Validation of Longitudinal Peak Systolic Strain by Speckle Tracking Echocardiography With Visual Assessment and Myocardial Perfusion SPECT in Patients With Regional Asynergy

Kenya Kusunose, MD, PhD; Hirotugu Yamada, MD, PhD; Susumu Nishio; Yukio Mizuguchi, MD; Masahito Choraku, MD, PhD; Yasuhiro Maeda; Shinobu Hosokawa, MD, PhD; Nobuo Yamazaki, BSc; Noriko Tomita, MD, PhD; Toshiyuki Niki, MD; Koji Yamaguchi, MD, PhD; Kunihiro Koshiba, MD, PhD; Takeshi Soeki, MD, PhD; Tetsuzo Wakatsuki, MD, PhD; Masashi Akaike, MD, PhD; Masataka Sata, MD, PhD

Background: Automated function imaging (AFI) is a recently developed method of calculating the longitudinal peak systolic strains (LS) of the regional left ventricular (LV) wall using speckle tracking echocardiography and displaying them on a single bull's-eye map. The feasibility of AFI in patients with regional LV wall motion abnormalities caused by myocardial infarction (MI) was evaluated by comparison with visual assessment and myocardial perfusion single-photon emission computed tomography (SPECT).

Methods and Results: Segmental LS was measured by AFI in 60 patients with MI (67±11 years) and 58 controls (71±9 years). Wall thickening (WT) was measured by SPECT in 20 patients with MI. There was a strong positive linear relationship between the wall motion score index by expert visual assessment and global LS. The receiver-operating characteristic analysis revealed the best cutoff value of −11% <LS to identify hypokinetic segments. The overall accuracy of wall motion scoring by LS in the 2,006 segments was 96.8% (κ=0.90) compared with visual assessment. The correlation coefficient between LS and WT was R²=0.65 in the 340 segments.

Conclusions: Assessment of LV regional asynergy by AFI showed good agreement with visual and SPECT assessments. AFI is clinically useful for quantitative assessment of LV regional wall motion abnormalities. (Circ J 2011; 75: 141–147)

Key Words: Myocardial infarction; Regional asynergy; Single-photon emission computed tomography (SPECT); Speckle tracking; Strain
ally associated with the angle dependence of tissue Doppler imaging, and can be applied to all segments, including the apical region. Recent studies suggested its usefulness for LV assessment of normal control, pediatric subjects, hypertension, myocardial infarction (MI), dyssynchrony, and LV rotation. Automated function imaging (AFI) has been recently developed to highlight potential wall motion abnormalities. The AFI algorithm noninvasively tracks and analyzes longitudinal peak systolic strain (LS) based on speckle tracking and provides a single bull’s-eye summary of the LV segmental wall strain. AFI is expected to be tool to support clinical decision-making, by assessing LV function semi-automatically with a simplified operational procedure and high reproducibility.

The objective of this study was to assess the feasibility of AFI in patients with regional LV wall motion abnormalities caused by MI by comparing the results with visual assessment and functional parameters derived from myocardial perfusion single-photon emission computed tomography (SPECT).

Methods

Study Design

Of 65 patients with a previous MI, 5 were excluded because of inadequate image quality for wall motion analysis. The remaining 60 patients were enrolled. Coronary angiography (CAG) was used to confirm the presence of coronary artery disease: 4 patients had 3-vessel disease, 10 had 2-vessel disease, 18 had isolated left anterior descending branch disease, 8 had isolated left circumflex branch disease and 20 had isolated right coronary artery disease; 22 patients had an anterior infarction, 16 had a posterior infarction and 28 had an inferior infarction. On the same day as CAG, 20 patients underwent SPECT imaging: 11 had 1-vessel disease, 6 had 2-vessel disease and 3 had 3-vessel disease. The patients were prospectively enrolled in the study between May 2008 and September 2009 at multiple centers (Tokushima University Hospital, Higashi Tokushima National Hospital, Health Insurance Naruto Hospital and Tokushima Red Cross Hospital). The control group comprised 58 healthy volunteers. None of the patients had atrial fibrillation or severe valvular disease. Clinical data were obtained by complete review of each patient’s medical record, history taking, physical examination and transthoracic echocardiography. Conventional medical treatment such as angiotensin-converting enzyme inhibitors, angiotensin II receptor blockers, diuretics and vasodilators were continued throughout the study. Echocardiographic and SPECT digital data obtained in each hospital were corrected and interpreted at Tokushima University Hospital. The institutional review board of each hospital approved the protocol of this study and written informed consent was given by all subjects.

Echocardiographic Examination

All patients underwent precordial M-mode, 2-D and Doppler
echocardiography while in the left lateral position. Images were obtained with 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. LV end-diastolic dimension (LVEDD), end-systolic dimension (LVEDS), interventricular septum thickness (IVS), posterior wall (PW) thickness and left atrial (LA) dimension were measured from the M-mode echocardiogram. LV ejection fraction and LA volume were calculated by Simpson’s method using 2-D images. LA volume was indexed to body surface area. Visual regional wall motion (RWM) was interpreted according to the American Society of Echocardiography criteria with a 17-segment model by 2 experts’ consensus and 2 inexperienced observers consensus who had reached level 1 training and performed 150 standard echocardiographic examinations for 3 months. Disagreements were adjudicated by discussion echo conference. Each segment was scored as: (1) normal, (2) hypokinetic, (3) akinetic, or (4) dyskinetic. The sum of the wall motion scores, gave the wall motion score index (WMSI). These values were considered significantly different at \( P<0.05 \).

SPECT Imaging Protocol
SPECT images were acquired on a dual detector camera (E.CAM, Toshiba Medical Co, Tochigi, Japan), equipped with a low-energy general-purpose collimator, using stepwise detector rotation and 30 s of data collection per projection. While they were at rest, patients received an intravenous injection of \( ^{201} \)thallium (2.5–3.5 mCi), with the dose adjusted for patient weight, and SPECT imaging was initiated 10 min later, using a 20% window centered over the 68- to 80-keV and the 167-keV photopeaks. The protocol used 8 frames per cardiac cycle, and 100% of beats were accepted. The gated projection data sets were filtered with a 2-D Butterworth filter (order 8, cutoff 0.45 cycles/pixel). Quantitative gated SPECT (QGS) was analyzed using the QGS protocol. Bull’s eye maps of regional perfusion and wall thickening (WT) were generated. WT was expressed as the percentage increase in WT from the end-diastolic to the end-systolic phase. The QGS-derived bull’s-eye map of the regional wall was then divided into 20 segments, and for each segment the different parameters were quantified. In this study 20 segments with SPECT were converted to 17 segments with echocardiography by changing 2 apex mean scores into 1 apex score and 6 distal mean scores into 4 distal scores (Figure 2).

Statistical Analysis
Relationships between variables were assessed using linear regression analysis and expressed as \( R^2 \). Differences between each wall motion score group were assessed by analysis of variance (ANOVA) and Student-Newman-Keuls post-hoc test. Values were considered significantly different at \( P<0.05 \). The diagnostic abilities of LS for judging wall motion abnormality was determined by the receiver-operating characteristic (ROC) curve. We used \( \kappa \) statistics to assess concordance between modalities. Statistical analysis was performed pri-
Reproducibility
Ten randomly selected studies were measured for reanalysis of AFI and QGS by 1 observer at 2 separate times, and 10 studies were chosen at random for reanalysis of AFI and QGS by 2 observers, for determination of intra- and interobserver variability, respectively.

Results
Baseline Clinical Characteristics of the Patients
The mean age of the control group was 67±11 years and that of the MI group was 71±9 years. LVDd, LVDs, LV mass index, LAVI, GLS and WMSI in the MI group were greater than those in the control group. Ejection fraction, IVS and PW in the MI group was decreased compared with the control group. There were no significant differences in other parameters (Table). Examples of the decrease in LS after MI are shown in Figure 1, which presents the analysis for each segment together with LS value for the LV by EchoPAC.

Cut-Off Values of LS for Wall Motion Abnormalities
A total of 2,006 segments of the LV wall were evaluated. In all patients, 1,636 segments were judged as normokinetic, 233 as hypokinetic, 116 as akinetic, and 21 as dyskinetic by agreement between expert reading and each method. LS values of the normokinetic (−19.5±5.8%), hypokinetic (−7.1±5.3%), akinetic (−3.2±4.8%) and dyskinetic (2.4±2.2%) wall

<table>
<thead>
<tr>
<th>Table. Clinical Characteristics of the Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
</tr>
<tr>
<td>Age (years old)</td>
</tr>
<tr>
<td>Body mass index</td>
</tr>
<tr>
<td>Systolic blood pressure (mmHg)</td>
</tr>
<tr>
<td>Diastolic blood pressure (mmHg)</td>
</tr>
<tr>
<td>Heart rate (beats/min)</td>
</tr>
<tr>
<td>End-diastolic LV diameter (cm)</td>
</tr>
<tr>
<td>End-systolic LV diameter (cm)</td>
</tr>
<tr>
<td>LA diameter (cm)</td>
</tr>
<tr>
<td>Interventricular septal thickness (cm)</td>
</tr>
<tr>
<td>LV posterior wall thickness (cm)</td>
</tr>
<tr>
<td>LV mass index (g/m²)</td>
</tr>
<tr>
<td>LA volume index (ml/m²)</td>
</tr>
<tr>
<td>Ejection fraction (%)</td>
</tr>
<tr>
<td>WMSI</td>
</tr>
<tr>
<td>GLS (%)</td>
</tr>
</tbody>
</table>

MI, myocardial infarction; LV, left ventricular; LA, left atrial; WMSI, wall motion score index; GLS, global longitudinal strain.

Figure 3. Correlation between wall motion score index (WMSI) and global longitudinal strain (GLS) in myocardial infarction patients.
Feasibility of Automated Function Imaging

segments were significantly different from each other (P<0.01). In the MI patients, there was a positive linear relationship between WMSI by expert visual assessment and GLS (R²=0.55, P<0.01, Figure 3).

Comparison With AFI
The ROC analysis revealed the best cutoff value of LS to identify visual hypokinetic segments as >−11%. For detection of hypokinetic wall segments by expert visual assessment, AFI assessment of the wall motion score showed a sensitivity of 96.2%, with a specificity of 96.9% and an overall accuracy of 96.8% (κ=0.90). The inexperienced observers had a κ of 0.72. Akinetic and dyskinetic segments were analyzed by ROC analysis as follows: (1) normal: LS≤−11%, (2) hypokinetic: −11%<LS≤−4%, (3) akinetic: −4%<LS≤0%, or (4) dyskinetic: 0%<LS. The LS wall motion score was automatically scored from the AFI analysis. Intra-observer variability for LS measurement was 6.8±5.2% and interobserver variability was 10.2±9.2%. The κ in each segment was summarized on a bull’s-eye map of 60 patients with MI (Figure 4). The κ values in the basal anteroseptal and mid-lateral regions were less than 0.75.

Comparison With SPECT
The WT of the normokinetic (30.7±7.8%), hypokinetic (17.2±5.9%), akinetic (11.3±6.5%) and dyskinetic (7.5±5.2%) wall segments significantly differed from each other (P<0.01). There was a negative linear relationship between WT and LS (R²=0.65, P<0.01, Figure 5). Intra-observer variability for WT measurement was 2.5±2.2% and interobserver variability was 3.8±3.2%. The ROC analysis revealed a cutoff value of 20% <WT in the base and midportion and 30% <WT in the apical and apex portion for visually identifying hypokinetic segments. Each segment was scored as: normokinetic=WT >20% in the base and midportion and WT >30% in the apical and apex portion; hypokinetic=20% <WT in the base and midportion and 30% <WT in the apical and apex portion. The sensitivity, specificity, and accuracy of AFI, and the expert and inexperienced observers’ detection of hypokinetic segments from the SPECT assessment are shown in Figure 6. Sensitivity and specificity were greater with AFI and the expert observers than with the inexperienced observers’ assessment.

Discussion
This study demonstrated that, in patients with MI, the AFI algorithm was in agreement with the visual assessment of RWM abnormalities by experts. In addition, we found good
overall correlation and agreement of regional LS measured by AFI with regional WT obtained from SPECT, which demonstrated the accuracy of wall motion assessment using the AFI algorithm. The results of our study suggest that AFI can be applied clinically to assess LV RWM abnormalities in a noninvasive and objective manner.

Relation Between Wall Motion Score by Visual Assessment and by AFI
Overall, strong correlation and agreement between AFI and visual assessment was found in all 17 LV segments. A previous study using LS and strain rate reported impaired tracking in the posterior wall, whereas we found small discrepancies in the basal anteroseptal and mid-lateral segments, not in the posterior. The 11 cases of a discrepancy in the basal anteroseptal segment included 8 patients with a sigmoid septum for whom AFI gave a low value for LS and suggested a wall motion abnormality whereas visual assessment judged it as normal. AFI tended to give a low value for LS in the mid-lateral segment, where poor image quality may cause insufficient accuracy of speckle tracking. In this study, because there was good image quality for the posterior segments, the posterior wall did not impair tracking. Image quality tends to affect the assessment of wall motion abnormality using AFI.

Comparison of GLS With Results Obtained Using Other Methods
Jamal et al reported that strain obtained by tissue Doppler imaging could accurately identify infarct-involved segments, by setting the cutoff value of –13%. Quantitative assessment of contractile function by magnetic resonance (MR) tissue tagging and strain analysis suggested that strain could accurately detect dysfunctional myocardium, with a cutoff value of –20%. Reisner et al developed and validated the AFI algorithm to assess global LV function, and demonstrated a strong linear correlation between WMSI and GLS with $R^2 = 0.55$. Our results show good agreement with theirs.

Comparison With Previous AFI Studies
Some validation studies for AFI method have been published. Our study had the following advantages and provided a unique assessment in comparison with previous validation studies: (1) subjects were prospectively enrolled at multiple centers, (2) comparison between expert and inexperienced observers, (3) $\kappa$ in all segments summarized on a bull’s-eye map, and (4) strong correlation between LS measured by AFI and WT measured by SPECT.

Clinical Implications
Interpretation of wall motion abnormalities with echocardiography is observer-dependent and requires experience. An inexperienced reader sometimes misinterprets a wall motion abnormality, and significant training is required to become expert. Assessment of LV LS using the AFI algorithm is a fast, easy and objective method with low interobserver error and its accuracy was equal to that of visual assessment by experts. Qualitative assessment in AFI may be not necessary for experts; however, quantitative assessment is another advantage of AFI.

Study Limitations
The study limitations were (1) AFI analysis could not be used...
for every patient because of poor image quality (5 of 65 patients were omitted), and (2) visual assessment is subjective and experience-dependent. In order to overcome these limitations, we compared AFI with WT measured by SPECT in some of the subjects, as well as conducting a multicenter trial to assess as many segments as possible, including 2,006 segments in total. SPECT analysis has high objectivity, reproducibility and automatically scores WT, so we used this method for gold standard. Although WT measured by SPECT is a parameter of radial thickening and LS by AFI is a measurement of longitudinal strain, radial thickening and longitudinal shortening are thought to be strongly linked and there were good correlations between those parameters in our study. However, in segments with a variable extent of transmural necrosis, the longitudinal (subendocardial) and radial (mid layers) functions may differ. SPECT still has limited spatial and temporal resolution (8 frames per cardiac cycle).

Conclusions

Assessment of LV regional wall strain abnormalities using the AFI algorithm showed good agreement with visual assessment by echocardiographic experts, as well as with assessment by SPECT in patients with MI. The results suggest that AFI may be clinically useful for quantitative assessment of LV RWM abnormalities.

References


2. Lang RM, Bierig M, Devereux RB, Flachskampf FA, Foster E, Pellikka PA, et al. Recommendations for chamber quantification: A report from the American Society of Echocardiography’s Guidelines and Standards Committee and the Chamber Quantification Writing Group, developed in conjunction with the European Association of Echocardiography, a branch of the European Society of Cardiology. J Am Soc Echocardiogr 2005; 18: 1440 – 1463.


