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CLINICAL RESEARCH

Prospective comparison of speckle tracking longitudinal bidimensional strain between two vendors

Comparaison prospective de la déformation longitudinale bidimensionnelle par *speckle tracking* entre 2 vendeurs

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KEYWORDS
Echocardiography;
Global longitudinal strain;
Speckle tracking

Summary

Background. — Speckle tracking is a relatively new, largely angle-independent technique used for the evaluation of myocardial longitudinal strain (LS). However, significant differences have been reported between LS values obtained by speckle tracking with the first generation of software products.

Aims. — To compare LS values obtained with the most recently released equipment from two manufacturers.

Methods. — Systematic scanning with head-to-head acquisition with no modification of the patient's position was performed in 64 patients with equipment from two different manufacturers, with subsequent off-line post-processing for speckle tracking LS assessment (Philips QLAB 9.0 and General Electric [GE] EchoPAC BT12). The interobserver variability of each software product was tested on a randomly selected set of 20 echocardiograms from the study population.

Abbreviations: Cb, Bias correction factor; CCC, Concordance correlation coefficient; CV, Coefficient of variation; GE, General Electric; GLS, Global longitudinal strain; LOA, Limits of agreement; LS, Longitudinal strain; LV, Left ventricular.

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Results. — GE and Philips interobserver coefficients of variation (CVs) for global LS (GLS) were 6.63% and 5.87%, respectively, indicating good reproducibility. Reproducibility was very variable for regional and segmental LS values, with CVs ranging from 7.58% to 49.21% with both software products. The concordance correlation coefficient (CCC) between GLS values was high at 0.95, indicating substantial agreement between the two methods. While good agreement was observed between midwall and apical regional strains with the two software products, basal regional strains were poorly correlated. The agreement between the two software products at a segmental level was very variable; the highest correlation was obtained for the apical cap (CCC 0.90) and the poorest for basal segments (CCC range 0.31—0.56).
Conclusions. — A high level of agreement and reproducibility for global but not for basal regional or segmental LS was found with two vendor-dependent software products. This finding may help to reinforce clinical acceptance of GLS in everyday clinical practice.

MOTS CLÉS
Échocardiographie ;
Strain longitudinal global ;
Speckle tracking

Résumé

Contexte. — Le *speckle tracking* est une technique relativement nouvelle, largement indépendante de l’angle, utilisée pour l’évaluation du strain myocardique longitudinal. Toutefois, des différences significatives ont pu être mises en évidence entre les valeurs de strain longitudinal obtenues par *speckle tracking* avec les premières générations des logiciels de différents vendeurs.
Objectifs. — Comparer les valeurs de strain longitudinal obtenues avec les 2 plus récentes versions de logiciels de 2 vendeurs.
Méthodes. — Une échocardiographie sans modification de la position du patient était réalisée chez 64 patients par 2 échographes de 2 vendeurs différents pour obtention en déporté du strain longitudinal (Philips QLAB 9,0 et GE EchoPAC BT12). La variabilité interobservateur de chaque logiciel était étudiée sur un échantillon aléatoire de 20 patients issus de la population de l’étude.
Résultats. — Les coefficients de variation de GE et Philips pour le strain longitudinal global étaient de 6,63 % et 5,87 % respectivement, indiquant une bonne reproductibilité. La reproductibilité était très variable au niveau segmentaire, avec des coefficients de variation variant de 7,58 % à 49,21 % pour le strain longitudinal avec les 2 logiciels. Le coefficient de concordance pour le strain longitudinal global était haut à 0,95, ce qui indique une bonne concordance entre les 2 méthodes. Tandis qu’une bonne concordance était observée pour le strain apical et médian, les valeurs de strain régionales basales étaient peu corrélées. La concordance entre les 2 méthodes était très variable au niveau segmentaire, les meilleures corrélations étant obtenues pour l’apex (coefficient de concordance à 0,90) et les plus mauvaises étant obtenues pour les segments basaux (coefficients de concordance allant de 0,31 à 0,56).
Conclusions. — Une bonne concordance et une bonne reproductibilité sont retrouvées pour le strain longitudinal global de 2 vendeurs, mais pas au niveau régional basal ou segmentaire. Les données de cette étude pourraient aider à renforcer l’importance du strain longitudinal global en pratique clinique.

Background

Longitudinal strain (LS) describes myocardial deformation, i.e. the fractional change in length of a myocardial segment. Speckle tracking is a relatively new, largely angle-independent technique used for the evaluation of myocardial LS that has been experimentally validated against sonomicrometry [1—3]. Global LS (GLS) is the average longitudinal component of strain in the entire myocardium, which can be approximated by the averaged segmental strain components in individual myocardial wall segments [4]. Clinical studies have demonstrated the major additional diagnostic and/or prognostic contribution of GLS compared with conventional indices of left ventricular (LV) systolic function in various clinical settings, such as heart failure, valvular heart disease or cardiomyopathies [5]. However, previous reports have demonstrated significant differences between LS values obtained by speckle tracking with the first generation of software products released by various manufacturers [6,7]. Post-processing appears to be the most important determinant in intervendor variation, while acquisition appears to have only a limited effect [6]. However, speckle tracking standardization among manufacturers is essential, as clinicians must be able to interpret data generated by different devices, irrespective of the vendor [8]. The present study was therefore designed to compare GLS and segmental LS values obtained with the most recent releases from two different manufacturers. To address this issue, systematic scanning with head-to-head acquisition was performed in patients with equipment obtained from two different manufacturers (Philips and General Electric [GE]), with subsequent off-line post-processing for speckle tracking LS assessment.

Methods

Study population

Patients referred for echocardiography during a 2-week period were screened for the following characteristics: good visualization of all LV segments allowing speckle tracking and measurement of LV GLS, sinus rhythm and consent to participate. Ninety-six patients were initially screened for inclusion in the present study. Twenty-three patients were excluded for poor echogenicity, as speckle tracking was not possible in at least one LV segment. Nine patients were also excluded for suboptimal echogenicity. The final study cohort consisted of 64 patients.

Standard echocardiography and workflow

Transthoracic echocardiograms were acquired by using two commercially available ultrasound transducers and equipment (X5-1 probe, iE33, Philips, Andover, MA, USA; M5S-D probe, Vivid E9, GE Medical, Milwaukee, WI, USA), both located in the same echocardiography room. Image acquisition was performed by three experienced sonographers (S.M., A.-L.C., and F.D.). Each participant first underwent comprehensive assessment of cardiac anatomy and function with one of the ultrasound systems. The order of examination on the two machines was randomized. Acquisitions with the two systems were performed during the same echocardiographic examination, with no modification of the patient's position. Sector size and depth were adjusted to achieve optimal visualization of all LV segments at the highest possible frame rate. The same frame rate was used with the two machines. Acquisition was obtained at the end of expiration. At least three video loops of one cardiac cycle were obtained for apical views. All echocardiographic examinations were stored as raw data in a picture archiving and communicating system (PACS) for subsequent off-line analysis on dedicated Xcelera and EchoPAC workstations.

Speckle tracking strain echocardiography

QLAB software 9.0 was used for images obtained from Philips IE33 and EchoPAC BT12 software was used to analyze those obtained with the Vivid E9. The three apical views obtained on each ultrasound machine were measured with each software package to obtain peak systolic LS (%). All acquired apical views were available for off-line quantification. LS values were computed after having determined the onset of aortic valve closure using Doppler recordings or visual inspection of the kinetics of the aortic valve in long-axis views.

The automatic tracking of the endocardial contour was performed in end-systole with EchoPAC software and in end-diastole with the QLAB software. Tracking was carefully verified and the region of interest was manually corrected to ensure optimal tracking and to cover the entire thickness of the LV myocardium. Longitudinal two-dimensional speckle tracking strain values were analyzed off-line by a single investigator (A.-L.C.) blinded to the patient's identity during image post-processing. The left ventricle was divided using the 17-segment American Society of Echocardiography model to derive segmental LS values [9]. GLS was obtained as the average of regional strains. Basal regional strain was calculated as the average of basal peak strains measured in the three apical views. Midwall regional strain was calculated as the average of midwall peak strains measured in the three apical views and apical regional strain was calculated as the average of apical peak strains measured in the three apical views. Territorial strain was calculated from the perfusion territories of the three major coronary arteries in a 16-segment LV model by averaging all segmental peak systolic strain values in each territory [10]. Details of this territorial segmentation are shown in Fig. 1. Interobserver variability of each software was tested on a randomly selected set of 20 echocardiograms from the study population.

Statistical analyses

Data are presented as means ± standard deviations or absolute numbers and frequencies. Variabilities between the two software products were evaluated by the mean of the coefficient of variation for each strain measure (CV). CVs were obtained for GLS, for each view (two-, three- and four-chamber), for basal, midwall and apical ventricular segments, for each segment of the 17-segment model and for the territories of the three major coronary arteries. All strain values were compared between two software products using different methods. Pearson's correlation coefficient (*r*), which measures the extent to which each value differs from the best-fit line, is a measure of precision. The concordance correlation coefficient (CCC) was calculated as the product of *r* and the bias correction factor (Cb), which measures the extent to which the best-fit line differs from the 45° line through the origin, and is a measure of accuracy [11]. Bland-Altman plots of

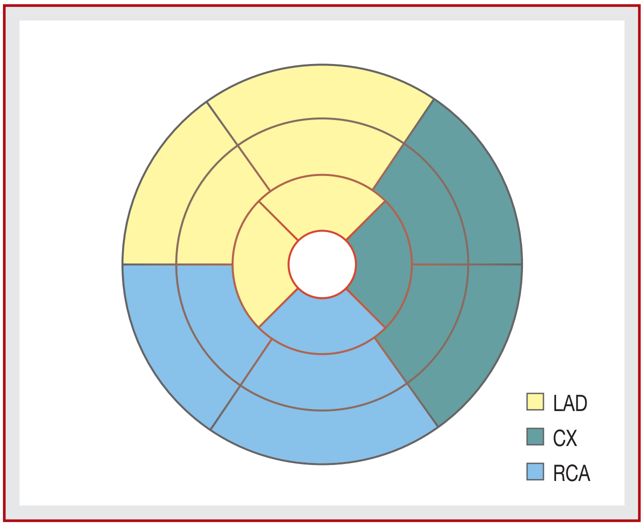

Figure 1. Territorial segmentation of the left ventricle based on the perfusion territories of the three major coronary arteries in a 16-segment left ventricular model. CX: circumflex artery; LAD: left anterior descending artery; RCA: right coronary artery.

differences between GLS values by GE and Philips and mean GLS values were obtained to detect a potential bias and to obtain limits of agreement (LOA) [12]. Statistical analyses were performed using PASW 18.0 (IBM Inc., Bois-Colombes, France) and MedCalc for Windows version 12.5.0 (MedCalc Software, Mariakerke, Belgium).

Results

Patient characteristics

The baseline characteristics of the study population are summarized in Table 1. The clinical indication for echocardiography was heart failure in 16 (25%) patients, ischemic heart disease in two (3%) patients and chest pain in eight (13%) patients. In addition, three (5%) patients had hypertrophic cardiomyopathy and 11 (17%) patients had significant valvular heart disease. Echocardiography was performed for other reasons in 17 (27%) patients (hypertension, diabetes, preoperative evaluation for non-cardiac surgery, diabetes or stroke). Among the 64 patients included in the present study, seven control subjects (11%) free of any cardiovascular disease, without any electrocardiogram abnormality and with a normal echocardiogram, were recruited from the hospital staff.

Table 1 Clinical and demographic data of the study population ($n = 64$).

Variables	
Men	38 (59)
Age (years)	62 ± 17
Body mass index (kg/m^2)	26.2 ± 5.4
Diabetes	13 (20)
Hypertension	28 (44)
Smoking	12 (20)
Dyslipidemia	25 (39)

Data are mean ± standard deviation or number (%).

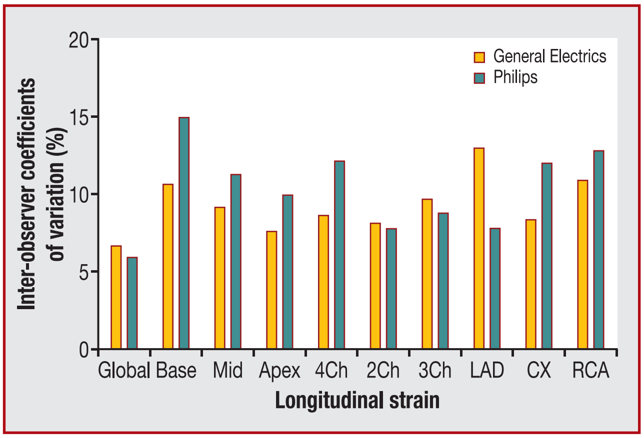

Figure 2. Interobserver coefficients of variation for longitudinal strains. 2Ch: apical two-chamber view; 3Ch: apical three-chamber view; 4Ch: apical four-chamber view; CX: circumflex artery; LAD: left anterior descending artery; RCA: right coronary artery.

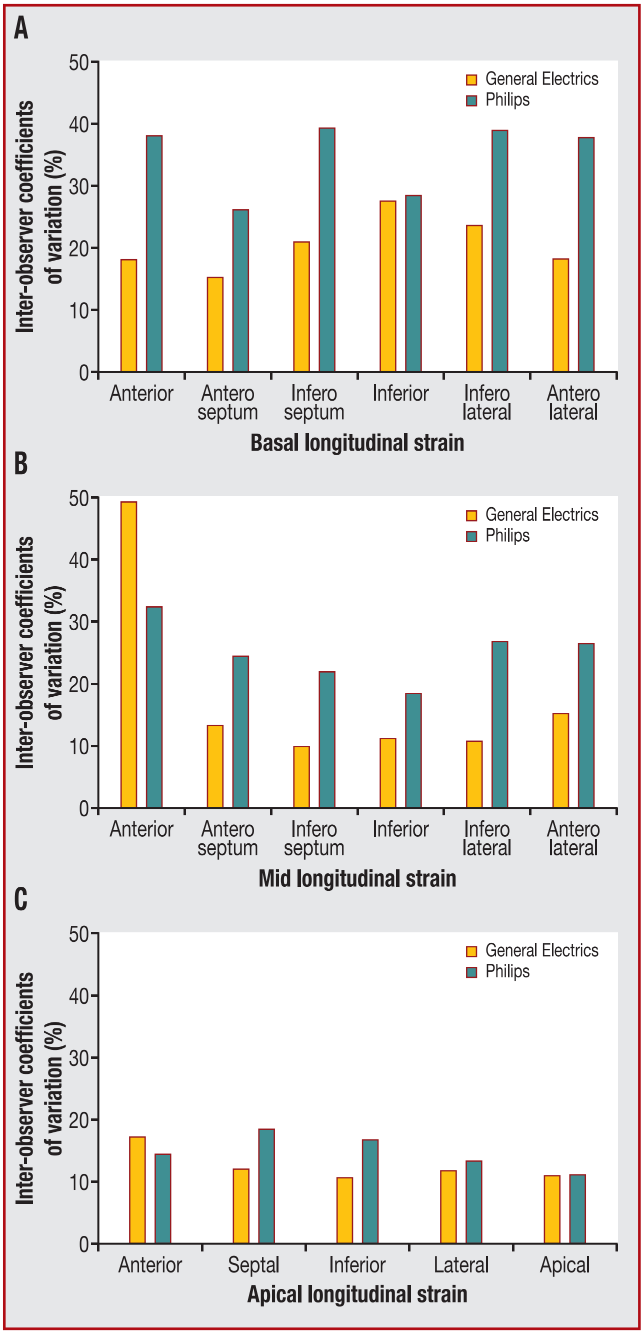

Figure 3. Interobserver coefficients of variation for (A) basal, (B) midventricular and (C) apical longitudinal strains.

Echocardiography

The mean frame rate for GE images was 62 ± 3 frames/s for apical four-chamber views, 62 ± 4 frames/s for two-chamber views and 63 ± 4 frames/s for apical long-axis views. The mean frame rate for Philips images was 61 ± 7 frames/s for apical four-chamber views, 61 ± 7 frames/s for two-chamber views and 61 ± 7 frames/s for four-chamber views. Mean LV ejection fraction was 52 ± 17%, mean LV end-diastolic volume index was 81 ± 35 mL/m^2 and mean LV end-systolic volume index was 43 ± 36 mL/m^2. LV ejection fraction was < 50% in 18 (28%) patients.

Reproducibility of longitudinal strain with each software

As shown in Fig. 2, GE and Philips interobserver CVs for GLS were 6.63% and 5.87%, respectively. Interobserver variability was substantially higher for basal strain than for midwall and apical strain, with higher CVs with the QLAB software compared with the EchoPAC software. In addition, interobserver CVs were substantially higher for each apical view with the two software products than for GLS (Fig. 2). CVs for each perfusion territory and segmental level are shown in Figs. 2 and 3, respectively.

Comparison of global longitudinal strain

The comparison of GLS values by Philips and GE is detailed in Fig. 4A. The CCC was high (0.95), indicating substantial agreement between the two methods, with minimal bias as shown by Bland-Altman plots (Fig. 4B). Data from the seven control patients showed good agreement for GLS values between the two software products for normal subjects ($r = 0.95$, $p = 0.0008$, Cb 0.88, CCC 0.84 [0.49—0.96], bias—0.84, LOA 1.08). Data from the nine patients with suboptimal echogenicity confirmed the good agreement between the two software products for GLS ($r = 0.95$, $p = 0.0002$, Cb 0.96, CCC 0.92 [0.74—0.98], bias 0.48, LOA 2.9).

Comparison of regional and territorial strains

As shown in Table 2 and Fig. 5A and B, basal strains obtained with the two software products were poorly correlated. In contrast, a good agreement was observed between midwall and apical strains with the two software products (Fig. 5C—F). The agreement between LS values was lower for each separate apical view than for GLS. LS values according to the 17-segment of the American Society of Echocardiography are depicted in Fig. 6. Comparison of LS values for each apical view with the two software products is shown in Table 3. The agreement between the two software products at a segmental level (Table 2) was very variable, with the highest correlations obtained for the apical cap (CCC 0.90), followed by the mid anteroseptum, inferoseptum, inferior walls and apical segments (all CCC $\geq$ 0.77). In contrast, poor correlations were found for basal segments with CCC values ranging from 0.31 to 0.56. Good correlations between software products were observed at a territorial level, with the highest correlation for the left anterior descending artery (CCC 0.92) followed by the right coronary artery (CCC 0.90) and the circumflex artery (CCC 0.80) (Table 3).

Discussion

The present data indicate good reproducibility between measurement of GLS using GE and Philips software products. A good agreement between GLS values was observed between the two software products. However, while midwall and apical LS values obtained with the two software products were similar, a poor agreement was found for basal LS values due to poor reproducibility. Segmental LS values obtained with the two software products were also poorly related due to poor reproducibility. In contrast, a good agreement between the two software products was observed for territorial strains, especially for the left anterior descending artery and right coronary artery territories. This study therefore supports the relevance of GLS in clinical practice.

A difference in speckle strain measurement has been previously reported between two echocardiographic machines obtained from different vendors in 50 healthy controls

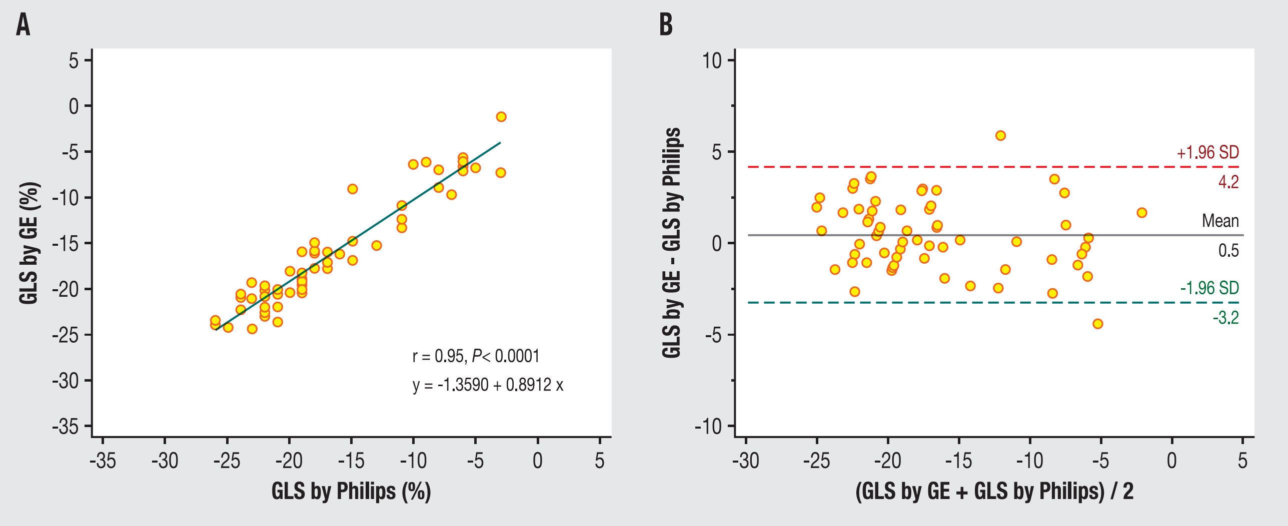

Figure 4. (A) Correlation between global longitudinal strain (GLS) by Philips and General Electric (GE): the line is the regression line; *r* is Pearson's correlation coefficient. (B) Scatterplot of the difference between GLS by Philips and GE and the mean values obtained by the two software products. SD: standard deviation.

Table 2 Comparison of segmental longitudinal strain data between EchoPAC (General Electric) and QLAB (Philips) software products.

	Pearson's ρ	*p*	Cb	CCC (95% CI)	Bland and Altman	
					Bias	LOA
Base						
Anterior	0.45	0.0002	0.90	0.40 (0.20; 0.57)	1.8	16.6
Anteroseptum	0.56	< 0.0001	0.99	0.56 (0.37; 0.71)	−0.8	12.1
Inferoseptum	0.48	0.0001	0.97	0.47 (0.26; 0.63)	−0.7	14.7
Inferior	0.33	0.0069	0.94	0.31 (0.09; 0.51)	2.7	16.8
Inferolateral	0.36	0.004	0.89	0.31 (0.10; 0.50)	4.0	20.1
Anterolateral	0.43	0.0004	0.86	0.37 (0.17; 0.54)	4.2	17.9
Mid						
Anterior	0.52	< 0.0001	0.99	0.51 (0.30; 0.67)	1.4	17.3
Anteroseptum	0.81	0.004	0.94	0.77 (0.65; 0.83)	−0.1	11.9
Inferoseptum	0.87	< 0.0001	0.97	0.85 (0.76; 0.90)	1.6	7.4
Inferior	0.86	< 0.0001	0.97	0.84 (0.76; 0.90)	−1.0	10.7
Inferolateral	0.72	< 0.0001	0.97	0.70 (0.55; 0.80)	1.5	13.8
Anterolateral	0.75	< 0.0001	1.00	0.75 (0.62; 0.84)	−0.6	11.5
Apex						
Anterior	0.79	< 0.0001	1.00	0.79 (0.67; 0.87)	−0.3	10.5
Septal	0.87	< 0.0001	0.98	0.85 (0.77; 0.90)	0.8	9.0
Inferior	0.85	< 0.0001	0.96	0.82 (0.73; 0.88)	2.3	9.3
Lateral	0.83	< 0.0001	0.98	0.81 (0.71; 0.88)	−1.4	8.8
Apical cap	0.90	< 0.0001	1.0	0.90 (0.84; 0.94)	0.1	6.5

Cb: bias correction factor; CCC: concordance correlation coefficient; CI: confidence interval; LOA: limits of agreement.

enrolled in a large multicentre study designed to define normal strain values, with a systematic overestimation of GLS values with Philips software (QLAB 7.0) compared with GE (EchoPAC 6.0) [7]. Another study by Negishi et al., using QLAB 8.0 and EchoPAC 11.0, demonstrated poor agreement for GLS values between the two software products [6]. However, use of the same vendor-independent software to measure strain in images from different vendors provided minimal bias for GLS. Post-processing and speckle tracking algorithms therefore appear to be the most important determinants in intervendor variation, while acquisition differences appear to have a limited effect [6]. Given the marked discrepancy between vendors that could compromise the widespread clinical use of speckle tracking strain, the American Society of Echocardiography and the European Association of Echocardiography have set up an expert group, comprising interested researchers and industry members, to achieve concordance concerning the details

Table 3 Comparison of longitudinal strain data between EchoPAC (General Electric) and QLAB (Philips) software products.

	Pearson's ρ	*p*	Cb	CCC (95% CI)	Bland and Altman	
					Bias	LOA
Global longitudinal strain (%)	0.95	< 0.0001	0.99	0.95 (0.91; 0.97)	0.5	3.7
Basal longitudinal strain (%)	0.68	< 0.0001	0.95	0.64 (0.48; 0.76)	1.9	9.1
Midventricular longitudinal strain (%)	0.94	< 0.0001	0.99	0.93 (0.88; 0.95)	0.5	5.4
Apical longitudinal strain (%)	0.92	< 0.0001	0.99	0.92 (0.87; 0.95)	0.3	6
Four-chamber view longitudinal strain (%)	0.87	< 0.0001	0.99	0.87 (0.80; 0.92)	0.4	6.1
Two-chamber view longitudinal strain (%)	0.89	< 0.0001	0.99	0.89 (0.82; 0.93)	0.1	5.6
Three-chamber view longitudinal strain (%)	0.90	< 0.0001	0.98	0.88 (0.82; 0.93)	1.3	5.8
LAD territorial strain (%)	0.92	< 0.0001	0.99	0.92 (0.87; 0.95)	0.5	4.8
CX territorial strain (%)	0.82	< 0.0001	0.97	0.80 (0.70; 0.87)	1.6	8.0
RCA territorial strain (%)	0.91	< 0.0001	0.99	0.90 (0.84; 0.94)	0.90	5.6

Cb: bias correction factor; CCC: concordance correlation coefficient; CI: confidence interval; CX: circumflex artery; LAD: left anterior descending artery; LOA: limits of agreement; RCA: right coronary artery.

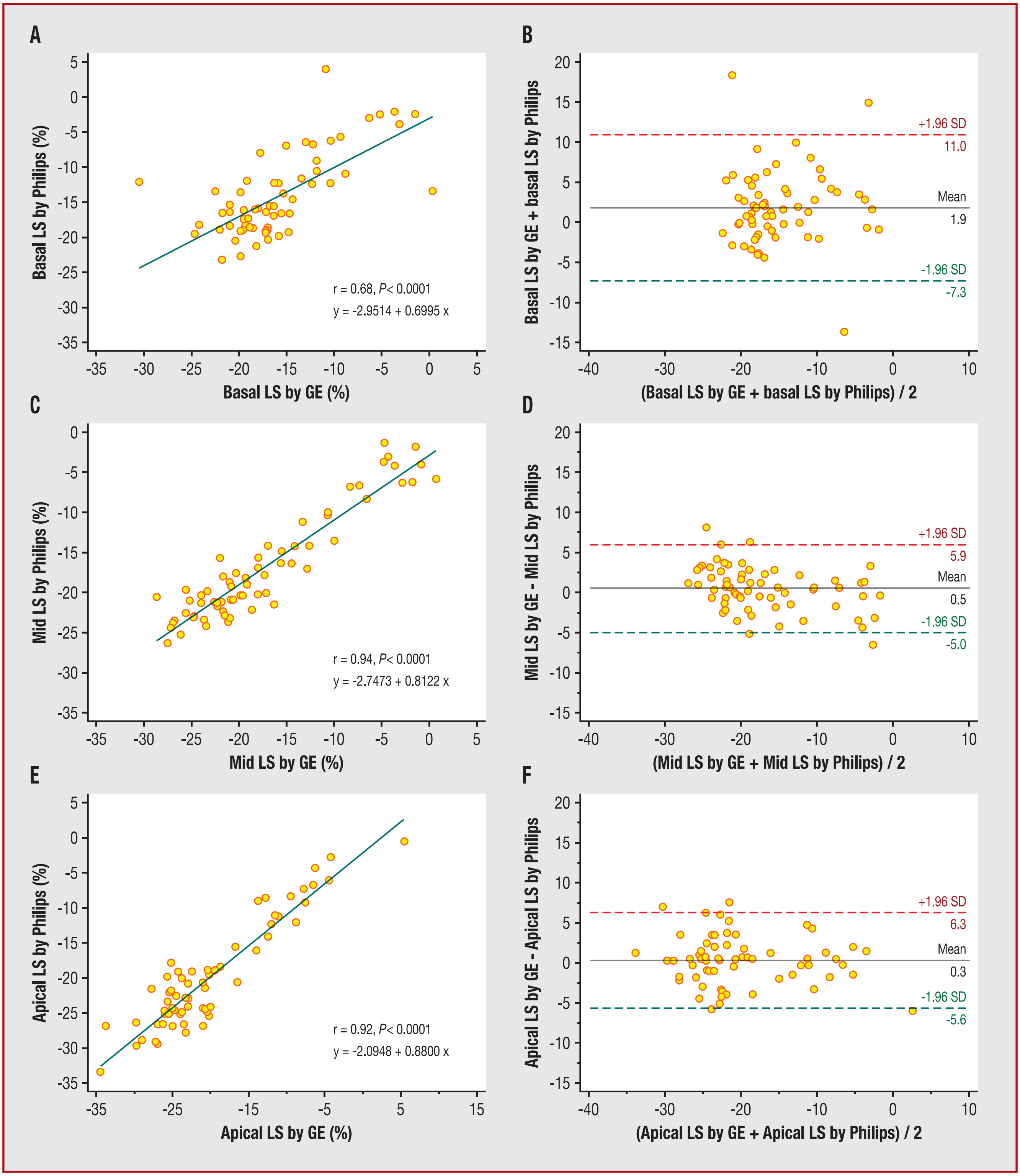

Figure 5. Correlation between (A) basal, (C) midventricular and (E) apical longitudinal strain (LS) by Philips and General Electric (GE): the line is the regression line; *r* is Pearson's correlation coefficient. Scatterplots of the differences between basal, midventricular and apical LS by Philips and GE and the mean values obtained by the two software products are presented in (B), (D) and (F), respectively. SD: standard deviation.

of what is measured by these techniques. However, in a recent meta-analysis of normal ranges of LV strain, blood pressure, but not the vendor, was associated with variations in normal GLS values [13]. In contrast with previous reports, we found a good agreement between GLS values obtained by two recent speckle tracking software products and algorithms. The apparent discrepancy between previously published results and our results could be explained

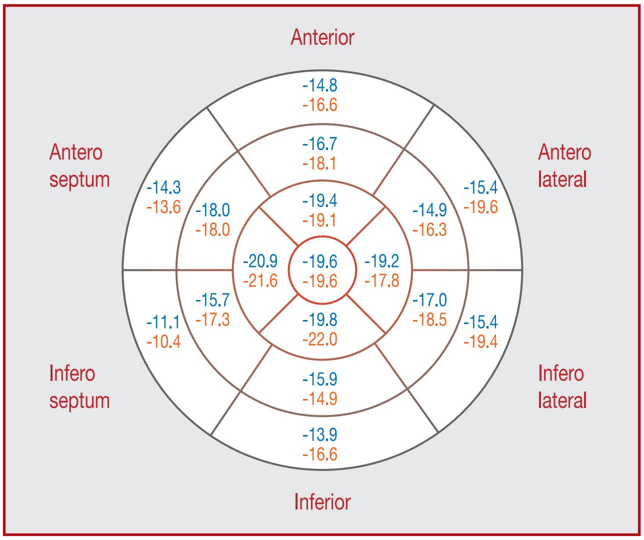

Figure 6. Mean segmental longitudinal strain values for General Electric (blue) and Philips (orange) in a 17-segment American Society of Echocardiography left ventricular model.

by differences in study design, equipment and population. Firstly, most previous reports enrolled only healthy controls. In contrast, consecutive patients referred to our echocardiography laboratory were screened for enrolment in the present study. In addition, both echocardiograms were performed with the patient lying in the same position in the same room, which may have limited blood pressure variations that can induce a potential bias between both echocardiograms using different software products [13]. Lastly, the most recent releases of vendor-specific software products were used in the present study, with substantial changes in tracking algorithms compared with the previous releases used in previously published studies [6,7].

The reproducibility of GLS is in agreement with previous reports [14]. CVs were lower using the 17-segment model than when using a single apical plane, resulting in decreased variation in GLS arising from averaging due to the number of segments measured. Similarly, we found poor reproducibility between segmental values of strain and poor correlation between the two vendor-dependent software products. The lowest interobserver variability was found for septal walls, while the highest variability was observed for strain of LV free walls, resulting in poor correlation between software products for these walls. From a technical viewpoint, the beam width is important, as the system displays all targets within the path of the beam along a single line represented by the central axis of the beam. In other words, the echocardiogram displays structures within the image as if the beam were infinitely narrow. Lateral resolution therefore decreases as beam width increases. Hence, the acoustic field is more uniform in the septum and the inferior walls than in the anterolateral, anterior and posterolateral walls. Secondly, interference by an overlying lung is more prominent in the lateral walls. Thirdly, the three septal segments move in a similar direction, parallel to the ultrasound beam, and may be easier to track than the posterior wall, which presents more movement across the scan line.

Clinical implications

Basal strain was less reproducible and poor agreement was observed between the two software products in the present study, as, in apical views, basal segments of the myocardium are situated in the far field or the ultrasound beam. A possible explanation for this finding may be that focusing of the transmitted beam tends to improve imaging in the near field, but increases the rate or angle of divergence in the far field. The ultrasound beam has a finite width, even in the near field, and tends to diverge as it propagates.

Most studies have demonstrated the clinical relevance of speckle tracking GLS in various clinical settings [15]. In 546 consecutive individuals, GLS was a superior predictor of outcome than either LV ejection fraction or wall motion score index. GLS provides independent prognostic information compared with LV ejection fraction in patients with heart failure and LV systolic dysfunction [16]. The combination of LS and wall motion score index provides a significant incremental increase in diagnostic accuracy for coronary artery disease [17]. Impaired GLS is associated with outcomes in patients with valvular heart disease, such as organic mitral regurgitation [18] and severe asymptomatic aortic stenosis [19]. GLS identifies subclinical disease in patients with diabetes or cardiomyopathies [20,21]. In addition, GLS is an independent early predictor of subsequent reductions in LV ejection fraction, incremental to usual predictors in patients at risk for trastuzumab-induced cardiotoxicity [22]. The finding that good reproducibility and good agreement are achieved between two major vendors for GLS reinforces the wide acceptance of GLS in clinical practice.

Interestingly, GLS was found to be more reproducible at a territorial level than at a segmental level, as a result of averaging over segments. Territorial LS was predictive of coronary occlusion in patients with non-ST-segment elevation myocardial infarction but with lower accuracy than circumferential strain [10]. Recently, the assessment of layer-specific strain by longitudinal territorial two-dimensional speckle tracking echocardiography identified non-ST-segment elevation acute coronary syndrome patients with significant coronary artery disease [23]. Endocardial function was more severely affected in patients with significant coronary artery disease compared with epicardial function and LV ejection fraction. Further studies are needed to confirm the clinical importance of longitudinal territorial strain in the detection of coronary artery disease.

Study limitations

The small number of patients may limit the clinical implications of the present study. Echocardiograms were performed and analyzed by cardiologists with extensive experience in echocardiography and speckle tracking strain analysis. The results of the present study may therefore not reflect those of clinical practice. Strains from short-axis views were not assessed, as radial strain cannot be obtained with Philips QLAB 9.0 software. Only two vendor-specific speckle tracking software products were tested in the present study. Despite these limitations, the high level of agreement and reproducibility for GLS with two vendor-dependent software products may help to reinforce the clinical acceptance of GLS in everyday clinical practice.

Conclusions

A high level of agreement and reproducibility for global but not for regional basal or segmental LS was found with two vendor-dependent software products. The present finding may help to reinforce the clinical acceptance of GLS in everyday clinical practice.

Disclosure of interest

Prof. Sylvestre Maréchaux has received grants or consulting fees from GE Healthcare and Philips Healthcare.

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