3D ECHOCARDIOGRAPHY IN HEART FAILURE

Christine Selton-Suty, Olivier Huttin, Damien Voilliot, Clément Venner, Yves Juillière
CONFLITS D’INTERET

- aucun
INTRODUCTION

- Cardiac motion is 3D in nature!
- Limits of 2D echo
  - Geometric assumptions for quantification of LVEF, risk of chamber foreshortening
  - Assessment of myocardial motion and deformation from different non simultaneous views with mental reconstruction of 3D LV shape and kinetics
  - Out-of-plane motion
- Development of matrix array transducers
- Limits of 3D echo
  - Low frame rate and limited temporal resolution
  - Motion artefacts (irregular rhythm, breathing)

Johri Heart 2010;96:390
• Real-time 3D acquisition
• Pyramidal full-volume acquisition of 4 to 6 consecutive cardiac cycles
• +/- Colour flow
• TTE and TEE
Volume 3D (pyramidal 90°X90°) with multiple dissection planes

Tri / multiplane display
Quantification of volumes

Direct quantification based on a semi-automated algorithm that detects cavity–endocardial wall interface (slice or mesh methods) and its excursion during the heart cycle.
3D IMAGES ANALYSIS

- Tracking of the speckles inside the 3D volume, irrespective of their direction
- Assessment of LV volumes by tracking of speckle templates at the endocardial border
- Assessment of myocardial motion and deformation of the entire LV in all three spatial dimensions through the entire cardiac cycle

Kleijn EHJ CVI 2012;13:159–168
3D DEFORMATION

LONGITUDINAL $\varepsilon$

CIRCUMFERENTIAL $\varepsilon$

RADIAL $\varepsilon$

AREA $\varepsilon$
**3D AREA STRAIN (AREA CHANGE RATIO)**

- Magnitude of deformation in an endocardial area
  - $S \approx L \times C$
  - $AS \approx (S_1 - S_0)/S_0$
  - $AS \approx (1 + LS)(1 + CS) - 1$
- Validated against sonomicrometry

Seo JACC Img 2011;4:358–65
3D ANALYSIS OF LV TWIST

- Twist (°) et Torsion (°/cm) = difference in rotation between base and apex
- Faesibility 78%
- global 3DSTE twist: 10.2 + 7.6°
- Significantly less than 2D measurements

Andrade Eur J Echocardiogr 2011;12:76-9
### Table 1: Reliability of left ventricular volumes and function measurements

<table>
<thead>
<tr>
<th>Variable</th>
<th>Intra-observer (n = 117)</th>
<th>Inter-observer (n = 117)</th>
<th>Test–retest (n = 50)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ICC</td>
<td>SEM</td>
<td>ICC</td>
</tr>
<tr>
<td>End-diastolic volume (mL)</td>
<td>0.99</td>
<td>4.1</td>
<td>0.98</td>
</tr>
<tr>
<td>End-systolic volume (mL)</td>
<td>0.99</td>
<td>3.1</td>
<td>0.99</td>
</tr>
<tr>
<td>Ejection fraction (%)</td>
<td>0.98</td>
<td>1.7</td>
<td>0.95</td>
</tr>
<tr>
<td>Global circumferential strain (%)</td>
<td>0.97</td>
<td>1.4</td>
<td>0.90</td>
</tr>
<tr>
<td>Global longitudinal strain (%)</td>
<td>0.92</td>
<td>1.0</td>
<td>0.74</td>
</tr>
<tr>
<td>Global radial strain (%)</td>
<td>0.88</td>
<td>4.4</td>
<td>0.58</td>
</tr>
<tr>
<td>Segmental circumferential strain (%)</td>
<td>0.89</td>
<td>3.6</td>
<td>0.78</td>
</tr>
<tr>
<td>Segmental longitudinal strain (%)</td>
<td>0.86</td>
<td>2.9</td>
<td>0.61</td>
</tr>
<tr>
<td>Segmental radial strain (%)</td>
<td>0.78</td>
<td>10.2</td>
<td>0.44</td>
</tr>
</tbody>
</table>

- Lack of gold standard in the measurements of myocardial deformation

*Kleijn EHJ CVI 2012;13:159–168*
Meta-analysis of 23 studies including 1638 examinations comparing 3DE with CMR (± 2DE)

As compared to CMR, 3DE underestimates volumes and has wide limits of agreement, but is more accurate for volumes than 2DE

Modest increase in precision for LVEF as compared to 2D

Dorosz J Am Coll Cardiol 2012;59:1799–808
- 100 patients with various EF
- Area strain
  - Lowest inter and intraobserver variability (5 - 6%)
  - Most reliable surrogate of LVEF

Réant JASE 2012;25:68
160 patients with various stages of HF

Feasibility of 3D analysis: 87%

Downward trend from normal to Stage D HF for all strain values

Difference between normal and stage A significant only for AS: sensitive and reproducible parameter to detect early and subtle LV systolic dysfunction

Table 2  Echocardiographic characteristics

<table>
<thead>
<tr>
<th>.Parameter</th>
<th>Control (n = 30)</th>
<th>Stage A HF (n = 29)</th>
<th>Stage B HF (n = 37)</th>
<th>Stage C HF (n = 26)</th>
<th>Stage D HF (n = 15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global LS, %</td>
<td>-16.93 ± 2.28</td>
<td>-15.94 ± 2.74</td>
<td>-13.72 ± 3.20*#</td>
<td>-7.64 ± 3.02*#</td>
<td>-6.38 ± 2.72*#</td>
</tr>
<tr>
<td>Global CS, %</td>
<td>-30.27 ± 4.43</td>
<td>-28.85 ± 4.52</td>
<td>-23.02 ± 5.81*#</td>
<td>-10.08 ± 5.18*#</td>
<td>-8.85 ± 4.60*#</td>
</tr>
<tr>
<td>Global RS, %</td>
<td>28.43 ± 8.32</td>
<td>27.59 ± 9.08</td>
<td>25.73 ± 8.73</td>
<td>12.21 ± 5.89*#</td>
<td>8.82 ± 5.54*#</td>
</tr>
<tr>
<td>Global AS, %</td>
<td>-43.85 ± 4.35</td>
<td>-40.11 ± 5.18*</td>
<td>-32.27 ± 5.60*#</td>
<td>-17.20 ± 7.10*#</td>
<td>-14.43 ± 6.61*#</td>
</tr>
</tbody>
</table>

LV MECHANICS AND HF

- 200 pts (nl, HTN, HFP EF, syst HF)
- Significant correlations with BNP
- Significant prognostic factors at 1.5 yr, in addition to (1)LVEF, (2)E’, (3)LA volume

Additional predictive value of both left and right ventricular ejection fractions on long-term survival in idiopathic dilated cardiomyopathy


Cardiologie B, CHU Nancy-Brabois, 54500-Vandoeuvre-les-Nancy, France
556 patients with high prevalence of CV disease (no AF or MV disease), FU 2.5 yrs.
In pts with MI, significant differences in all strain values between transmural and non transmural segments identified by MRI.

Abnormal 3D longitudinal and area strain values even in segments with limited (<25%) necrosis.

Good correlations between global longitudinal, circumferential, and area strain with global scar extent.

Huttin Int J Cardiovasc Imaging 2015; in press
Hayat Am J Cardiol 2012;109:180 -186
3D AND HF AETIOLOGY

- Ischemic HD
- Dilated cardiomyopathy
  - MR
- LV Non Compaction
Hypertrophic cardiomyopathy
- LV mass
- Nature and extent of hypertrophy

amyloidosis
**3D AND CRT**

- Precise assessment of LVEF, volumes, and simultaneous evaluation of 3D motion in all LV segments
- Use of volume, strain and twist parameters to assess dyssynchrony
  - SD of time to min regional volume: **systolic dyssynchrony index**
  - SD of time to peak regional strain (radial)
  - SD of time to min endocardial surface area
  - Maximal opposing wall delay in time to peak radial strain
  - Area tracking based strain dyssynchrony index
  - SD of time to peak rotation

- Identification of sites of latest mechanical activation

Meta analysis of 73 studies
More than 5000 subjects (3341 patients and 1832 healthy subjects)
Feasibility 94%
Reference values of SDI
- healthy subjects: 2.7±0.9%
- heart failure patients in general: 9.8±3.9%
- Patients eligible for CRT: 10.7±3.6%
In patients eligible for CRT, SDI > 9.8% predicted treatment response with a Se of 93% and a Sp of 75%
Significant differences in references values between software

Kleijn EHJ CVI 2012;13:763–775
3D ANALYSIS OF STRAIN CURVES

- Analysis of temporal pattern of deformation curves
  - SD of time to peak regional strain (radial, longitudinal, area)
  - SD of time to min endocardial surface area
3D AREA STRAIN AND QRS DURATION

- 32 pts FE < 35% QRS < 120 ms, 22 pts QRS > 120 ms, 25 nl pts
A single acquisition of a full-volume dataset allows quantification of numerous conventional and novel parameters including LV volumes, ejection fraction, global and regional 3D strains, endocardial area strain, twist, dyssynchrony and also RV and LA analysis

... all we need for the clinical, therapeutic and prognostic assessment of our HF patients!

But don’t forget the current limits of temporal and spatial resolutions and of inter vendor reproducibility
- Close relationship between electrical activation and regional wall motion
- Colour display of time delay of onset of myocardial segmental deformation

Switching from RV to biV pacing

- acute increase in all strain parameters
- improvement of dyssynchrony (standard deviation of time to peak strain)

Improvement and resynchronization of radial strain curves after CRT

Echocardiographic evaluation of left ventricular structure and function: new modalities and potential applications in clinical trials.

Kalogeropoulos AP¹, Georgiopoulou VV, Gheorghiade M, Butler J.

Abstract

Advances in modern echocardiography for quantification of cardiac structure and function have not been translated in clinical trial or practice applications to date. Imaging endpoints are especially well-suited for early trials with investigational therapies for heart failure as most drugs and devices approved for heart failure have shown favorable effects on cardiac structure and function also. Echocardiography is versatile and can be performed in most clinical settings. The modest interobserver and test-retest reproducibility of specific structural and functional parameters with conventional echocardiography can be improved on by using contemporary modalities, including 3-dimensional (3D) echocardiography for assessment of volumes and ejection fraction and speckle tracking for detailed functional assessment of the ventricles with mechanics-based parameters (strain and strain rate). The appropriate imaging endpoints (global vs. regional, systolic vs. diastolic) should be tailored to the specific research question and the mode of action of the therapy under investigation. The newer echocardiographic modalities, namely 3D echocardiography and speckle tracking, are more demanding in terms of equipment and personnel and therefore are better suited for implementation in experienced research centers with central interpretation. However, these modalities provide the best opportunity currently available to demonstrate treatment effects on the myocardium with investigational therapies and provide mechanistic insights for future directions.