

# A New Tool for Automatic Assessment of Segmental Wall Motion Based on Longitudinal 2D Strain

## A Multicenter Study by the Israeli Echocardiography Research Group

Noah Liel-Cohen, MD; Yossi Tsadok, BSc; Ronen Beeri, MD; Peter Lysyansky, PhD;  
Yoram Agmon, MD; Micha S. Feinberg, MD; Wolfgang Fehske, MD; Dan Gilon, MD; Ilan Hay, MD;  
Rafael Kuperstein, MD; Marina Leitman, MD; Lisa Deutsch, PhD; David Rosenmann, MD;  
Alik Sagie, MD; Sarah Shimoni, MD; Mordehay Vaturi, MD;  
Zvi Friedman, PhD; David S. Blondheim, MD

**Background**—Identification and quantification of segmental left ventricular wall motion abnormalities on echocardiograms is of paramount clinical importance but is still performed by a subjective visual method. We constructed an automatic tool for assessment of wall motion based on longitudinal strain.

**Methods and Results**—Echocardiograms of 105 patients (3 apical views) were blindly analyzed by 12 experienced readers. Visual segmental scores (VSS) and peak systolic longitudinal strain were assigned to each of 18 segments per patient. Ranges of peak systolic longitudinal strain that best fit VSS (by receiver operating characteristic analysis) were used to generate automatic segmental scores (ASS). Comparisons of ASS and VSS were performed on 1952 analyzable segments. There was agreement of wall motion scores between both methods in 89.6% of normal, 39.5% of hypokinetic, and 69.4% of akinetic segments. Correlation between methods was  $r=0.63$  ( $P<0.0001$ ). Interobserver and intraobserver reliability using interclass correlation for scoring segmental wall motion into 3 scores by ASS was 0.82 and 0.83 and by VSS 0.70 and 0.69, respectively. Compared with VSS (majority rule), ASS had a sensitivity, specificity, and accuracy of 87%, 85%, and 86%, respectively. ASS and VSS had similar success rates for correct identification of wall motion abnormalities in territories supplied by culprit arteries. VSS had greater specificity and positive predictive values, whereas ASS had higher sensitivity and negative predictive values for identifying the culprit artery.

**Conclusions**—Automatic quantification of wall motion on echocardiograms by this tool performs as well as visual analysis by experienced echocardiographers, with a greater reliability and similar agreement to angiographic findings. (*Circ Cardiovasc Imaging*. 2010;3:47-53.)

**Key Words:** echocardiography ■ left ventricular wall motion ■ strain ■ interobserver reliability  
■ intraobserver reliability

Evaluation of segmental wall motion (WM) abnormalities is of paramount importance for interpretation of echocardiograms. Echocardiographic detection of new WM abnormalities has been recognized as a criterion for diagnosing acute myocardial infarction by the recently published Universal Classification of Myocardial Infarction.<sup>1</sup> The identification of wall motion abnormalities has significant implications in clinical decision-making such as in patients with chest pain in the emergency department<sup>2</sup> and in patients with congestive heart failure.<sup>3,4</sup> WM evaluation is also important regarding prognosis, for example, in patients undergoing heart surgery<sup>5</sup> as well as in noncardiac conditions such as

dialysis and subarachnoid hemorrhage.<sup>6-8</sup> Decisions and guidelines are based on visual scoring of WM, i.e., assessment of displacement and thickening of left ventricular (LV) myocardial segments and grading them into 5 categories (normal, hypokinetic, akinetic, dyskinetic, and aneurysmatic).<sup>9</sup> This takes considerable skill gained by experience as outlined by American Society of Echocardiography criteria.<sup>10</sup> Advances in echo technology (eg, incorporation of second harmonics) have enhanced endocardial visualization; however, the classification of WM by visual assessment is highly observer-dependent<sup>11</sup> and is probably the only area of echocardiography that remains totally qualitative. Despite

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From the Soroka University Medical Center (N.L.-C.), Beer Sheva, Israel; Ben-Gurion University (Y.T.), Beer Sheva, Israel; Hadassah University Hospital (R.B., D.G.), Jerusalem, Israel; General Electric Healthcare (P.L., L.D., Z.F.), Haifa, Israel; Rambam Medical Center (Y.A.), Haifa, Israel; Sheba Medical Center (M.S.F., I.H., R.K.), Tel Aviv, Israel; St Vinzenz Hospital (W.F.), Cologne, Germany; Asaff Harofeh Medical Center (M.L.), Zerifin, Israel; Shaare Zedek Medical Center (D.R.), Jerusalem, Israel; Rabin Medical Center (A.S., M.V.), Petah Tikva, Israel; Kaplan Medical Center (S.S.), Rehovot, Israel; and Hillel-Yaffe Medical Center (D.S.B.), Hadera, Israel.

Correspondence to Noah Liel-Cohen, MD, Soroka University Medical Center, PO Box 151, Beer Sheva, 84101 Israel. E-mail lielnoah@bgu.ac.il  
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efforts to develop automated systems for detection and quantification of WM abnormalities, which would make this evaluation more objective and consistent, none has yet been able to replace the expert reader.

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New Doppler-based imaging techniques such as tissue velocity imaging, longitudinal strain, and strain-rate imaging have been evaluated for assessing WM abnormalities.<sup>12–15</sup> However, these methods have limitations including angle dependence and the fact that displacement of segments may reflect transitional changes secondary to heart motion with breathing or tethering of akinetic segments by neighboring normal segments.

A novel 2D imaging method based on speckle tracking has recently been introduced and validated.<sup>16</sup> This method identifies natural acoustic markers within the myocardium and tracks them over a number of frames. Myocardial deformation, including longitudinal strain and strain rate, can then be calculated.<sup>17</sup> Global longitudinal strain using this method has been shown to be of value in the assessment of global LV function.<sup>18,19</sup> The ability to evaluate and quantify segmental wall motion by similar methods has been demonstrated in small and limited clinical studies.<sup>20,21</sup>

The purpose of this multicenter study was to generate and to test the usefulness of an automatic tool, based on longitudinal strain, for detection and quantification of segmental WM abnormalities. This was accomplished by comparing the segmental scoring using the automated analysis with the conventional visual method as performed by 12 experienced echocardiographers and to angiographic results in a large group of normal subjects and patients with ischemic heart disease or with cardiomyopathy.

## Methods

### Patients

One hundred five patients took part in this study (mean age,  $59.3 \pm 14.4$ ; 67% men). The group included 90 patients hospitalized in a single medical center for a first episode of chest pain (mean age,  $57.4 \pm 14.1$  years; 68% men) and had a standard echocardiographic study performed within 48 hours of admission. Of these, 62 patients (age,  $59.2 \pm 13.1$ ; 75% men) had a myocardial infarction (58 of them had single-vessel disease: left anterior descending artery, 25; right coronary artery, 22; circumflex artery, 11). In 28 subjects (age,  $53.4 \pm 15.7$ ; 54% men) cardiac disease was excluded by history, lack of ischemic changes on ECG, no rise in enzymatic markers of infarction, and by a negative coronary angiogram (not performed in 3 patients). An additional 15 patients (from another medical center; age,  $70.5 \pm 10.9$ ; 60% men) with a confirmed diagnosis of dilated cardiomyopathy were also included in the study cohort.

### Analysis by Experienced Physicians

Twelve physicians with extensive experience in reading echocardiograms (interpretation of echocardiograms as their main daily activity, >12 analyses per day, 8 of them heads of echocardiography laboratories/noninvasive units) from 9 major Israeli cardiology centers participated in the study. Each received CDs with studies from 105 patients for blinded assessment of WM abnormalities by both the visual segmental score (VSS) and automatic segmental scores (ASS) methods. Ten of these studies were randomly chosen and sent on a separate occasion to 11 of the same echocardiographers for determination of intraobserver reliability.

### Analysis of 2D Images

For each of the 105 patients, 2D clips of a single cardiac cycle from the 3 apical views (long-axis, 2-chamber, and 4-chamber views) were provided. All echo recordings were made on a Vivid 7 digital ultrasound scanner (General Electric, Horten, Norway) with a frame rate of 50 to 80 per second and were analyzed on workstations equipped with EchoPac software (GE package). Each reader was required to mark both sides of the mitral annulus and the LV apex in each of the 3 views; the endocardial border was automatically detected (could be adjusted manually, if necessary), and the LV myocardium was automatically divided into 18 segments (6 basal, 6 mid, and 6 apical segments per patient), thus providing for identical segmentation for both VSS and ASS analyses (readers blinded to the latter).

For the ASS method, the mean longitudinal peak systolic strain was determined automatically for each segment (Vivid 7, 2D Strain software, GE). For the VSS method, the readers scored the quality of the perceived WM of each of the above segments into 1=normal, 2=hypokinetic, 3=akinetic, 4=dyskinetic, and 5=aneurysmatic, in compliance with American Society of Echocardiography standards.<sup>9</sup> Because the number of dyskinetic and aneurysmatic segments was small, they were grouped together with the akinetic segments, and hereafter the term “akinetic segments” includes them. Readers were blinded to results of their ASS analysis and to clinical data. Data from both VSS and ASS methods were automatically stored in an Excel file that was later sent to a central laboratory for statistical analysis.

### Construction of an Automatic Tool for WM Analysis

To create an automatic method using longitudinal strain for WM analysis that would correlate with analyses by the human eye-balling method, it was necessary to categorize peak longitudinal systolic strain (continuous data) by defining ranges that correspond to normal, hypokinetic, and akinetic segments by VSS. Thus, it was necessary to construct a gold-standard for VSS ( $VSS_{GS}$ ), which was accomplished by using the majority score assigned to each segment by the readers. To ascertain a clear majority score for each segment, strict criteria for agreement between readers were used: The  $VSS_{GS}$  included only segments with scores that received a majority of at least 3 readers above the second most prevalent score for each segment. Segments without a majority as required (“equivocal”) and segments which  $\geq 3$  readers could not score (“uninterpretable”) were excluded from the  $VSS_{GS}$ . Cutoff points for segmental peak systolic strain that best discriminated between normal, hypokinetic, and akinetic segments as defined by the  $VSS_{GS}$  were determined for 3 LV levels (base, mid, and apical) by receiver operating characteristic (ROC) analysis.

### Interobserver and Intraobserver Reliability

Data were analyzed by the interclass correlation (ICC) coefficient, described in detail in the Statistical Analysis section below to determine the interobserver and intraobserver reliability for both VSS and ASS methods separately, using all segments analyzed by each reader.

### Association Between ASS and VSS

A representative score was constructed for both methods (VSSrs and ASSrs), defined as the most frequent score given to each segment by a simple majority of the readers (the mode). Sensitivity, specificity, positive and negative predictive values, and accuracy of ASS versus VSSrs were determined for all segments that were scored by both methods. The analysis of the agreement between ASS and VSS methods for determining segmental WM abnormalities was done for 3-level ordinal scores (normal, hypokinetic, and akinetic) and repeated for binary segregation into normal versus abnormal (ie, any score other than normal).

### WM Score Index

A wall motion score index (WMSI)<sup>22</sup> was calculated for each patient as the average score of his readable segments. Using each method separately, WMSIs were calculated for each patient by each reader.

WMSIs by each reader's ASS were compared with WMSIs by VSS as described in the Statistical Analysis section below.

### WM Analysis by ASSrs and VSSrs Versus Angiographic Data

The angiographic data of the 83 patients who were catheterized and had either 1 coronary artery disease or no significant coronary disease was used as the gold standard to compare the diagnostic ability of both methods (VSSrs and ASSrs). First, we sought to establish the ability of the methods to identify WM abnormalities in segments supplied by the culprit artery. Correct identification of abnormal segmental contraction was considered when it was detected in the territory supplied by the culprit artery and incorrect when it was detected in a non-culprit artery territory. The sensitivity, specificity, positive and negative predictive values, and accuracy of both methods versus the angiographic findings as a gold standard were determined. Second, the ability of each method to correctly identify the culprit artery per patient was determined. When the majority of WM abnormalities were located in the territory supplied by a culprit artery, the patient was considered correctly diagnosed and vice versa. The American Society of Echocardiography classification of territories supplied by each coronary artery was used,<sup>9</sup> with necessary modification.

### Statistical Analysis

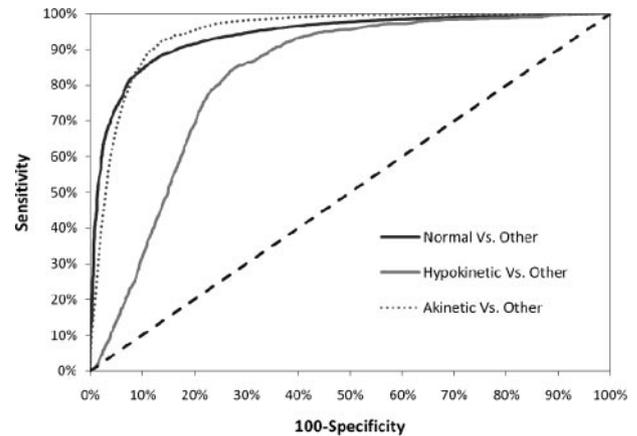
Data were analyzed using Matlab (MathWorks, Inc, Natick, Mass) and SAS version 9.1 (SAS Institute, Inc, Cary NC) software. Continuous data are presented as mean  $\pm$  SD. Categorical data are presented as a count and percentage. Statistical significance was defined as a probability value  $<0.05$ .

To calibrate ASS to VSS categories, cutoff values for peak systolic longitudinal strain were defined for each category by ROC curve analysis.<sup>23</sup> This process was repeated for basal, mid, and apical segments of the LV.

Using the cutoff values obtained from the ROC analysis, the ASS of each segment was classified as normal, hypokinetic, or akinetic. For each reader, the specificity, positive and negative predictive values, and accuracy of ASS classification across segments versus the VSSrs were calculated. Mean values across readers are presented. The correlation between these scores was estimated using Spearman rank correlation coefficient, and the level of significance is presented.

The ICC coefficient was used as an index of interobserver and intraobserver reliability/agreement.<sup>24</sup> The interobserver reliability was assessed by fitting several random effects models using the PROC MIXED procedure in SAS, where the score was modeled with physician and segment (subject) entered as random effects. The segmental score of WM abnormality was modeled as a 3-level ordinal variable (normal=1, hypokinetic=2, akinetic or worse=3) and then as 3 separate binary variables: normal versus other, hypokinetic versus other and akinetic or worse versus other; the "other" classification was assigned a 0 and each of the classifications normal, hypokinetic, and akinetic were assigned a 1. For the estimation of intraobserver reliability, the ICC was calculated again using similar models; however the data entered into the models represented a sample of 10 randomly selected subjects segments scored a second time by 11 of the physicians. For intraobserver reliability, the mean and standard deviation of the readers' individual ICCs are reported. The clinical significance of ICC coefficients was interpreted as: excellent,  $\text{ICC} \geq 0.80$ ; good,  $0.60 \leq \text{ICC} < 0.80$ ; moderate,  $0.40 \leq \text{ICC} < 0.60$ ; and poor,  $\text{ICC} < 0.40$ .

The interobserver ICCs were also calculated for WMSI by both ASS and VSS, using similar models as described above. Because this variable is continuous, we also estimated the interobserver variability from the models using the variance components and the overall mean WMSI score of the study sample adjusted for physicians, using the estimated intercept and its 95% confidence interval. WMSI was also compared between the methods. The mean correlation (Spearman) between ASS and VSS WMSI scores are presented, as well as a Bland-Altman plot<sup>25</sup> of the difference in WMSI between VSS and ASS scores versus the mean score for each reader.



**Figure 1.** ROC curve for determining optimal ASS cutoff points between normal, hypokinetic, and akinetic segments, each versus all other segments.

Using angiographic data as a gold standard, we assessed whether the VSS and ASS correctly identified WM abnormalities. Sensitivity, specificity, positive and negative predictive values, and accuracy of the VSSrs and ASSrs are presented as well, for correctly classifying a diseased segment and for correctly identifying a culprit artery in catheterized subjects.

## Results

### Construction of the ASS Tool

A total of 1890 segments from 105 patients were analyzed by 12 experienced readers, who used both VSS and ASS methods for assessing WM but were blinded to the ASS results.

The VSS<sub>GS</sub> was constructed from 1536 (81.3% of total) segments, after exclusion of 354 segments with equivocal scores (18.7%) and 78 noninterpretable segments (4.1%). Ranges of ASS that best defined the 3 WM categories (as determined by ROC analysis, shown in Figure 1) by LV level are as follows: basal segments: normal  $< -10.9\%$ , hypokinetic  $-10.9$  to  $-6.2\%$ , akinetic  $> -6.2\%$ ; mid-LV segments: normal  $< -12.6\%$ , hypokinetic  $-12.6$  to  $-7.9\%$ , akinetic  $> -7.9\%$ ; apical segments: normal  $< -14.1\%$ , hypokinetic  $-14.1$  to  $-9.1\%$ , akinetic  $> -9.1\%$ . The mean ASS values for each WM category were: normal  $-19.8 \pm 4.9\%$ , hypokinetic  $-10.3 \pm 1.9\%$ , akinetic segments  $-3.9 \pm 3.7\%$  (for all abnormal segments the mean ASS was  $-7.1 \pm 4.3\%$ ). Use of these cutoff values for detection of normal versus abnormal segments resulted in excellent average (of all readers) sensitivity, specificity, and accuracy rates (89% for each) for the ASS tool versus the VSS<sub>GS</sub> from which it was derived.

### Interobserver and Intraobserver Reliability ASS Versus VSS

Overall, both interobserver and intraobserver reliabilities were better for the ASS than the VSS method (Table 1). There was a low reliability for scoring hypokinetic segments by both methods but to a lesser degree by the ASS method (Figure 2). Of note, for each experienced reader, ASS had a better reliability than VSS regarding all segments and within each category of WM.

Interobserver reliability by VSS was highest for segments in the left anterior descending artery territory (ICC, 0.73) and

**Table 1. ICC Coefficients for Interobserver and Intraobserver Reliability of VSS and ASS Methods**

Reliability	2 Categories: Normal/Abnormal		3 Categories: Normal/Hypokinetic/Akinetic	
	VSS	ASS	VSS	ASS
Interobserver	0.63	0.76	0.70	0.82
Intraobserver	0.71±0.12	0.84±0.05	0.79±0.06	0.88±0.03

lowest in the circumflex territory (ICC, 0.61), whereas by ASS, reliability was highest in right coronary artery territory (ICC, 0.87) and lowest but still very good in left anterior descending artery territory and exceeded the reliability of VSS (ICC, 0.84). Interobserver reliability was better by the ASS method also when looking at basal, mid, and apical LV levels (ICC for VSS, 0.60, 0.67, and 0.77 and for ASS, 0.80, 0.87, and 0.80, respectively).

**Segmental WM Scores: ASS Versus VSS**

There was agreement of WM scores between both methods in 89.6% of normal, 39.5% of hypokinetic, and 69.4% of akinetic segments as classified by VSSrs. Fewer segments were classified as normal by each reader’s ASS compared with VSSrs, and more segments were classified as hypokinetic and akinetic.

The VSSrs was composed of 1839 segments (51 [2.7%] had no majority) (Table 2). The average correlation between both methods was 0.63 ( $P<0.0001$ ). The means of all readers’ sensitivity, specificity, positive and negative predictive values, and accuracy for detection of normal versus abnormal segments by ASS versus VSSrs, were 87±5%, 85±3%, 94±1%, 70±7%,

**Table 2. Segmental Wall Motion Scores Analyzed by VSSrs and ASSrs Methods**

	VSSrs		ASSrs	
	No.	%	No.	%
Excluded	51	2.7	32	1.7
Normal	1351	71.5	1295	68.5
Abnormal				
All	488	25.8	563	29.8
Hypokinetic	200	10.6	256	13.5
Akinetic	288	15.2	307	16.2

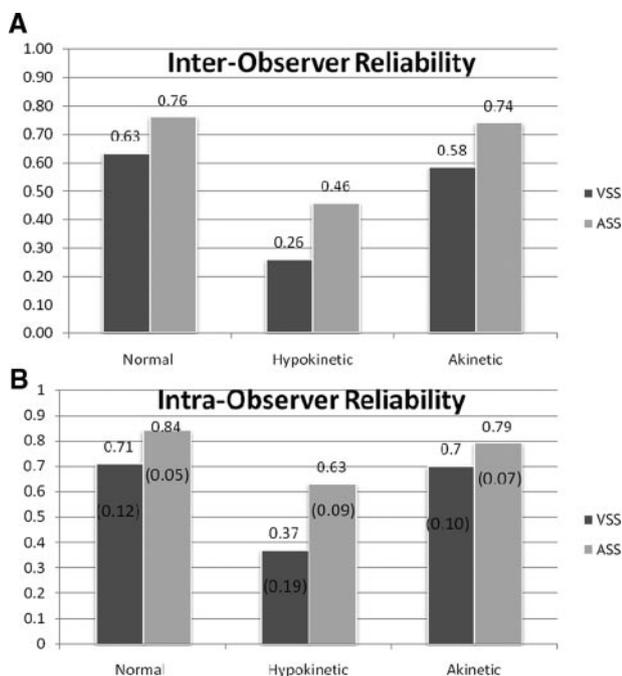
and 86±3%, respectively. The mean specificity of ASS was high in basal, mid, and apical segments (80±3% and 81±4%, 92±4%, respectively), as was the mean sensitivity (86±2%, 89±3%, and 86±11%, respectively).

**Patient WMSI: ASS Versus VSS**

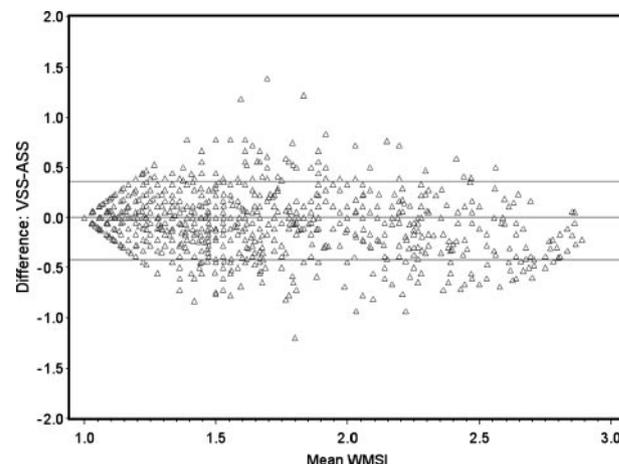
There was no statistically significant difference between readers’ mean WMSI scores when calculated by the ASS and VSS methods (1.50±0.12 versus 1.47±0.19,  $P=0.27$ ), and the correlation between the methods was 0.82 ( $P<0.0001$ ). The reliability of WMSI determination was better by ASS than by VSS (ICC coefficient, 0.95 versus 0.84). The Bland-Altman plot (Figure 3) confirms that the agreement is high at the lower and upper boundaries, that is, for patients with normal/nearly normal and with significantly abnormal WMSI (close to 1 and close to 3); however the variability for moderate WMSI values (close to 2) is greater.

**Relation of ASS and VSS to Angiographic Findings**

Segmental WM abnormalities were detected in culprit artery territories by VSSrs versus ASSrs in 74% versus 93% of patients with myocardial infarction, respectively, but in patients with normal coronary arteries none were found by VSS but WM abnormalities were detected in 32% of them by ASS. Although both methods had a similar accuracy for identifying



**Figure 2.** Interobserver and intraobserver reliabilities (A and B, respectively) for binary classification of normal versus abnormal, hypokinetic versus other, and akinetic versus other segments using both VSS and ASS methods (intraobserver reliabilities are mean [SD] values).



**Figure 3.** Bland-Altman plot of the difference in WMSI between ASS and VSS per reader and per subject versus the mean of the 2 values (the lines on either side of the line of equivalence are the 95% limits of agreement).

**Table 3. Ability of VSSrs and ASSrs to Identify WM Abnormalities in Territories Supplied by Culprit Arteries in Patients With Acute Myocardial Infarction and Normal Subjects**

	Segmental Level*		Patient Level†	
	VSSrs, %	ASSrs, %	VSSrs, %	ASSrs, %
Sensitivity	52	65	74	93
Specificity	94	89	100	68
PPV	71	65	100	86
NPV	88	89	65	83
Accuracy	85	83	83	85

\*Concordance of location of normally and abnormally contracting segments and territories supplied by culprit arteries.

†Correct identification of culprit artery in patients with significant single vessel disease. The culprit artery was considered the artery supplying the territory where most WM abnormalities were located.

patients with WM abnormalities in territories supplied by the culprit artery, the sensitivity of ASSrs was better compared with VSSrs (93% versus 74%) at the expense of a lower specificity (100% versus 68%) (Table 3).

The culprit artery was determined correctly in an average of 44% (range for individual readers, 36% to 49%) of all catheterized patients by VSS and in 49% on average (range, 40% to 60%) by the ASS tool.

## Discussion

In this article, we present a practical tool for automated segmental WM assessment that scores LV segments at least as well as visual determinations by expert readers. The importance of having an automatic tool that is able to assess WM contraction at least as well as an expert echocardiographer is enormous, because many clinical decisions and guidelines are based on this evaluation, but an experienced echocardiographer is not always available and even when present, the tool could be used as a second opinion.

The longitudinal strain values we found for normal segments by ASS were similar to those recently published by Marwick<sup>26</sup> and Leitman,<sup>18</sup> and, for infarcted segments, ASS values were similar to those found by Leitman.<sup>18</sup> The scores assigned to segments by the ASS tool were in good correlation with the average expert readers' scores (ASS versus VSSrs) using a 3-category scale and had high sensitivity, specificity, and accuracy rates. Importantly, the ASS method had a greater reliability than the VSS method (Table 1 and Figure 2). Another important feature of this tool is that when using coronary angiography as a gold standard, it had a better sensitivity in per-segment analysis and in per-patient analysis, at a cost of a lower specificity (Table 3).

The ability of 2D strain to identify segmental WM abnormalities was initially shown in animal studies.<sup>27,28</sup> Sun et al<sup>27</sup> showed in a pig model that radial and circumferential strains are significantly decreased in ischemic and infarcted territories. Migrino et al<sup>29</sup> demonstrated that radial and circumferential strain distinguished viable from infarcted myocardium in a rat ischemia/perfusion model. The ability of 2D strain to evaluate segmental WM abnormalities was assessed in 2 small studies<sup>20,28</sup> in humans. Leitman et al<sup>20</sup> showed that there was a graded decrease in longitudinal peak systolic strain

between normal, hypokinetic, and akinetic segments. Recently, Becker et al<sup>30</sup> showed that radial and circumferential 2D systolic strain could identify WM abnormalities well compared with MRI. These results are consistent with our data; however, our study is the first to show in a large group of patients that longitudinal 2D strain can be used as a tool to identify and score segmental WM abnormalities in a manner similar to the experienced human eye. Although MRI could be used as a gold standard, we preferred to compare the proposed automated tool with the visual method used in routine clinical work and on which the cardiological literature is based.

WM scores assigned by the ASS method tended to be somewhat higher than by the VSS method, due to the larger number of abnormal segments that were detected (Table 2). This tendency for a higher sensitivity of ASS is also supported by the comparison of the results to angiographic findings in the subgroup of patients with acute myocardial infarction (Table 3). It may be related to the fact that the ASS is based on longitudinal shortening, whereas visual scoring (VSS) is mainly based on wall thickening and radial translation. Anatomically, longitudinal fibers are abundant in the subendocardium, whereas circumferential and diagonal myocardial fibers are in the mid and outer layers of the myocardium.<sup>31</sup> Because the subendocardium is the most vulnerable myocardial layer, even patients who undergo a nontransmural myocardial infarction may have detectable impairment of longitudinal strain without visually detectable WM abnormalities. Also, in the ischemic cascade, impairment of longitudinal strain precedes impairment of wall thickening and motion, as was demonstrated by tagged MRI measurements.<sup>32</sup> Thus, myocardial damage may be overlooked by the human eye but picked up by a tool highly sensitive to longitudinal function and would assign it a higher score than VSS assessment would. Gjesdal et al<sup>33</sup> suggested that longitudinal strain could differentiate between normal, subendocardial, and transmurally infarcted segments as determined by MRI. In the future, longitudinal strain may actually become the preferred parameter for classifying WM abnormalities not only because of its objective nature (being automatic) but also due to its higher sensitivity to nontransmural myocardial damage.

As expected, agreement between ASS and VSS methods was much better regarding normal and akinetic segments (agreement in 89.6% and 69.4%, respectively) than regarding hypokinetic segments, for which there were also lower intraobserver and interobserver reliabilities. Thus, of the hypokinetic segments determined by VSS, only 39.5% were considered so by ASS, whereas 31% were classified as akinetic and 27.5% as normal. Some of the reasons for the lesser agreement regarding the classification of hypokinetic segments may relate to the definition of hypokinesis ("reduced endocardial inward motion and reduced wall thickening"), which is much more subjective than the definition for both normal segments ("normal contraction") and akinetic segments ("total absence of motion and thickening").<sup>34</sup> Also, discrepancies between the arbitrary segmentation used for reporting and actual areas of decreased contraction cause a nonuniform type of contraction within segments. Thus, readers are forced to decide whether to score such segments by the most severe, least severe, or average WM abnormality in the

segment. Finally, tethering of akinetic segments may make them appear hypokinetic to the human eye but would be analyzed more accurately and consistently by longitudinal strain. For all these reasons, an automatic, unbiased scoring system would be expected to have a greater reliability compared with VSS, especially for hypokinetic segments, consistent with the finding in this study.

Although not all patients with an acute myocardial infarction have detectable WM abnormalities (especially when the echo is performed within 48 hours after admission, sometimes after PCI was performed) and vice versa, the probability of finding WM abnormalities in territories supplied by arteries with culprit lesions is much greater than finding them in territories supplied by normal arteries. Obviously, inconsistencies between coronary anatomy and WM abnormalities could result from interpatient variations in coronary anatomy, collateral blood supply, small-vessel disease, or resolution of WM abnormalities after percutaneous coronary intervention. The ASS method tended to be more sensitive for identifying WM abnormalities in the territory of the culprit artery, but VSS was more specific; thus, both methods may be considered complementary.

The strength of this study is in its being a multicenter study in which 105 echocardiographic studies were read by the largest number of highly experienced echocardiographers ever to participate in such a study. Despite their expertise, the tool we propose proved to be as good as expert readers, with superior reliability and sensitivity for detection of WM abnormalities but with a lower specificity. Thus, the ASS method may be useful as an adjunct to the VSS method for detection of WM abnormalities, whether performed by expert or novice echocardiographers. This we hope to show in an ongoing study in which WM scores by nonexperts using the ASS tool are compared with assessment by experts without the ASS tool (eyeballing only). This automatic tool can also be used for teaching, standardization of segmental scoring, and for routine objective evaluation of segmental wall motion. Further validation of our results would facilitate the acceptance of this automatic method in routine clinical practice.

### Limitations

The study design presented here was limited to visual wall motion assessment and to longitudinal strain analysis performed on a single cardiac beat from each of the 3 apical views only. This was because we were interested in comparing the proposed echocardiographic tool for assessment of WM abnormalities (ASS) with a well-established echocardiographic tool (VSS) in a standardized setup and in views in which longitudinal strain could be obtained. Readers were required to classify WM quality of each segment as they would in their everyday practice so that the comparison of ASS and VSS methods would reflect expectations in “real world” clinical practice. Thus, no form of collaboration between the readers before the study, regarding reading standards or predetermined definitions of WM classification, was considered necessary. Although the study design used is ideal for determination of interobserver and intraobserver reliability, to more fully define the usefulness of ASS for clinical practice additional studies on beat-to-beat and test-

retest variability are required. Also, studies with different patient characteristics will be required because in this study the same patients were used for construction of the ASS tool and its verification.

### Conclusion

We have shown that an automated tool for segmental WM scoring based on 2D longitudinal strain can be used to assess WM contraction in patients, with good agreement to visual assessment by experienced echocardiographers and to angiographic data, with a somewhat better reliability as well. Our preliminary data suggest that this newly constructed tool may assist in detection and quantification of WM abnormalities, and its performance warrants further evaluation in a prospective study.

### Disclosures

Two of the authors (L.P. and F.Z.) work for GE Healthcare and are involved in developing echo software for automatic detection and quantification of LV WM abnormalities and function.

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### CLINICAL PERSPECTIVE

Identification and quantification of segmental left ventricular wall motion abnormalities on echocardiograms is still performed by a highly observer-dependent visual method despite advances in echo technology. This method requires training and expertise and is probably the only area of echocardiography that remains totally qualitative. It is clinically very important to have an automatic tool for assessment of regional function that is more objective, consistent, and widely available to less trained personnel and yet as accurate as an expert echocardiographer. For example, this tool could be used when an experienced echocardiographer is not available or could be used as a second opinion by experts. Thus, this study presents a practical tool, based on longitudinal 2D strain, for automated segmental wall motion assessment that scores left ventricular segments at least as well as visual determinations by expert readers. The tool presented has accuracy similar to experts' assessments using visual estimations but with superior reliability and sensitivity for detection of wall motion abnormalities at the cost of a somewhat lower specificity. It may serve as an adjunct tool to the widely used qualitative method for detection of wall motion abnormalities and as a screening tool for the novice echocardiographer. In addition, this automatic tool can be used for teaching, standardization of segmental scoring and routine objective evaluation of segmental wall motion.