Impact of acoustic window on accuracy of longitudinal global strain: a comparison study to cardiac magnetic resonance

Laurent Macron¹, Olivier Lairez², Julien Nahum¹, Mathieu Berry², Leslie Deal¹, Jean-François Deux³, Alexandre Bensaid¹, Jean-Luc Dubois Randé¹,4, Pascal Gueret¹,4, and Pascal Lim¹,4*

¹Cardiovascular Department, APHP, Henri Mondor University Hospital, Creteil, France; ²Cardiac Imaging Center, University Hospital of Rangueil, Toulouse, France; ³Radiology Department, APHP, Henri Mondor University Hospital, Creteil, France; and ⁴INSERM U955, Creteil, France

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Aims
To evaluate the impact of acoustic window on the feasibility and accuracy of longitudinal global strain (global-ε) by speckle tracking for assessing left ventricular (LV) systolic function.

Methods and results
The study included 70 patients (57 ± 17 years, 64% men), 28 selected patients with a suboptimal image quality (IQ) defined by three or more segments (4 ± 3 segments/patient) with wall motion score not analysable visually and 42 patients with an optimal two-dimensional (2D) echocardiography IQ. Left ventricular ejection fraction (LVEF) by Simpson’s biplane method (2D-EF), global-ε by speckle tracking, and peak systolic mitral annulus velocity [systolic tissue Doppler imaging (S-TDI)] were compared with LVEF by cardiac magnetic resonance (EF-CMR; 45 ± 18%, range 9–76%). Speckle-tracking analysis was feasible in all segments with an optimal acoustic window and in 85% (103/121) of segments poorly visualized. Global-ε similarly correlated with LVEF by CMR in patients with and without optimal IQ (r = 0.81 vs. 0.82 for good vs. poor IQ). In contrast, 2D-EF (r = 0.76) and S-TDI (r = 0.64) less correlated with LVEF by CMR in patients with a suboptimal IQ. Importantly, IQ only impacted on 2D-EF inter-observer reproducibility (9 ± 1 vs. 24 ± 22% for good vs. poor IQ) but not on global-ε reproducibility (9 ± 1 vs. 8 ± 7% for good vs. poor IQ).

Conclusion
In patients with a limited acoustic window, longitudinal strain by speckle tracking remains accurate and reproducible for assessing global and regional LV systolic function.

Keywords
Left ventricular function • Speckle tracking • 2D strain • Acoustic window

Introduction
Left ventricular (LV) systolic function is a strong predictor of cardiovascular outcome¹ and the severity of myocardial systolic dysfunction is determinant in the decision to introduce specific drugs or devices.²–⁴ In daily practice, systolic LV function is based on the measurement of LV ejection fraction (LVEF) using two-dimensional echocardiography imaging (2D-EF). However, the accuracy and reproducibility of LVEF measurement is still greatly dependent on the image quality (IQ) and the operator’s experience.⁵ Several quantitative automatic methods have been proposed⁶–¹⁰ to overcome these limitations, and so far, only tissue Doppler imaging (TDI) seems to reach a clinical application.¹¹,¹² However, TDI data have limited values, especially due to angle-dependence and the low signal-to-noise ratio. Recently, speckle tracking, a new image processing algorithm, has been proposed to overcome these issues. Speckle-tracking analysis allows for a study of the three components of myocardial deformation. Several studies have consistently reported that longitudinal strain by speckle tracking may provide a fair and reproducible...
measurement of regional and global LV systolic function correlated to sonomicrometry data and cardiac magnetic resonance (CMR) imaging data. However, these studies had been performed in selected patients with adequate IQ and the accuracy of speckle tracking has never been clearly addressed in patients with poor acoustic windows. The aim of our study was to evaluate the feasibility, accuracy, and reproducibility of longitudinal strain by speckle tracking for LV systolic function assessment in patients with a poor IQ.

Methods

Population

The study included 70 (57 ± 17 years, 45(64%) men) non-consecutive patients referred to our echocardiography laboratory for LVEF assessment. The 70 patients included 28 selected patients with a 2D echocardiography IQ and 42 patients with an optimal acoustic window. A poor 2D echocardiography IQ was defined by three or more myocardial segments (16-segment model) inaccurately visualized that prevents wall motion assessment and endocardial border delineation for LVEF calculation. All patients were referred to CMR imaging to provide an accurate assessment of LVEF (mean = 45 ± 18%, range, 9–76) in patients with ischaemic (n = 30) and non-ischaemic cardiomyopathy (n = 40). The study included only patients in sinus rhythm, without a contraindication to CMR study. All patients received informed consent and the study was approved by our local Ethics Committee.

Two-dimensional echocardiography

Two-dimensional echocardiography was performed using a 2D phased-array probe with a commercially available system (3 MHz, Vivid E9, GE Medical Systems, Horten, Norway). LV volumes and LVEF were computed from four- and two-chamber apical views using the Simpson biplane method. Longitudinal strain (ε) was computed from high frame rate (>50 frames per cardiac cycle) apical views (four-, two-, and three-chamber) using speckle-tracking analysis (EchoPac, Version 7.0.0, GE Vingmed, Horten, Norway). From each apical view, myocardial speckles were automatically tracked frame by frame throughout the entire cardiac cycle. Regional peak-ε was defined as the minimal strain value during the cardiac cycle. Segments not adequately tracked were excluded from the analysis. Global-ε was obtained by averaging the segmental strain curves adequately tracked (16-segment model). Peak systolic mitral annulus velocity (lateral wall) was quantified in 40 patients (20 with a limited acoustic window) using TDI.

Cardiac magnetic resonance

CMR was performed with a 1.5 T system (Avanto, Siemens Medical Systems, Erlangen, Germany). Patients were positioned in the supine position with a cardiac phased-array coil (six element) placed over the chest. Retrospectively gated and breath-hold LV cine short-axis views were acquired using a steady-state free precession sequence with the following parameters: image matrix = 192 × 156 mm, FOV = 240 mm, RT = 31 ms, echo time = 1.40 ms, flip angle = 81°, slice thickness = 6 mm, no slice gap, and 25 heart phases per cardiac cycle. A stack of LV cine short axis was obtained with the first slice positioned at the LV base as to cover the mitral valve. CMR data were analysed using commercially available semi-automatic software (Argus, Siemens Medical Systems). All slices with at least 50% of the LV cavity circumference surrounded by myocardial tissue were included for analysis. LV endocardial borders for LV volumes and EF calculation were automatically traced and manually adjusted as leaving the papillary muscles and the trabeculations within the LV cavity. Regional wall motion was graded as normal, hypokinetic, akinetic, or dyskinetic from CMR apical views (four-, two-, and three-chamber) by an experienced and independent operator blinded to speckle-tracking analysis.

Statistical analysis

Continuous variables were tested for normal distribution using the Kolmogorov–Smirnov test and expressed as mean ± SD. Nominal values were expressed as percentages. Correlation of global longitudinal strain (GLS) and LVEF by 2D echocardiography with LVEF by CMR was performed by a regression analysis (Pearson) and the Bland–Altman analysis was used to assess agreement for LVEF measurement. Continuous variables were compared using t-test or variance analysis with paired comparison when required. Reproducibility was assessed in 10 randomly selected patients and expressed as the absolute difference between two paired measurements divided by their average. Two-way ANOVA was used to assess the impact of acoustic window on the association between peak-ε and regional wall motion. Statistical difference was considered as significant when P-value was <0.05. All analysis was performed using Statview (SAS Institute Inc., Version 5).
Results

Feasibility of speckle tracking and image quality
In patients with optimal IQ, all segments were analysable by speckle tracking. In patients with a suboptimal IQ ($n = 28$), $27\%$ ($121/448$) of segments were not correctly visualized ($4 \pm 3$ segments per patient). These segments were mostly located in the apical part of the LV, belonging to the lateral or anterior wall (Figure 1).

Despite a limited acoustic window, speckle-tracking analysis was feasible in $88\%$ ($n = 107$) of the 121 poorly visualized segments. Segments non-analysable by speckle tracking were more likely located in basal segments ($8/14, 57\%$).

Regional left ventricular function and image quality
In patients with a poor IQ, regional wall motion was graded from CMR apical views: 177 segments were considered as normal and 257 segments as dysfunctional (158 hypokinetic and 99 akinetic). Peak longitudinal strain by speckle tracking averaged $-17 \pm 6, -12 \pm 6$, and $-9 \pm 5$% in normal, hypokinetic, and akinetic segments, respectively. No significant difference in peak strain according to wall motion was observed between segments with and without optimal 2D echocardiography IQ (Figure 2).

Accuracy of two-dimensional left ventricular ejection fraction, global strain, and tissue Doppler imaging according to image quality
LVEF by 2D echocardiography was lower than LVEF by CMR ($49 \pm 16$ vs. $45 \pm 17\%$, $P < 0.0001$). LVEF by 2D echocardiography less correlated with LVEF by CMR in patients with a poor IQ ($r = 0.76$ vs. $0.89$; Figure 3) with the Bland–Altman analysis showing a greater bias between 2D LVEF and LVEF by CMR when acoustic window was suboptimal ($6 \pm 13$ vs. $4 \pm 7\%$, $P < 0.001$; Figure 4). In contrast, the correlation between the GLS and LVEF by CMR remained similar regardless of the IQ ($r = 0.81$ for good vs. $r = 0.82$ for poor IQ; Figure 3). However, the mean bias between LVEF derived from global strain (using regression equation) and LVEF by CMR remained greater in

Figure 3 Correlation between two-dimensional left ventricular ejection fraction and global longitudinal strain with left ventricular ejection fraction by cardiac magnetic resonance in patients with and without an optimal acoustic window.
patients with a poor IQ (Figure 4). For TDI, peak systolic annular velocity moderately correlated with LVEF by CMR ($r = 0.61$, $P = 0.004$) in patients with a poor and adequate acoustic window.

Impact of wall motion abnormalities on global left ventricular systolic function assessment

In patients with a poor IQ, the wall motion score index (WMSI) by CMR averaged $1.9 \pm 0.6$. LVEF by 2D, GLS, and systolic TDI correlated with WMSI (Figure 5). In patients exhibiting a severe wall motion abnormalities (WMSI $\geq 2$), GLS ($r = -0.74$) better correlated with LVEF by CMR than LVEF by 2D ($r = 0.56$; Figure 6).

Reproducibility

Inter-observer variability averaged $9 \pm 5$ and $24 \pm 22\%$ for 2D LVEF with and without optimal IQ, respectively. In contrast, Global-$\varepsilon$ inter-observer variability averaged $9 \pm 1$ and $8 \pm 7\%$ in patients with and without optimal IQ.

Discussion

Assessment of myocardial function plays an important role in clinical decision-making and therapeutic strategy. In daily practice, myocardial function is assessed through LVEF measurement, which is usually determined by 2D echocardiography using the
Simpson biplane model. For practical reasons, this approach appears as the current gold standard but is limited by the IQ that greatly impacts on its accuracy and reproducibility. In contrast, we demonstrate that speckle tracking appears more robust, less influenced by acoustic window with longitudinal global-ε similarly correlated with LVEF by magnetic resonance imaging (MRI) in patients with and without optimal images quality.

Despite the improvement of IQ,16,17 the assessment of myocardial function remains a challenging part of the echocardiographic examination.18 Accuracy and reproducibility of the results still depend on the IQ and operator’s experience.5 Our results clearly underline the impact of IQ on the accuracy and reproducibility of 2D LVEF assessment. Endocardial border delineation remains difficult and currently one or more apical segments of lateral or anterior wall cannot be adequately visualized in numerous patients. In daily practice, this may be overcome by extrapolating the tracing or the use of a foreshortened apical view that leads to a two-fold higher bias for LVEF measurement with a lower reproducibility. Several methods6–10 have been proposed to overcome these limitations, and so far, only tissue Doppler velocity imaging has reached a clinical application.11,12 However, TDI is limited by the Doppler signal which may be particularly noised by misalignment of the Doppler sample volume and the reduced signal–noise ratio especially in patients with severe LV enlargement and myocardial dysfunction.19,20 In addition, the accuracy of Doppler signal still requires a good IQ. As an alternative to TDI, a new non-angle-dependent image processing algorithm based on speckle-tracking analysis has recently been developed. Several studies reported that regional strain amplitude derived from speckle tracking correlates with sonomicrometry and MRI strain measurements.13,14,21 Strain curves from the 16 segments can be averaged to compute a global-ε to assess global myocardial function. The use of speckle tracking to assess LV systolic function offers the main advantage to provide a fast and simultaneous quantification of both regional and global myocardial function. Global-ε considers all segments of the myocardium compared with the Simpson biplane model (16- vs. 12-segment model) and thus may be more precise for the assessment of myocardial contractility. In addition, the quantification of myocardial contractility by speckle tracking is not based on LV volume changes measurement and thus does not rely on a geometric model unsuitable for patients with complex LV deformation. Indeed, this advantage of speckle tracking over the Simpson method has been demonstrated by Brown et al.22 who reported that in patients with more than five abnormal contractile segments, global-ε by speckle tracking correlated better with LVEF by MRI than LVEF derived from 2D echocardiography using the Simpson biplane model. However, despite 2D strain robustness, an exact linear correlation of longitudinal global-ε with LVEF by CMR should not be expected since longitudinal motion partly contributes to the LVEF value. Indeed, impaired myocardial contractility seems to first affect the endocardial layers in several cardiac diseases, explaining that longitudinal motion markers may be more sensitive and superior than LVEF in detecting early changes in myocardial contractility and predicting cardiovascular outcome.23–26

Importantly, for the first time, our study demonstrates that the assessment of global and regional LV systolic function can be extended to patients with a limited acoustic window. In these patients, a poor IQ strongly impacts on the accuracy of endocardial borders delineation that prevents an accurate assessment of LVEF. In addition, a poor acoustic window reduces the reproducibility of wall motion score and stress echocardiography assessment.27 In contrast, speckle-tracking analysis which is easy and fast to compute without requiring a specific training28 seems more robust and poorly affected by the grey-scale IQ. The consistency of longitudinal global strain regardless of the IQ may be explained by the fact that the whole stack of images is used for speckle-tracking analysis and that endocardium–blood interface is less crucial for longitudinal strain analysis. Nonetheless, a minimal grey-scale IQ is required to allow for an adequate tracking of myocardial speckle throughout the cardiac cycle.

**Limitations**

Important limitation of the study is the lack of contrast agents used to improve endocardial borders visualization. However, contrast
echocardiography requires a venous access and is not routinely performed, despite improvement accuracy provided for LV volumes and EF assessment. In the same way, 3D transthoracic echocardiogram (TTE) have demonstrated better accuracy and reproducibility than 2D TTE for LVEF assessment in comparison to accepted reference techniques including MRI. Nevertheless, IQ deeply impacts on the feasibility of 3D TTE. In addition, the use of CMR as the gold standard for EF has limitations related to the difficulty to accurately define the first basal slice and the spatial resolution of the apical region.

Conclusion

In patients with a limited acoustic window, longitudinal strain by speckle tracking remains accurate and reproducible for assessing global and regional LV systolic function.

Conflict of interest: none declared.

References


