Assessing Ventricular Function with SPECT and PET

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SPECT & PET Quantitative Function Analysis

- Software availability – Main algorithms
  - **Cedars-Sinai**
    QGS / AutoQUANT / QBS
    www.csaim.com
  - **Emory University / Syntermed**
    Emory Cardiac Toolbox
    www.syntermed.com
  - **University of Michigan / Invia**
    Corridor4DM
    www.inviasolutions.com

- All provide: systolic function, diastolic function, wall motion, wall thickening, phase analysis (dyssynchrony)
- See [http://csaim.com/validation](http://csaim.com/validation)
QUANTITATIVE FUNCTION BASICS: SEGMENTATION AND SYSTOLIC FUNCTION

3D LV Surfaces

- Mid-myocardial surface computed using constrained maximal counts
- Epi- and endocardial surfaces derived from mid-myocardial surface
  - Using count variations throughout the cardiac cycle
  - Constrained by constant myocardial mass
- Surfaces are ellipsoidal, “clipped” by a valve plane
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3D LV Surfaces

Emory Cardiac Toolbox

Michigan Corridor 4DM

3D LV Volumes & Ejection Fraction

- Cavity volumes are calculated using the endocardial surface at each interval
- EDV = max volume; ESV = min volume
- \( EF \% = 100 \times \frac{(EDV - ESV)}{EDV} \)
- 3D geometric approach: no background counts subtraction, Simpson’s Rule, etc…

EF=75%

EF=27%
3D LV Volumes & Ejection Fraction

8- or 16-frame gating?

- **8-frame** gating causes **LVEF underestimation** by ~ 4% when compared to 16-frame gating
  [Germano, JNM 1995; 36:2138-2147]

- Any other reasons?
  - Diastolic Function: 16
  - Phase Analysis: 8 or 16

- We use 16-frame gating

PET vs. SPECT

- QGS was initially developed and calibrated for SPECT images and noise characteristics
- **QGS-PET** uses a modified algorithm that takes advantage of increased resolution as well as visibility of the basal portion of myocardium, yielding a slightly higher LVEF
- One should not use a SPECT algorithm to process PET data!
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PET vs. SPECT

- SPECT: LV function assessed at rest and post stress
- PET: LV function assessed at rest and peak stress

- Patients with 3-vessel CAD or left main CAD may be identified by LVEF decrease and/or wall motion abnormalities during peak stress even in the absence of apparent perfusion abnormalities.

[Di Carli, JNM 2007; 48(5):783-793]

DIASTOLIC HEART FAILURE & DIASTOLIC FUNCTION ASSESSMENT
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### Diastolic Function: Parameters

* rates normalized to EDV

- Time-volume curves are interpolated
- Compute first derivative
- Extract parameters of interest: PER, PFR, TTPF, MFR/3

[Nakajima, JNM 2001; 42:183-188]

### Diastolic Function: QGS

- Time-volume curves are interpolated
- Compute first derivative
- Extract parameters of interest: PER, PFR, TTPF, MFR/3

90 normal patients

**Mean values**
- PFR: $2.62 \pm 0.46$ EDV/s
- TTPF: $164.6 \pm 21.7$ ms

**Abnormality thresholds**
- PFR: < 1.70 EDV/s
- TTPF: > 208 ms

[Akincioglu, JNM 2005; 46(7):1102-8]
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REGIONAL FUNCTION: WALL MOTION AND WALL THICKENING

17-segment model

**Motion**

0 = normal  
1 = mild hypokinesis  
2 = moderate hypokinesis  
3 = severe hypokinesis  
4 = akinesis  
5 = dyskinesis

**Thickening**

0 = normal  
1 = equivocal reduction  
2 = definite reduction  
3 = no thickening

Myocardial Function Scoring
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“Normal” Myocardial Wall Motion Pattern

The septum moves less than the lateral wall in most normal patients [Sharir, JNM 2001; 42(11):1630-8]

“Normal” Myocardial Wall Thickening Pattern

The apex thickens more than the base in most normal patients [Sharir, JNM 2001; 42(11):1630-8]
Automatically-Derived Motion / Thickening Scores

DYSSYNCHRONY ASSESSMENT: PHASE ANALYSIS
**What is LV Dyssynchrony?**

- Normal LV contraction occurs synchronously
- Dyssynchrony occurs when parts of the LV contract at different times from others, i.e., “out of phase”
- This type of dyssynchrony is “mechanical dyssynchrony”
- Dyssynchrony within the LV: intra-ventricular
- Contraction delay between LV and RV: inter-ventricular
- Patients with LV dyssynchrony may be most responsive to cardiac resynchronization therapy (CRT)

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**What Does “Phase” Mean?**

- A shift or delay with respect to a reference signal of the same frequency
- Expressed as an angle or time
- In our case, one cardiac cycle = 360° (= 1 sec @ 60bpm)
Phase Analysis in Nuclear Cardiology

- Goal: global and regional dyssynchrony analysis
- Fourier analysis: technique used to extract a phase angle (proxy for the “onset of contraction”) for each LV surface sampling point

- Myocardial perfusion SPECT/PET: based on timing of local thickening (derived from count variations during cardiac cycle)
- Also possible from gated blood pool SPECT using count variations near the endocardium—motion based, not thickening!

Phase Analysis: Parameters

- Using the phase angle at each surface sampling point we build global and regional histograms
- From the phase histograms we compute:
  - Standard deviation $\sigma$ (traditional, degrees)
  - Bandwidth $\beta$: smallest angle range that includes 95% of histogram measurements (degrees)
  - Entropy $\varepsilon$: measure of variability rather than dispersion (%)
  - Mean (regional)
Assessment of Dyssynchrony

Conduction abnormalities
- **Low likelihood** patient: low dyssynchrony
- **LBBB** patient: conduction delay → mechanical contraction delay → **higher** dyssynchrony
- Discriminating parameters: histogram bandwidth, SD & entropy, regional (LAT-SEP) differences
- $Ss/Sp$ 81/63% → 90/94%

LV dyssynchrony quantification of **normal** subjects (n=157), **LBBB** (n=33), **RBBB** (n=19), **RV paced** rhythms (n=23), and **LV dysfunction** (EF <40%, n=120).

[Van Kriekinge, JNM 2008; 49:1790-7]

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Predicting Response to CRT: Emory

- CRT Response Prediction: who benefits?
  - **Low** dyssynchrony: non-responder
  - **High** dyssynchrony: responder
  - Predictive parameters: histogram bandwidth (Ss/Sp 70/70%), standard deviation (Ss/Sp 74/74%)

![Image A](image1.png) ![Image B](image2.png)

[Henneman, JNM 2007; 48(7):1104-11]

(A) Non-responder, (B) Responder

Predicting Response to CRT: QGS

- CRT Response Prediction: who benefits?
  - **Low** dyssynchrony: non-responder
  - **High** dyssynchrony: responder
  - Predictive parameters: histogram bandwidth (Ss/Sp 83/81%), standard deviation (Ss/Sp 83/81%)

![Image A](image3.png) ![Image B](image4.png)

How do we improve CRT?

- Global dyssynchrony may predict whether a patient is likely to respond
- Combining regional dyssynchrony and myocardial scar location (non-reversible defect) may help guide lead placement
- Using dyssynchrony-guided CRT, reverse LV remodeling and increase in LVEF are observed, with improved long-term prognosis

- Echo: Ypenburg, JACC 2008; 52(17):1402-9
- Nuclear: Friehling, Circulation: Cardiovascular Imaging 2011; 4:532-9
- Case for using dyssynchrony: Delgado, Circulation; 2011; 123: 640-655

Phase Analysis: Caveat

- Uncorrected gating errors affect phase measurements
- Dyssynchrony is artifactually decreased by gating errors
- These can be corrected post-hoc by normalizing the affected frames

[Ludwig, JNM 2012; 53(12):1892-6]
Thank you!

Please visit the Cedars-Sinai AIM Program web site

http://csaim.com

for additional resources including validation information and publications (many full-text papers available)