Cardiac Resynchronization Therapy
Selection therapy Echocardiography

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Candidates for CRT: class IA

- NYHA Functional Class III or IV (Subjective)
- QRS duration > 120 ms (> 150 ms usually considered)
- LVEF < 35% (overestimated in case of MR)
- Stable HF medical treatment for ≥ 1-month
- All Guidelines are unanimous in defining who should receive CRT

BUT > 30% of patients are "nonresponders"
EVALUATION OF LV FUNCTION AND SIZE

Modified Simpson’s Method of discs

- Endocardial Border?
- Load dependent
- Geometric assumptions
- Foreshortening in 90%

PROSPECT STUDY
20% had LVEF > 35%
Causes of 30% CRT nonresponse

- Inappropriate patient selection
- Inappropriate lead position
- Lead in front of necrotic tissue in ischemic pts
- Non optimal AV and/or VV delays

Likelihood of CRT response?

- Dyssynchrony
- Scar tissue in LV lead
- Extensive scar (>50% of LV)
- LV lead mismatch
  (vs site of latest mechanical activation)

HIGH LOW
Evaluate cardiac dyssynchrony “globally”:

1. Atrio-ventricular dyssynchrony,
2. Inter-ventricular dyssynchrony,
3. Intra-ventricular dyssynchrony.

- Because there is no clear demonstration that only intra-ventricular dyssynchrony is useful.
Inter-Ventricular dyssynchrony

Normal physiologic delay
Interventricular Asynchrony
inter-ventricular mechanical delay (IVMD)

\[ \text{IVMD} = \text{LV}_{PEI} - \text{RV}_{PEI} = 48\text{ms} \]

Significant when > 40 ms

Rouleau et al., PACE 2001
Patient selection:
Currently based on electrical, but not mechanical dyssynchrony assessment

Interventricular delay and response to CRT

Miracle study
N = 279 pts
FU = 6 months

IVMD < 40 ms (49%) IVMD > 40 ms (51%)

* : p<0.05 CRT off vs on
** : p<0.05 IVMD<40ms vs IVMD>40ms

Adamson PB et al, AHA 2002
Predictors and treatment response with cardiac resynchronization therapy in patients with heart failure characterized by dyssynchrony: a pre-defined analysis from the CARE-HF trial.

The benefits of cardiac resynchronization were modified by systolic blood pressure and interventricular mechanical delay (IVMD). Patients with increasing systolic blood pressure appear to receive reduced benefit from CRT (HR 1.02, 95% CI 1.00-1.03), whereas those patients with more severe IVMD appear to benefit more from treatment (HR 0.99, 95% CI 0.98-1.00).
AV Dyssynchrony

Long AV

\[ \frac{262}{768} = 34\% \]

Diastolic MR

AV asynchrony < 40%

Correction of AV delay
→ LV remodeling
(short > long AV ?)

C. Parsai, ESC 2007
INTRA-VENTRICULAR ASYNCHRONY
In the *normal heart*, there is spatial and temporal heterogeneity of function

**Mechanical dispersion = 40 ms**

<table>
<thead>
<tr>
<th>47 subjects 38-81 yr, ms</th>
<th>Maximal delay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time to peak systolic velocity</td>
<td>82 ± 47</td>
</tr>
<tr>
<td>Time to peak systolic strain rate</td>
<td>183 ± 67</td>
</tr>
<tr>
<td>Time to peak systolic strain</td>
<td>202 ± 108</td>
</tr>
<tr>
<td>Time to peak systolic displacement</td>
<td>110 ± 96</td>
</tr>
<tr>
<td>Time to peak early diastolic velocity</td>
<td>73 ± 36</td>
</tr>
</tbody>
</table>

Inhomogeneity of LV systolic function – peak radial shortening precedes peak longitudinal shortening

Velocity of shortening

$m/s$

Short axis

Long axis

$\Delta \sim 20\ ms$

Time $s$

Page C et al, ESC 2007
Patient selection:
Currently based on electrical, but not mechanical dyssynchrony assessment

\[ r^2 = 0.13 \]
\[ p = \text{ns} \]

INTRA-VENTRICULAR ASYNCHRONY

Spatial
- Protosystolic
  - Electro mechanical
- Mesosystolic
  - Electro systolic
- Endsystolic
  - TM, Tracking
  - 2D-Strain
  - 3D

Temporel
- AV closure
- MV opening

1 Wall: TM lateral
6 Walls: TM/Tracking
VISUAL INTERPRETATION : Asynchrony?

Delays < 70 ms cannot be detected with the human eye

Message: simple visual assessment of LV dyssynchrony is useful (maybe even better than all conventional and TDI measures of dyssynchrony) to predict response to CRT.

Voigt, Szulik et al., 2007
Apical Transverse Motion

Pre-CRT

Post-CRT

No Rocking

Rocking

Voigt et al., EHJ 2009
Septal to posterior wall motion delay
M-mode or color M-mode

Radial Spatial

Feasible in only 76% of normals and 45% of patients
Predicts reverse remodeling when > 130 ms (specificity ?)
Poor spatial resolution : 1 point in each wall

Pitzalis JACC 2005 (n=20), Diaz-Infante AJC 2007 (n=67), Contak CD (n=79)
Septal Flash
M-mode or color M-mode
short, early systolic septal motion

161 patients, multicenter, septal flash rest: Sens 64%, Spec 55%

Eliminating the septal flash by CRT predicts LV remodeling (100%)
DLC (IDCM) : Longitudinal Temporal
Left lateral wall post-systolic displacement

Contraction into early diastole

Delay in MV opening

Not assessable in 33%

Cazeau Heart 2000, Sassone Am J Cardiol 2007 (n=31)
Color-coded Tissue Doppler Imaging (Longitudinal Spatial)

IDCM : QRS 118 ms

IntraVA = 290 – 180 = 110 ms (> 60 ms Bax AJC 2003)

Septal-lateral delay (n=25) : Sens : 76% Spec : 88% ↑ LV EF
Agreement between SPWMD and SL delay

<table>
<thead>
<tr>
<th></th>
<th>SPWMD &gt;130 ms</th>
<th>SPWMD ≤130 ms</th>
</tr>
</thead>
<tbody>
<tr>
<td>S-L Delay ≥65ms</td>
<td>29 (50%)</td>
<td>12 (21%)</td>
</tr>
<tr>
<td>S-L Delay &lt;65ms</td>
<td>7 (12%)</td>
<td>10 (17%)</td>
</tr>
</tbody>
</table>

Response | Septo-to-Lateral delay > 65 ms | SPWD > 130 ms |
---|---|---|
Sens | 90% | 66% |
Spec | 82% | 50% |
IntraVA = 330 – 160 = 170 ms (> 65 ms Bax JACC 2004)

LV disp (n=85): Sens : 92% Spec : 92% reverse remodeling+outcome
Time to Peak Systolic Velocity: SD of 12 segments

SD\textsubscript{12} = 87 ms

SD > 32.6 ms (n=54): predictor of LV reverse remodeling

Sens: 96%, Spec: 78%

Yu et al, Am J Cardiol 2002;91:684-688
Other modalities: Strain

(n=37) $SD_{-12} \geq 60$ ms
Reverse remodeling
Mele Eur Heart J 2006

(n=59) $Exct_{-12} = 760$ ms
Sens: 94%, Spec: 83%
For reverse remodeling
Porciani Eur Heart J 2006
Other modalities: Strain

Advantages
- Regional function
- Passive vs active motion

Limitations
- Angle dependency
- Low signal to noise ratio
- Moderate reproducibility
- High operator variability
Strain delay index = \( \frac{n}{1} (\varepsilon_{\text{peak}} - \varepsilon_{\text{ES}}) \)

n=16 segments
Longitudinal + Radial

- 190 HF pts with CRT
- TDI SD-12 (n=67) + SL delay (only ejection phase)
- Radial dyssynchrony

SPWD ≥ 130 ms

Gorscan JACC 2007

EF Responders (%)

Long 2 sites

Long 12 sites

Sens: 88%
Spec: 80%
if both for EF
at 6 months
3-D ASSESSMENT OF MECHANICAL LV DYSSYNCHRONY (Normal) (Radial, Longitudinal, Circumferential)

EDV  89.51 ml
ESV  28.49 ml
SV   61.02 ml
EF   68.17 %
SDI16 1.2 %
3-D ASSESSMENT OF MECHANICAL LV DYSSYNCHRONONY (Patient)

SD-16 segments 8.3 % for reverse remodeling (n=26)

Kapetanakis Circ 2005

Poor agreement with TDI SD-12 : 56.5% for LVMD
Prospect study

- Prospective non randomized
- identify echo measures of asynchrony and predict response
- 53 centers, 426 patients QRS > 130 ms

The presence of single MD measures added
11-13 % response to CCS and 13-23 % to LVESV

12 echo measures → 8 were associated with response

No single measure of mechanical dyssynchrony may be recommended

ESC 2007 Hotline
Prospect study: Interpretation

High interecholab variability → Need for standardization

- Coefficient of variation
  - 6.5% LPEI
  - 33.7% TS-SD
  - 72.1% SPWMD

- The yield for echo measures
  - LPEI 95%
  - TS Lat-Se 67%
  - TS-SD 50%

No clear conclusion can be made
Use your own standardized stepwise approach

ESC 2007 Hotline
IDCM: QRS 130 ms
NYHA III

SD_{12} = 9 ms

Limitations

• Angle dependency
• Active vs passive motion?
• Peak? Low Systolic velocity
IDCM : QRS 130 ms
NYHA III

Advantages
• Angle independent
• Passive vs active motion
• Radial/longitudinal/Circonf
Pre: SD 18%
FAILURE TO CRT RESPONSE

1. ERO ≥ 20 mm²
2. LV EDD ≥ 75 mm
3. Ischemic disease
4. Narrow QRS
5. Absence of asynchrony
   → Lack of reverse LV remodeling

Cabrero-Bueno Europace 2007
Diaz-Infante AJC 2005,95:1436

Care HF : only 11 % QRS < 150 ms

Reuter AJC 2002,89:346

Care HF NEJM 2007
Extent of Myocardial Necrosis

Thin myocardium

Microvascular damage

Delayed enhancement

Thin
DWT < 5.5 mm

Resting echo

Contrast echo

Cardiac MRI
Extent of Myocardial Necrosis

PL Scare

Bleeker GB et al. Circulation 2006
Global Contractile Reserve

- Independent predictor of event-free survival after CRT (Da Costa et al. Heart Rhythm 2006) (IVD + ↑ 1.25 LV EF at 10 µg/kg/min)

- Predictive value of 7.5 % dobu-induced increase in LVEF (Ypenburg et al. Am Heart J 2007)

- Global CR: increase in LVEF by ≥ 6.7 % (Lancellotti et al Eur J Echo 2009)
Local Contractile Reserve

Lancellotti et al Eur J Echo 2009
Role of Stress Echo: dynamic asynchrony

- 30% normalization (asynchrony at rest)
- 30% induction (No asynchrony at rest)
- 30% No changes

Exercise LV asynchrony predicts response to CRT

Lancellotti et al AJC 2005, Rocchi et al Eur Heart J 2009
Dynamic Septal Flash Predicts CRT Response

- low dose dobutamine

52 patients

septal flash rest
- sensitivity 82%
- specificity 88%

septal flash LDD
- sensitivity 97%
- specificity 88%

Parsai / Sutherland et al, Eur Heart J 2009
Veinous anatomy and Necrosis

CT
Veins

MRI
Necrosis

CT/MRI
How do you select a CRT candidate?

1. Application of official guidelines only
2. Guidelines + evidence of dyssynchrony
3. Guidelines + integrated approach by different imaging methods
Conclusions

Dyssynchrony is normal and is dynamic

Many tools and many (too many ?) criteria not included in the guidelines (own echo criteria)

No one single echo parameter represents a magic number. Used several matched parameters ?.

A patient should not be denied CRT on the absence of LV Dyssynchrony alone

If no correctable mechanism is present – the patient will **NOT** respond!
Stepwise approach

QRS > 120 ms, NYHA III, EF < 35%

- IVD > 49 ms
  - Yes: CRT
  - No: Inter + Intra V delay > 102 ms

- AV asynchrony
- ERO ≥ 20 mm²
- LV EDD ≥ 75 mm

- LV MD
  - TDI, 2D Strain
  - 3D echo
    - +/- Exer echo
      - Yes: PL necrosis
      - No: CRT

- No LV MD

- CRT ?
  - LV MD
  - No LV MD

- Others ?
  - Viability
  - No Viability
  - CRT