was significantly lower in segments with hypokinesis than segments with akinesis ($P<0.01$). The classification of segments by experienced cardiologist was statistically significantly correlated with those found on LPSS (all $P<0.01$) (Fig. 3).

3.3. Temporary criteria of AFI for differentiation of normal, hypokinesis, and akinesis of LVWM by experienced cardiologist and previous study

Marwick and his colleagues recently reported that the range of LV LPSS using AFI was −18.6 ± 5.1% at all wall levels in normal subjects [12], which is nearly the same value as shown in Fig. 3 for normal. Therefore, using this information and distribution of LPSS values obtained by AFI in segments of normal, hypokinesis, and akinesis in Fig. 3, the temporary AFI criteria of LPSS were set as follows: normal, less than −12; hypokinesis, −12-2; and akinesis, more than 2. Of the 342 segments analyzed, 239, 87, and 16 segments were classified with these criteria as normal, hypokinesis, and akinesis by LPSS using AFI, respectively.

3.4. Qualitative subjective naked eye evaluation of LVWM by experienced cardiologists and non experienced residents

From a total of 342 segments with successfully tracked AFI on the stored TTE data, the numbers of segments which were retrospectively diagnosed as normal, hypokinetic, and akinetic were 249, 85, and