Role of imaging in electrophysiology

F.F.Faletra
Cardiocentro Ticino Lugano
Guess where I was born.

...in “Magna Grecia”!!
EP Procedures
Role of imaging in…

Cardiac Resynchronization Therapy (CRT)

Pre-procedural 3D TEE assessment and intra-procedural guidance of cavo-tricuspid isthmus and pulmonary veins ablation
EP Procedures

Role of imaging in...

Cardiac Resynchronization Therapy (CRT)

Pre-procedural assessment and intra-procedural guidance of cavo-tricuspid isthmus and pulmonary veins ablation
The role of Echo and allies techniques (M-Mode, 2D TTE, DTI, Speckle tracking and 3D TTE)

MRI

CT
M-mode echocardiography
M-mode echocardiography

Use of M-mode echocardiography in the Assessment and Using

Table 3
Clinical response and echocardiographic

<table>
<thead>
<tr>
<th>Variable</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responders</td>
<td>0.7</td>
</tr>
<tr>
<td>Increase in NYHA functional class</td>
<td>0.9</td>
</tr>
<tr>
<td>Increase in 6-min distance</td>
<td>0.9</td>
</tr>
<tr>
<td>Decrease in Minnesota</td>
<td>0.6</td>
</tr>
<tr>
<td>Increase in LVEF (%)</td>
<td>0.7</td>
</tr>
<tr>
<td>Decrease in LV end-diastolic dimension</td>
<td>0.7</td>
</tr>
<tr>
<td>Decrease in LV end-systolic dimension</td>
<td>0.2</td>
</tr>
<tr>
<td>&gt;5% increase in LVESD</td>
<td>0.2</td>
</tr>
<tr>
<td>&gt;10% increase in LVESD</td>
<td>0.6</td>
</tr>
<tr>
<td>&gt;15% decrease in LVESD</td>
<td>0.4</td>
</tr>
</tbody>
</table>

* Comparison between SPWMD >130 and <130 ms
† p < 0.001 versus baseline.

155 ± 113 ms and median 135. Thirty-four patients (51%) had an SPWMD >130 ms. At 6-month follow-up, there were 17 nonresponders. At baseline, there were no significant differences between patients with SPWMD >130 or <130 ms in age, drug therapy, permanent atrial fibrillation, New York Heart Association functional class, underlying cause of cardiomyopathy, QRS duration, left ventricular (LV) ejection fraction, LV dimensions, or neurohormonal activation (norepinephrine and atrial and brain natriuretic peptide). At 6-month follow-up, baseline SPWMD was not associated with clinical response, New York Heart Association functional class, distance walked in 6 minutes, LV reverse remodeling, or neurohormonal activation. SPWMD >130 ms was also not a predictor. In conclusion, SPWMD is not a good predictor of response to CRT. © 2007 Elsevier Inc. All rights reserved. (Am J Cardiol 2007;100:84–89)
Dyssynchrony pattern

Anatomic M-mode echocardiography

Septal flash
Mechanical Abnormalities Detected With Conventional Echocardiography Are Associated With Response and Outcome

**Presence of a Septal Flash?**
(2D or M-Mode)
- Yes
- No

**Type of Filling Abnormality:**
- Septal Flash
  - N = 106 (53%)
  - 80.2% Response
- EA Fusion with Diastolic MR
  - N = 26 (13%)
  - 38.5% Response
- Truncated A-wave
  - N = 11 (5.5%)
  - 63.6% Response
- Long AV
  - N = 28 (13%)
  - 38.5% Response
- Short AV
  - N = 11 (5.5%)
  - 63.6% Response
- Others
  - N = 52 (26%)
  - 5.8% Response

**Abnormalities in LV Filling?**
- Yes
- No

**Passive Motion of a Dysfunctional Septum?**
- Yes
- No

---

*filling, or exaggerated interventricular dependence. Response to CRT was defined as a reduction in left ventricular (LV) end-systolic volume (ESV) >15%. Four subgroups of extent of response were defined: LVESV reduction >26.68% (extensive remodeling); LVESV reduction 6.8% to 26.68% (slight remodeling); LVESV reduction ≤6.8% (no remodeling) and clinical response; and LVESV reduction ≤6.8% without clinical response or the occurrence of death or heart transplantation. Midterm cardiovascular survival was evaluated (mean follow-up 38 ± 19 months).

**RESULTS** The presence of a correctable abnormality was independently associated with a better rate (odds ratio: 0.03 [95% confidence interval (CI): 0.01 to 0.10], p < 0.001) and extent of response to CRT (n = 59 [96.7%]) for the extensive remodeling subgroup vs. n = 53 [85.5%] for the slight remodeling subgroup vs. n = 19 [47.5%] for the no remodeling with clinical response subgroup vs. n = 17 [45.9%] for the no remodeling without clinical response subgroup, p = 0.0001), as well as with increased midterm survival (hazard ratio: 0.11 [95% CI: 0.2 to 0.6]). Other independent predictors included creatinine level and LV end-systolic diameter for response; New York Heart Association functional class IV, creatinine, LV end-systolic diameter, and transmurality index for extent of response; and New York Heart Association functional class IV for cardiovascular mortality.

**CONCLUSIONS** The presence of a correctable abnormality evaluated by conventional echocardiography is associated with LV reverse remodeling and better survival at midterm follow-up. Clinical characteristics and myocardial viability also have an influence. (J Am Coll Cardiol Img 2014;7:969–79) © 2014 by the American College of Cardiology Foundation.)
Relationship of visually assessed apical rocking and septal flash patterns with long-term survival after CRT

Aims

To determine if apical rocking and septal flash (SF) patterns before cardiac resynchronization therapy (CRT) are associated with long-term survival in patients with heart failure.

Methods

We followed 942 patients for 6 months after CRT and evaluated SF before and after the procedure along with other clinical parameters. Patients were divided into two groups based on the presence or absence of apical rocking and septal flash patterns. Cox proportional hazards models were used to assess the impact of SF and ApRock on long-term survival. The log-rank test was used for comparing survival curves.

Conclusion

A specific LV mechanical dyssynchrony pattern, characterized by ApRock and SF, is associated with a more favourable long-term survival after CRT. Both parameters are also indicators of an effective therapy.

Keywords

Apical rocking • Septal flash • Mechanical dyssynchrony • Cardiac resynchronization therapy • Survival
Doppler Tissue Imaging

Keywords: Echocardiography, Doppler ultrasound, Congestive Heart Failure, Pacing Therapy
Results of the Predictors of Response to CRT (PROSPECT) Trial

Conclusions

Despite promising preliminary data from prior single-center studies, echocardiographic measures of dyssynchrony aimed at improving patient selection criteria for CRT do not appear to have a clinically relevant impact on improving response rates when studied in a multicenter setting such as PROSPECT. Thus, at present, the echocardiographic parameters analysis. Indicators of positive CRT response were improved clinical composite score and ≥15% reduction in left ventricular end-systolic volume at 6 months. Clinical composite score was improved in 69% of 426 patients, whereas left ventricular end-systolic volume decreased ≥15% in 56% of 286 patients with paired data. The ability of the 12 echocardiographic parameters to predict clinical composite score response varied widely, with sensitivity ranging from 6% to 74% and specificity ranging from 35% to 91%; for predicting left ventricular end-systolic volume response, sensitivity ranged from 9% to 77% and specificity from 31% to 93%. For all the parameters, the area under the receiver-operating characteristics curve for positive clinical or volume response to CRT was ≤0.62. There was large variability in the analysis of the dyssynchrony parameters.

Conclusion—Given the modest sensitivity and specificity in this multicenter setting despite training and central analysis, no single echocardiographic measure of dyssynchrony may be recommended to improve patient selection for CRT beyond current guidelines. Efforts aimed at reducing variability arising from technical and interpretative factors may improve the predictive power of these echocardiographic parameters in a broad clinical setting. (Circulation. 2008;117: 2608-2616.)
Doppler Tissue Imaging
**Conclusions**

RT3DE is a feasible and reproducible method to quantify LV function and intraventricular mechanical dyssynchrony. We demonstrated that RT3DE can provide accurate and reliable measurements for global and segmental LV systolic function. LV systolic function was highly synchronized in the group with primary cardiomyopathy (15.6±1%; P for trend <0.001) and highly dyssynchronous in the group with atrial fibrillation (6.9±1.1% to 6.9±1%; P<0.0001). RT3DE represents a promising novel technique for CRT. *(Circulation. 2005;112:992-1000.)*
Real time 3D echocardiography

Real-Time 3-Dimensional Echocardiographic Assessment of Left Ventricular Dyssynchrony

Pitfalls in Patients With Dilated Cardiomyopathy

Apical cap. The abnormally high LV dyssynchrony in all patients with EF < 35% irrespective of QRS duration is likely a result of the inability of RT3DE to accurately determine regional ejection times in all LV segments because of the low signal-to-noise ratios of the regional volume curves. The conse-

and ejection fraction < 35% had abnormally high LVDI, likely as a result of low signal-to-noise ratio in low-amplitude regional volume curves hampering accurate determination of regional ejection time.

CONCLUSIONS Normal values established in this study resulted in indiscriminate diagnosis of abnormal dyssynchrony in all patients with reduced LV function. The value of RT3DE-derived LVDI in the evaluation of dyssynchrony in patients with reduced LV function needs to be critically reassessed because of the inability to accurately detect end-ejection in low-amplitude regional volume curves. Alternative indices of dyssynchrony need to be developed to address this limitation. (J Am Coll Cardiol Img 2009;2:802–12) © 2009 by the American College of Cardiology Foundation
Real time 3D echocardiography

Pre

After CRT
**Conclusions**—Speckle-tracking radial strain can quantify dyssynchrony and predict immediate and long-term response to CRT and has potential for clinical application. (*Circulation*. 2006;113:960-968.)
Speckle tracking

Shortening

Stretching

Shortening

Stretching
Selecting Patients for Cardiac Resynchronization Therapy

Echocardiographic measures should not be used to deny patients potentially life-saving therapy or expose them to unnecessary risks. Patient selection must use the parameter prospectively validated in landmark clinical trials: the QRS duration.

4,000 patients randomized in landmark trials. Small, observational, nonrandomized studies with surrogate endpoints have promoted echocardiography as a superior method of patient selection. Over 30 dyssynchrony parameters have been proposed. Most lack validation in appropriate clinical settings, including demonstration of short- and long-term reproducibility and intra- and interobserver variability. Prospective multicenter trials have proved informative in unexpected ways. In core laboratories, parameters exhibit striking variability, poor reproducibility, and limited predictive power. We are concerned that many centers today are using these techniques to select patients for CRT. Publication density and bias have misinformed clinical decision making. Echocardiographic parameters have no place in denying potentially life-saving treatment or in exposing patients to unnecessary risks and draining health care resources. Such measures should not stray beyond the research environment unless validated in randomized trials with robust clinical end points. The electrocardiogram remains a simple, inexpensive, and reproducible tool that identifies patients likely to benefit from CRT. Patient selection must use the parameter prospectively validated in landmark clinical trials: the QRS duration. (J Am Coll Cardiol 2009;53:1944-59) © 2009 by the American College of Cardiology Foundation
2013 ESC Guidelines on cardiac pacing and cardiac resynchronization therapy

1) LBBB with QRS duration >150 ms.

CRT is recommended in chronic HF patients and LVEF ≤35% who remain in NYHA functional class II, III and ambulatory IV despite adequate medical treatment.

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The disclosure forms of the authors and reviewers are available on the ESC website www.escardio.org/guidelines
Reasons for fallacy of echocardiography

- Pacing site
- Scar burden
- Coronary vein anatomy
- End stage LV dysfunction
- Severe mitral regurgitation or other valvular diseases
- Right ventricular function
- Left atrial size
- Others (….unknown to me)
Reasons for fallacy of echocardiography

- Pacing site
- Scar burden
- Coronary vein anatomy
- End stage LV dysfunction
- Severe mitral regurgitation or other valvular diseases
- Right ventricular function
- Left atrial size
- Others (….unknown to me)
Correction of Mitral Regurgitation in Nonresponders to Cardiac Resynchronization Therapy by MitraClip Improves Symptoms and Promotes Reverse Remodeling

Angelo Auricchio, MD, PtD,* Wolfgang Schillinge, MD,† Sven Meyer, MD,‡ Francesco Maisano, MD,§ Rainer Hoffmann, MD,‖ Gian Paolo Ussia, MD,¶ Giuseppe B. Pedrazzini, MD,* Ian van der Heyden, MD,* Simona Bottrini, MD, PtD,**

MitraClip treatment in CRT nonresponders with clinically significant FMR was feasible and safe, and produced improved NYHA functional class, increased LVEF, and reverse LV remodeling in a significant proportion of these study patients. Prospective studies are warranted to confirm our findings and to evaluate appropriate timing of MitraClip treatment after CRT.

Results

MC treatment was feasible in all patients (49% 1 clip, 46% 2 clips). There were 2 periprocedural deaths. Median follow-up was 14 months (25th to 75th percentile: 8 to 17 months). New York Heart Association functional class improved acutely at discharge (73%) and continued to improve progressively during follow-up (regression model, p < 0.001). The proportion of patients with significant residual FMR (grade ≥2) progressively decreased during follow-up (regression model, p < 0.001). Reverse LV remodeling and improved LVEF were detected at 6 months, with further improvement at 12 months (regression model, p = 0.001, p = 0.008, and p = 0.031 for ESV, EDV, and LVEF, respectively). Overall 30-day mortality was 4.2%. Overall mortality during follow-up was 19.9 per 100 person-years (95% confidence interval: 10.3 to 38.3). Nonsurvivors had more compromised clinical baseline conditions, longer QRS duration, and a more dilated heart.

Conclusions

FMR treatment with the MitraClip in CRT nonresponders was feasible, safe, and demonstrated improved functional class, increased LVEF, and reduced ventricular volumes in about 70% of these study patients. (J Am Coll Cardiol 2011;58:2183–9) © 2011 by the American College of Cardiology Foundation
New tools, New hope
New tools, new hope

**Conclusion**

Activation imaging using 3D-STE appears to be a feasible and promising technique in assessing LV mechanical dyssynchrony from the viewpoint of propagation imaging of the wavefronts of activation.

**Conclusions:** Activation imaging with 3D-STE may be a feasible noninvasive method of dyssynchrony imaging based on electromechanical coupling. (Circ J 2013; **77**: 2481–2489)
CRT

The role of

Echo and allies techniques

MRI

CT
CRT
The role of MRI
LV volume and EF
3D TTE quantitative assessment

Diastole

Systole

VS

Gold standard
Postero-lateral Scar Tissue Imaging: Response to Cardiac Resynchronization Therapy

CRT
The role of MRI

Postero-lateral scar tissue imaging is needed to improve the response to CRT. In the current case, the patient showed CRT implantation symptoms but did not improve in clinical status. This was likely related to the presence of extensive LV pacing. In patients with postero-lateral scar tissue, cardiac resynchronization therapy, contrast-enhanced magnetic resonance imaging, left ventricular dyssynchrony, tissue Doppler imaging, postero-lateral scar tissue.
CRT
The role of MRI
CRT

The role of

Echo and allies techniques

MRI

CT
CRT

Coronary vein anatomy
What we do..............

Visual assessment of septal flash and apical rocking motion (qualitative: yes/no)

Radial and longitudinal speckle tracking (quantitative)

MRI (before the CRT) for quantitative assessment of LV volumes and EF and to exclude extensive, lateral, transmural scar

Follow up with automated quantitate LV volumes and EF with 3D TTE
EP Procedures

Role of imaging in...

Cardiac Resynchronization Therapy (CRT)

Pre-procedural 3D TEE assessment and intra-procedural guidance of cavo-tricuspid isthmus and pulmonary veins ablation
Cavo-Tricuspid Isthmus anatomy

LAO 30°

RAO 30°

Courtesy of Sew Yen HO
Conclusions

This study demonstrated that routine pre-procedural 3D TEE imaging is extremely helpful in the qualitative and quantitative evaluation of CTI anatomy. Specific anatomic features, such as deep right atrial pouch, were found to be associated with significantly prolonged CTI ablation time to achieve bidirectional block in patients undergoing RFA for symptomatic typical atrial flutter. This cardiac imaging modality is already well-integrated in the current workflow of patients undergoing RFA of CTI, and may, therefore, provide valuable information to the electrophysiologist for more efficient peri-procedural planning.

Keywords
- 3D-TEE and RF ablation
- Three-dimensional transesophageal imaging
- cavo-tricuspid isthmus ablation
- typical atrial flutter
CVTI intra-procedural guidance

Table 3. Procedural Data

<table>
<thead>
<tr>
<th>Variable</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total procedural time (min)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Fluoroscopy time (min)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Fluoroscopy dose (cGy·cm⁻²)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Number of RF applications</td>
<td>0.007</td>
</tr>
<tr>
<td>Ablation time (min)</td>
<td>0.145</td>
</tr>
</tbody>
</table>

Values are median (interquartile range). RF = radiofrequency; RT3DTEE = real-time 3-dimensional transesophageal echocardiography.

Conclusions: RT3DTEE-guided ablation of CVTI was feasible, allowing real-time detailed morphological CVTI characterization as well as continuous visualization of the ablation catheter during radiofrequency ablation. This approach entailed marked reductions in procedural time, radiation exposure, and the number of radiofrequency applications. (J Am Coll Cardiol Img 2011;4:716–26 © 2011 by the American College of Cardiology Foundation)
CVTI intra-procedural guidance

One example

Eustachian Valve
Tip of cath
Tricuspid annulus
Pulmonary vein ablation

Anatomy of Pulmonary Veins by Real-Time 3D TEE

Implications for Catheter-Based Pulmonary Vein Ablation

Francesco F. Faletra, MD,* Gaetano Nucifora, MD,* François Regoli, MD, PhD,* Siew Yen Ho, MD, PhD,† Tiziano Moccetti, MD,* Angelo Auricchio, MD, PhD*

Real-time 3-dimensional transeosophageal echocardiography (RT3DTEE) provides high quality images of the posterior structures of the heart (1) and has been used for guiding several catheter-based procedures (2).

The electrical isolation of pulmonary veins (PVs) has become a highly effective treatment option for symptomatic, drug-resistant atrial fibrillation (AF). RT3DTEE may potentially represent a novel monitoring modality for anatomy-driven PVs isolation. However, a standardized RT3DTEE protocol for imaging acquisition and processing of PVs is lacking. We describe a systematic step-by-step approach of acquisition modality of each PV by RT3DTEE, their normal appearance, comparison with equivalent
Pulmonary veins anatomy

Left pulmonary veins

Courtesy from SY Ho
Pulmonary veins anatomy

Right pulmonary veins

Courtesy from SY Ho
Pulmonary veins anatomy

Catheters
Intra-procedural guidance

LUPV
Intra-procedural guidance

RUPV
Pulmonary veins ablation
Pulmonary Vein Isolation Guided by Real-Time Three-Dimensional Transesophageal Echocardiography

FRANÇOIS REGOLI, M.D., Ph.D.,* FRANCESCO F. FALETRA, M.D.,*
MARCO SCAGLIONE, M.D.,† GAETANO NUCIFORA, M.D.,* TIZIANO MOCETTI, M.D.,*
and ANGELO AURICCHIO, M.D., Ph.D.*

From the *Division of Cardiology, Fondazione Cardiocentro Ticino, Lugano, Switzerland; and †Division of Cardiology, Cardinal Massaia Hospital, Asti, Italy

The present case illustrates pulmonary vein isolation guided by real-time three-dimensional transesophageal echocardiography. This imaging modality allowed to navigate in a point-by-point fashion around pulmonary veins to assess both catheter location in relation to pulmonary vein ostia and stability of catheter tip. Also, it offered high-resolution visualization of a thickened, prominent tissue that surrounded the left upper pulmonary vein (the ligament of Marshall). The ability to visualize this anatomical structure along with intracardiac recording of electrical signals allowed to safely modulate in loco radiofrequency energy delivery, thus achieving electrical isolation of the pulmonary vein. (PACE 2011; 1–4)

atrial fibrillation, echocardiography, imaging, mapping, electrophysiology–clinical
Our results suggest that RT3DTEE has limited value in identifying PV ostia and catheter location during PVI.
Food for thoughts …

• The use of the 3D TEE during a simple, straightforward procedure, such as CVTI ablation, remains limited by the need of general anesthesia and the presence of an experienced operator with a fully equipped echo-machine.

• However, in selected cases, (during pregnancy or in young female at childbearing age) 3D TEE may be useful as additional imaging tool for minimizing the risk of radiations.

• 3D TEE has in our hands limited value in guiding pulmonary veins ablation.
Thank you for your attention
CRT
The role of MRI
Pulmonary Vein Isolation Guided by Real-Time Three-Dimensional Transesophageal Echocardiography

FRANÇOIS REGOLI, M.D., Ph.D.,* FRANCESCO F. FALETRA, M.D.,*
MARCO SCAGLIONE, M.D.,† GAETANO NUCIFORA, M.D.,* TIZIANO MOCCEITI, M.D.,*
and ANGELO AURICCHIO, M.D., Ph.D.*

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atrial fibrillation, echocardiography, imaging, mapping, electrophysiology–clinical
Doppler Tissue Imaging
The peri-infarct zone
The peri-infarct zone

A
Normal myocardium

Normal electrogram: Good cell-cell coupling allows synchronous depolarization

B
Postinfarct Scar tissue

Fractionated electrogram: Poor cell-cell coupling leads to dysynchronous depolarization
Global longitudinal strain

Global circumferential strain

Global radial strain

Courtesy of Chiara Bucciarelli Ducci
TRACKING-CMR RV

Global longitudinal strain

Global circumferential strain

Global radial strain

Courtesy of Chiara Bucciarelli Ducci
Real-time visualization. Much of what is required to help improve efficacy and safety of complex ablation procedures is imaging what we ablate at the time of energy delivery and catheter manipulation.
3D TEE during ablation procedures should be able to:

1. Imaging 3D details of the ‘anatomical terrain’ where the ablation takes place

2. Guiding “in real time” catheter navigation

3. Continuously monitoring the catheter-tissue contact points during the energy delivery.
How catheters look like
Mapping Catheter
How catheters look like
Ablation Catheter
Tracking catheters
RUPV
Tracking catheters
RUPV
Catheter tip-wall contact
Catheter tip-wall contact
Visualizing the act of ablation...
Visualizing the act of ablation...
Limitations.....
Limitations.....
The main limitation......
Left pulmonary veins