Κλινικές εφαρμογές του Speckle Tracking

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ΠΑΝΕΠΙΣΤΗΜΙΟ ΑΘΗΝΩΝ
ΝΟΣΟΚΟΜΕΙΟ ΑΤΤΙΚΟΝ
Επιμήκης (Longitudinal)

Κυκλοτερής (Circumferential)

Ακτινική (Radial)
Speckle tracking
Speckle tracking

Normal values:

- Longitudinal strain >18 %
- Longitudinal strain rate > 1.1/s.
- Radial strain > 44%
- Radial strain rate > 2.43/s
- Reduced with older age
Η Ελικοειδής παραμόρφωση

Στροφική κίνηση κορυφής
(αντιωρολογιακή φορά)

Στροφική κίνηση βάσης
(ορολογιακή φορά)
ΚΛΙΝΙΚΕΣ ΕΦΑΡΜΟΓΕΣ
SPECKLE TRACKING

- Μυοκαρδιοπάθειες
- Στεφανιαία νόσος
  - Μεγέθος OEM
  - Πρόγνωση μετά OEM
  - Βιωσιμότητα
  - Πρόβλεψη αρρυθμιολογικού κινδύνου

- Μυοκαρδίτιδα
- Απεικόνιση μυοκαρδιακής ινώσης - Ανίχνευση υποκλινικής δυσλειτουργίας της ΑΡ κοιλίας
  - Χημειοθεραπεία, ΑΥ, ΣΔ
- Καρδιακή ανεπάρκεια (HFLEF, HFP EF)
- Βαλβιδοπάθειες
  - Μελέτη ΔΕ κοιλίας
Example of impaired segmental strain measured by speckle tracking in the apical long-axis view in a mutation carrier without HCM phenotype expression.

http://www.plosone.org/article/info:doi/10.1371/journal.pone.0036115
Segmental strain measured by speckle tracking of the basal anteroseptal and posterior walls in each group:

- controls,
- mutation carriers without phenotype expression (Mut+/Phen−) N=46
- mutation carrier with phenotype expression (Mut+/Phen+). N=47

http://www.plosone.org/article/info:doi/10.1371/journal.pone.0036115
Association of GLS with fibrosis in HCM
HCM- FH sudden death
Restrictive
79 y HF
Cardiomyopathy

AL amyloid
Amyloidosis
Differential diagnosis: LongS<-10%, LongSR<-1.1l/s
Global strain: normal, AMI and HF

GLPSS Avg (%)

<table>
<thead>
<tr>
<th></th>
<th>HF</th>
<th>AMI</th>
<th>Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td>GLPSS Avg</td>
<td>-7.3 ± 3%</td>
<td>-13.8 ± 3.3%</td>
<td>-19.1 ± 3.1%</td>
</tr>
</tbody>
</table>

P<0.001
Το επίμηκες strain (-4%) είναι ο δείκτης απουσίας βιωσιμότητας μετά OEM

Migrino R Am J Cardiol 2009;104:1023–1029
Longitudinal and Circumferential Strain Rate is related with LV Remodeling, and Prognosis after AMI during 20-month f/up: VALIANT Investigators

J Am Coll Cardiol 2010;56:1812–22
Early Echocardiographic Deformation Analysis for the Prediction of Sudden Cardiac Death and Life-Threatening Arrhythmias After AMI

GLS $> -12\%$

GLS $< -15.5\%$

MD $> 61.5\text{ms}$

MD $< 49\text{ms}$

Ersbøll J Am Coll Cardiol Img 2013;6:851–60
Independent and additive prognostic value of radial strain at rest and ΔGLS post dobutamine in ADHF during 4y f/u
DSE: 3-Chamber

PATIENT WITH ALCOHOL ABUSE AND 2VESSEL CAD
ΔΙΑΚΟΠΗ ΑΛΚΟΟΛ ΦΑΡΜΑΚΕΥΤΙΚΗ ΑΓΩΓΗ

F/U1
ΤΙΜΕΣ LGS < -5%
ΑΝΤΙΣΤΟΙΧΟΥΝ ΣΕ ΟΥΛΗ
(>75% ΙΝΩΣΗ ΣΕ MRI)
Layer-Specific Quantification of Myocardial Deformation by Strain Echocardiography May Reveal Significant CAD in Patients With Non-ST-Segment Elevation Acute Coronary Syndrome.

![Graph showing Receiver-Operating Characteristic (ROC) curves for various myocardial deformation parameters.](image)

### Table: Receiver-Operating Characteristic (ROC) Analyses of TLS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>AUC</th>
<th>95% CI</th>
<th>Optimal cutoff</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
<th>PPV (%)</th>
<th>NPV (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Troponin T (ng/l)</td>
<td>0.83</td>
<td>0.72-0.93</td>
<td>8</td>
<td>64</td>
<td>94</td>
<td>66</td>
<td>82</td>
</tr>
<tr>
<td>EF (%)</td>
<td>0.63</td>
<td>0.50-0.76</td>
<td>82</td>
<td>61</td>
<td>61</td>
<td>73</td>
<td>47</td>
</tr>
<tr>
<td>WMSI</td>
<td>0.74</td>
<td>0.62-0.85</td>
<td>1.07</td>
<td>70</td>
<td>73</td>
<td>63</td>
<td>86</td>
</tr>
<tr>
<td>Endocardial TLS (%)</td>
<td>0.91</td>
<td>0.84-0.97</td>
<td>-16.4</td>
<td>89</td>
<td>81</td>
<td>73</td>
<td>90</td>
</tr>
<tr>
<td>Mid-myocardial TLS (%)</td>
<td>0.91</td>
<td>0.86-0.96</td>
<td>-14.7</td>
<td>82</td>
<td>88</td>
<td>79</td>
<td>89</td>
</tr>
<tr>
<td>Epicardial TLS (%)</td>
<td>0.79</td>
<td>0.68-0.90</td>
<td>-12.6</td>
<td>78</td>
<td>69</td>
<td>58</td>
<td>85</td>
</tr>
</tbody>
</table>

*Figure 3. ROC Analyses of TLS*

Receiver-operating characteristic (ROC) curve analyses for the ability of troponin T, ejection fraction (EF), wall motion score index (WMSI), and territorial longitudinal strain (TLS) parameters to identify patients with significant coronary artery disease. The analyses include all study participants (N = 77). AUC = area under the curve; PPV = positive predictive value; NPV = negative predictive value.

*J Am Coll Cardiol Img 2013;6:535–44*
In patients with acute myocarditis, evidence of subepicardial damage and no wall motion abnormalities, longitudinal deformation is diffusely impaired, whereas circumferential is regionally sited in the areas of subepicardial damage.

**Table 3.** Longitudinal, Circumferential and Radial Strain in Segments Without DE (No DE), With DE Transmural Extent of 1-25% (DE 1-25%) and With DE Transmural Extent >25% (DE>25%)

<table>
<thead>
<tr>
<th></th>
<th>No DE</th>
<th>DE 1-25%</th>
<th>DE &gt;25%</th>
<th>P value</th>
<th>P value*</th>
<th>P value**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longitudinal strain (%)</td>
<td>-23±6</td>
<td>-20±4</td>
<td>-19±4</td>
<td>0.04</td>
<td>0.001</td>
<td>NS</td>
</tr>
<tr>
<td>Circumferential strain (%)</td>
<td>-27±7</td>
<td>-28±3</td>
<td>-24±6</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Radial strain (%)</td>
<td>32±10</td>
<td>39±12</td>
<td>34±14</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>
Admission

MYOCARDITIS DD FROM AMI

2 months
2 months

admission
DCM – RIGID BODY ROTATION
Adverse prognosis
Subclinical LV dysfunction in asymptomatic diabetic patients assessed by 2D ST: correlation with diabetes duration

In addition to diastolic dysfunction,
- Longitudinal strain was significantly lower in diabetic patients compared with control subjects.
- The decrease in LS correlated with duration of diabetes.
- Subclinical LV longitudinal dysfunction is frequently observed in asymptomatic diabetes patients with normal LVEF.

Table 2. Results of longitudinal strain, Doppler diastolic indices and perfused boundary region (PBR) of the sublingual arterial microvessels before (time = 0) and after (time = 120min) the OGTT.

<table>
<thead>
<tr>
<th>Time, min</th>
<th>Normglycaemic subjects (n=20)</th>
<th>First degree relatives (n=40)</th>
<th>Dysglycaemic subjects (n=40)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GLS, %</td>
<td>ENDO LS, %</td>
<td>MID LS, %</td>
</tr>
<tr>
<td>0</td>
<td>-19.2±2.1</td>
<td>-20.1±3.4</td>
<td>-16.8±2.8</td>
</tr>
<tr>
<td>120</td>
<td>-19.2±2.4</td>
<td>-20.4±4.5</td>
<td>-19.0±4.2</td>
</tr>
<tr>
<td></td>
<td>-18.4±2.6*</td>
<td>-19.0±4.2*</td>
<td>-19.6±2.3*</td>
</tr>
<tr>
<td></td>
<td>-17.6±2.3*</td>
<td>-17.9±4.1*</td>
<td>-16.8±2.0*</td>
</tr>
<tr>
<td></td>
<td>-16.2±1.4*</td>
<td>-15.9±2.9*</td>
<td>-15.9±3.0*</td>
</tr>
<tr>
<td></td>
<td>ENDO LS, %</td>
<td>MID LS, %</td>
<td>EPI LS, %</td>
</tr>
<tr>
<td>0</td>
<td>-14.2±2.4</td>
<td>-14.7±3.4</td>
<td>-14.6±2.9</td>
</tr>
<tr>
<td>120</td>
<td>-14.7±3.4</td>
<td>-15.4±3.6*</td>
<td>-13.2±3.2*</td>
</tr>
<tr>
<td></td>
<td>-14.6±2.9</td>
<td>-15.2±2.6*</td>
<td>-13.1±2.4*</td>
</tr>
<tr>
<td></td>
<td>-13.1±2.4*</td>
<td>-14.0±2.6*</td>
<td>-12.1±2.2*</td>
</tr>
<tr>
<td></td>
<td>E/A</td>
<td>E' (cm/sec)</td>
<td>E/E'</td>
</tr>
<tr>
<td>0</td>
<td>1.2±0.1</td>
<td>14±3</td>
<td>5.5±1.7</td>
</tr>
<tr>
<td>120</td>
<td>1.3±0.2</td>
<td>14±4</td>
<td>5.7±1.8</td>
</tr>
<tr>
<td></td>
<td>1.2±0.2</td>
<td>14±3</td>
<td>5.7±2.2</td>
</tr>
<tr>
<td></td>
<td>1.1±0.3</td>
<td>12±4</td>
<td>5.8±1.9</td>
</tr>
<tr>
<td></td>
<td>1.0±0.2</td>
<td>12±3</td>
<td>5.8±1.5</td>
</tr>
<tr>
<td>PBR 20-25, μm</td>
<td>2.4±0.3</td>
<td>2.3±0.3</td>
<td>2.5±0.5*</td>
</tr>
<tr>
<td></td>
<td>2.7±0.4*</td>
<td>2.5±0.6*</td>
<td>2.6±0.4*</td>
</tr>
</tbody>
</table>

Data are presented as mean±SD values. GLS: Global longitudinal strain; ENDO LS: Subendocardial longitudinal strain; MID LS: Mid - myocardial longitudinal strain; EPI LS: Subepicardial longitudinal strain; PBR 20-25μm: perfused boundary region of the sublingual arterial microvessels ranged from 20-25μm. ANOVA for paired comparisons using post-hoc analysis with Bonferroni correction. The model was adjusted for age, sex, smoking,

GLS greater than -18% of subendocardial LS greater than -19.5% and pTw less than 16 deg differentiated FDR with LV dysfunction from normal controls with sens 70% spec 75%
Association of post-prandial glucose with LV deformation in first degree relatives of DM

Ikonomidis I et al Int J Cardiol 2017
Incremental Value of Deformation Indices for Predicting Subsequent Reduction in EF>10% at 1 year post chemotherapy

ΔGLS>11% at 6m
ΔGLS>10% at 3m*

Impaired systolic function GLS, GCS despite preserved global LVEF in HFpEF

Prognostic value of GLS in HEPEF: KaReN study
Diastolic suction

Control

Hypertensive

Δ1: 33%
Δ2: 79%

Δ1: 26%
Δ2: 64%

MVO
EDF

Ikonomidis I et Eur J J Heart Fail 2015
Exercise capacity in hypertensives

A reverse association between PWV and VO2PEAK was revealed in hypertensives with delayed BPRR

Increased LV untwisting rate was associated with increased NT-proBNP and reduced VO2 peak

Triantafyllidi H, Ikonomidis I Blood Pressure Monit, 2013

Ikonomidis I, Eur J Heart Failure 2015
Ikonomidis et al. Circulation Cardiovascular Imaging 2015
Atrial deformation a sensitive marker of Diastolic Dysfunction
RA/LA Contractile phase strain = 0
LA Deformation Predicts Eventful Course

Atrial fibrillation

Paraskevaidis I, Ikonomidis I et al,. Am Heart J 2009;158:444
Key Points

1. LV global longitudinal diastolic strain rate measurements during the isovolumic relaxation period and during early diastole by STE have a significant association with the time constant of LV relaxation (τ). These parameters have been used in conjunction with mitral E velocity to estimate LV filling pressures and to predict outcome in several disease states.

2. The timing of peak untwisting rate can be of value in diagnosing patients with diastolic dysfunction and normal LV volumes and EF. In the latter group of patients, delayed peak of LV untwisting rate is often present.

3. An inverse correlation is present between LA systolic strain and mean wedge pressure. Although promising, there are technical limitations, and experience is essential.
### Table 3. Association Between Echocardiography and Outcome

<table>
<thead>
<tr>
<th>Baseline Measurement</th>
<th>Outcome During Conservative Management (n = 33)</th>
<th>Outcome After Surgery (n = 29)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Stable (n = 25)</td>
<td>Progression (n = 8)</td>
</tr>
<tr>
<td>Conventional echocardiography</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LV EF (%)</td>
<td>58.7 ± 5.4</td>
<td>57.6 ± 3.6</td>
</tr>
<tr>
<td>LVEDVI (ml/m²)</td>
<td>58.9 ± 16.4</td>
<td>64.9 ± 21.1</td>
</tr>
<tr>
<td>LV ESVI (ml/m²)</td>
<td>24.2 ± 7.1</td>
<td>27.8 ± 10.2</td>
</tr>
<tr>
<td>Speckle tracking</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\kappa_{np}$ (%)</td>
<td>-19.0 ± 2.6</td>
<td>-16.3 ± 3.3</td>
</tr>
<tr>
<td>SR_{np} (s^{-1})</td>
<td>-1.19 ± 0.17</td>
<td>-1.04 ± 0.14</td>
</tr>
<tr>
<td>SR_{Iso} (s^{-1})</td>
<td>1.60 ± 0.30</td>
<td>1.20 ± 0.34</td>
</tr>
<tr>
<td>Tissue Doppler</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$L_{Dys}$ (mm)</td>
<td>11.2 ± 1.8</td>
<td>10.7 ± 2.1</td>
</tr>
<tr>
<td>s’ (cm/s)</td>
<td>6.0 ± 1.1</td>
<td>5.5 ± 0.6</td>
</tr>
<tr>
<td>e’ (cm/s)</td>
<td>-6.5 ± 2.1</td>
<td>-5.9 ± 1.8</td>
</tr>
</tbody>
</table>

Data are expressed as mean ± SD.

CI = confidence interval; OR = odds ratio associated with 1 SD of worsening in predictive measure; other abbreviations as in Table 2.
**GLS predicts LV dysfunction after mitral valve repair**

A GLS of -19.9 is an independent predictor of long-term LV dysfunction after adjustment for parameters currently implemented into guidelines.

**Table 4** Predictors of LV dysfunction (LVEF <50%) at long-term follow-up after mitral valve corrective surgery: univariate and multi-variate logistic regression analysis

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Univariate analysis</th>
<th>Multivariate analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( \chi^2 )</td>
<td>Odds ratio</td>
</tr>
<tr>
<td>Atrial fibrillation</td>
<td>4.2</td>
<td>2.29</td>
</tr>
<tr>
<td>Presence of symptoms</td>
<td>5.18</td>
<td>2.91</td>
</tr>
<tr>
<td>LV ejection fraction ( \leq 60% )</td>
<td>19.9</td>
<td>6.61</td>
</tr>
<tr>
<td>LV end-systolic diameter ( &gt; 40 \text{ mm} )</td>
<td>21.6</td>
<td>9.38</td>
</tr>
<tr>
<td>LV global longitudinal strain ( &gt; -19.9 % )</td>
<td>48.9</td>
<td>24.11</td>
</tr>
</tbody>
</table>

**Area under curve:** 0.88 (95% CI 0.83–0.93), \( p < 0.001 \)

**Cut-off value** LV GLS 19.9% predicts long-term postoperative LV dysfunction sensitivity 90% specificity 79%
GLS is a strong independent predictor of all-cause mortality in patients with AOS pEF

- **GLS detects subclinical dysfunction** and has incremental prognostic value over traditional risk markers
  - including haemodynamic severity, symptom class, and LVEF in patients with AS.
- Independent predictor of all-cause mortality (HR: 1.38, P=0.001)
- Incorporation of GLS into risk models may improve the identification of the optimal timing for AV replacement.

*European Heart Journal – Cardiovascular Imaging 2012;13:827–833*
Amyloid RV infiltration
Prognostic Value of RV Longitudinal Peak Systolic Strain in Patients With PH

- 142 PH patients (37% PAH)
- 2.6y f-up
- Death 37

In patients with PH, RV LPSS is significantly associated with all-cause mortality. RV LPSS may be a valuable parameter for risk stratification of these patients.

RVGLS Provides Prognostic Value Incremental to LVEF in Patients with HF

RV strain < -14.8% predicted adverse events after adjustment for age, LVEF, RV S, E/Ee septal, and right atrial volume index.
Worse RV strain provides prognostic value incremental to LV function.

Increased benefit of IL-1 inhibition in RA-CAD (EF=45%)

Ikonomidis I Lekakis J. Circulation Cardiovasc Imaging 2014
IMPAIRED LONGITUDINAL DEFORMATION IN PSORIASIS – IMPROVEMENT AFTER IL12/23 INHIBITION

Ikonomidis I,Makavos Canadian Journal of Cardiology 2015 Circ Cardiovasc Imag 2017
Percentage changes in NYHA and BNP levels 48 hours after levosimendan infusion in CR+ versus CR- ADHF patients as assessed by changes in longitudinal strain rate using speckle tracking imaging.

Paraskevaidis J, Ikonomidis I, Parissis J, Kremastinos DT

Am J Cardiol 2008;102:1225–1229.
LV-RV function ASE/EACVI

Table 1 Continued

<table>
<thead>
<tr>
<th>Parameter and method</th>
<th>Technique</th>
<th>Advantages</th>
<th>Limitations</th>
</tr>
</thead>
</table>
| Echocardiographic imaging | 3D data sets | • No geometrical assumption  
• Unaffected by foreshortening  
• More accurate and reproducible compared to other imaging modalities | • Lower temporal resolution  
• Less published data on normal values  
• Image quality dependent |

Global longitudinal strain
Peak value of 2D-longitudinal speckle tracking derived strain (%).

Table 9 Continued

<table>
<thead>
<tr>
<th>Echocardiographic imaging</th>
<th>RV longitudinal systolic function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technique</td>
<td>TAPSE</td>
</tr>
<tr>
<td>Advantages</td>
<td>Peak systolic velocity of tricuspid annulus by pulsed-wave DTI (cm/s), obtained from the apical approach, in the view that achieves parallel alignment of Doppler beam with RV free wall longitudinal excursion</td>
</tr>
</tbody>
</table>
| Limitations              | Easy to perform  
• Reproducible  
• Validated against radial outflow EF  
• Established prognostic value |

Recommendations for Cardiac Chamber Quantification by Echocardiography in Adults

- Tricuspid annulus longitudinal excursion by M-mode (mm), measured between end-diastolic and peak systole
- Proper alignment of M-mode cursor with the direction of RV longitudinal excursion should be achieved from the apical approach.
- Pulsed tissue Doppler S wave
- Color tissue Doppler S wave

- Peak systolic velocity of tricuspid annulus by color DTI (cm/s) after image acquisition
- Allows multiple sampling on the same beat
- Easy to perform  
• Reproducible  
• Validated against radial outflow EF  
• Established prognostic value |

GLS
Peak value of 2D longitudinal speckle tracking derived strain, averaged over the three segments of the RV free wall in RV-focused apical four-chamber view (%)

- Peak value of 2D longitudinal speckle tracking derived strain, averaged over the three segments of the RV free wall in RV-focused apical four-chamber view (%)
- Angle independent  
• Established prognostic value |

- GLS
- GLS
- GLS

ECHO, End-diastolic area, EOA, end-systolic area, EF, ejection fraction, GLS, global longitudinal strain, IVC, inferior vena cava; WT, wall thickness; TID, tricuspid valve closure-to-open time.
Συμπεράσματα

Η μέτρηση του 2D strain είναι ιδιαίτερα χρήσιμη

- Εκτίμηση παρουσίας μυοκαρδιακής ουλής και τμηματικών διαταραχών κινητικότητας σε ασθενείς με στεφανιαία νόσο
- Διαφορική Διάγνωση μυοκαρδιοπάθειας από αθλητική καρδιά
- Διάγνωση καρδιακής ανεπάρκειας με διατηρημένο κλάσμα εξώθησης
- Διαστρωμάτωση κίνδυνου σε ασθενείς με οξύ έμφραγμα του μυοκαρδίου, μυοκαρδιοπαθειες, βαλβιδοπαθειες
- Παρακολούθηση ασθενών σε χημειοθεραπευτικα σχήματα για την έγκαιρη διάγνωση καρδιοτοξικοτητας
- Έλεγχος αποτελεσματικότητας θεραπευτικών παρεμβάσεων σε ασθενείς με υπέρταση και καρδιακή ανεπάρκεια και συστηματικές νόσους
- Έλεγχος λειτουργικότητας δεξιάς κοιλιας σε ασθενείς με πνευμονική υπέρταση και αριστερή καρδιακή ανεπάρκεια
ΕΥΧΑΡΙΣΤΩ ΓΙΑ ΤΗΝ ΠΡΟΣΟΧΗ ΣΑΣ!
<table>
<thead>
<tr>
<th></th>
<th>Liraglutide (n=30)</th>
<th>Metformin (n=30)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Time, months</strong></td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td><strong>GLS, %</strong></td>
<td>-15.4±3</td>
<td>-16.6±2.7*</td>
</tr>
<tr>
<td><strong>GLSR, 1/sec</strong></td>
<td>0.77±0.2</td>
<td>0.89±0.2*</td>
</tr>
<tr>
<td><strong>pTw, deg</strong></td>
<td>15.5±4</td>
<td>13.2±6*</td>
</tr>
<tr>
<td><strong>Utw velocity, deg/sec</strong></td>
<td>-97±49</td>
<td>-112±52*</td>
</tr>
<tr>
<td><strong>%dpTw-Utw_{MVO}</strong></td>
<td>31±10</td>
<td>40±14*</td>
</tr>
<tr>
<td><strong>%dpTw-Utw_{PEF}</strong></td>
<td>43±19</td>
<td>53±22*</td>
</tr>
<tr>
<td><strong>E/A</strong></td>
<td>0.92±0.2</td>
<td>0.98±0.3</td>
</tr>
<tr>
<td><strong>E/E'</strong></td>
<td>7.0±2.3</td>
<td>7.2±2.4</td>
</tr>
</tbody>
</table>

Effect of treatment with GLP-1 RA liraglutide versus treatment with metformin
Trends of GLS in three different chemo regimens, with or without beta-blocker

European Heart Journal – Cardiovascular Imaging (2014) 15, 324–331
Trends of EF in three different chemo regimens, with or without beta-blockers
Early detection of subclinical LV dysfunction after chemotherapy using GLS

* The data supporting the initiation of cardioprotection for the treatment of subclinical LV dysfunction is limited.

**Figure 9** Bullseye plot showing GLS of the patient shown in Figure 8. (A) GLS and regional longitudinal strain at baseline. (B) GLS and regional longitudinal strain 3 months during trastuzumab-based therapy after anthracyclines. GLS has decreased from $-20.6\%$ to $-14.4\%$ (30% decrease). The decrease in GLS is therefore considered of clinical significance (>15% vs baseline).
3D-STRAIN
3D speckle tracking allows the quantification of 2 new 3-dimensional indexes:

- **3-dimensional strain** obtained by the sum of radial, circumferential, and longitudinal vectors
- **area strain** that assesses endocardial area changes.

ED end diastole; ES end systole; L length; L₀ initial length; Lᵣ radial length.

**Am J Cardiol 2012;109:180 –186**
Longitudinal strain by 3D, but not by 2D, differentiated non transmural segments with scar <25%. 

Am J Cardiol 2012;109:180–186
Normal reference values of LV strain using 3-D speckle tracking echocardiography: results from a multicentre study

| Table I Normal values of echocardiographic variables for all healthy subjects and stratified according to gender |
|--------------------------------------------------|---------------------------------|-----------------|-----------------|-----------------|
| Variable                                         | All (n = 303)                   | Men (n = 156)   | Women (n = 147) | P-value (gender) |
| Volumetric                                       |                                 |                 |                 |                 |
| EDV (mL)                                         | 110 ± 20                        | 118 ± 22        | 103 ± 15        | <0.001          |
| ESV (mL)                                         | 44 ± 10                         | 47 ± 11         | 40 ± 8          | <0.001          |
| SV (mL)                                          | 67 ± 11                         | 71 ± 12         | 63 ± 9          | <0.001          |
| EF (%)                                           | 61 ± 3                          | 60 ± 3          | 61 ± 3          | 0.02            |
| Mass (g)                                         | 118 ± 19                        | 125 ± 19        | 109 ± 16        | <0.001          |
| Global strain                                    |                                 |                 |                 |                 |
| Radial (%)                                       | 35.6 ± 10.3                     | 35.2 ± 9.5      | 35.9 ± 11.0     | 0.58            |
| Circumferential (%)                              | −30.6 ± 2.6                     | −30.5 ± 2.5     | −30.6 ± 2.7     | 0.63            |
| Longitudinal (%)                                 | −15.9 ± 2.4                     | −15.5 ± 2.4     | −16.3 ± 2.3     | 0.003           |
| Area (%)                                         | −42.0 ± 2.4                     | −41.7 ± 2.5     | −42.4 ± 2.2     | 0.01            |
| Segmental strain                                 |                                 |                 |                 |                 |
| Radial (%)                                       | 35.4 ± 17.5                     | 35.1 ± 17.1     | 35.7 ± 17.9     | 0.31            |
| Circumferential (%)                              | −30.5 ± 6.0                     | −30.5 ± 5.9     | −30.6 ± 6.1     | 0.63            |
| Longitudinal (%)                                 | −15.9 ± 6.0                     | −15.4 ± 6.0     | −16.4 ± 6.0     | <0.001          |
| Area (%)                                         | −42.0 ± 6.7                     | −41.7 ± 6.7     | −42.4 ± 6.7     | 0.001           |

EDV, end-diastolic volume; ESV, end-systolic volume; SV, stroke volume; EF, ejection fraction.
Αρχιτεκτονική μ.ινών-Σύνθετη η συστολή της ΑΚ

subendocardium: longitudinally right handed helix
subepicardium: left handed helix

rotation and torsion
