Diastolic Function in Patients with Atrial Fibrillation

Tough Diastole!!

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* No conflicts to declare
Diastolic Function in Patients with Atrial Fibrillation

- Case presentation
- Physiologic Issues
- Filling Pressures
- Prognosis
- New Approaches
Diastolic Dysfunction
Linked with Two Epidemics

- Atrial Fibrillation
  - DD shows increased risk for 1st AF
- Heart Failure
  - DD shows increased risk for 1st HF in NSR
  - Risk of HF increased once AF develops
- Evaluation of DF in AF is challenging

Al-Omari et al Am J Cardiol 2008; 101:1759-1765
Future of Atrial Fibrillation
ATRIA Study
Projected Number of Adults With AF in the US: 1995 to 2050.

Mitral Inflow
Tough Diastole
Can Diastology be done in Afib?

A. Yes
B. No
Can Diastology be done in Afib?

A. Yes
B. No
Patterns of Diastolic Function

- **Mitral inflow**
  - **PV flow**
  - **TDE**
  - **CMM - Vp**

- **NL (Young)**
- **NL (Adult)**
- **Delayed Relaxation**
- **Pseudo normal**
- **Restrictive**

www.escardio.org/EAE
Practical Approach to Grade Diastolic Dysfunction

- **Septal e’ ≥ 8**
  - **Lateral e’ ≥ 10**
  - **LA < 34 ml/m2**
  - **Normal function**

- **Septal e’ ≥ 8**
  - **Lateral e’ ≥ 10**
  - **LA ≥ 34 ml/m2**
  - **Normal function, Athlete’s heart, or constriction**

- **Septal e’ < 8**
  - **Lateral e’ < 10**
  - **LA ≥ 34 ml/m2**
  - **Grade I**
    - **E/A < 0.8**
    - **DT > 200 ms**
    - **Av. E/e ≤ 8**
    - **Ar-A < 0 ms**
    - **Val ΔE/A < 0.5**

- **E/A 0.8-1.5**
  - **DT 160-200 ms**
  - **Av. E/e 9-12**
  - **Ar-A ≥ 30 ms**
  - **Val ΔE/A ≥ 0.5**

- **E/A ≥ 2**
  - **DT < 160 ms**
  - **Av. E/e ≥ 13**
  - **Ar-A ≥ 30 ms**
  - **Val ΔE/A ≥ 0.5**

Grade I

Nageh et al JASE 2009

www.escardio.org/EAE
71 yo Woman with Atrial Fibrillation, Peripheral Edema and Extra Heart Sound
Apical 4 Chamber

LAVI = 38 ml/m²
Tricuspid Inflow
Doppler Tissue Imaging

Average $e' = 18$
$E/e' = 6$
Color M-Mode

Vp=120 cm/s
E/Vp=0.8
What is the Diagnosis in Atrial Fibrillation?

- A) Restriction
- B) Constriction
- C) Mixed
- D) Effusive constriction
- E) Send him to Mayo Clinic
What is the Diagnosis in Atrial Fibrillation?

- A) Restriction
- B) Constriction
- C) Mixed
- D) Effusive constriction
- E) Send him to Mayo Clinic
Key Diagnostic Findings in Atrial Fibrillation

- Abnormal septal bounce
- Pericardial thickening
- Respiratory Doppler variation
- Short DT
- Increased TDI annular velocities
- Increased CMM flow propagation
- Paradoxically low E/e’ and E/Vp
Practical Approach to Grade Diastolic Dysfunction

Grade I
- E/A < 0.8
- DT > 200 ms
- Av. E/e ≤ 8
- Ar-A < 0 ms
- Val ∆E/A < 0.5

Grade II
- E/A 0.8-1.5
- DT 160-200 ms
- Av. E/e 9-12
- Ar-A ≥ 30 ms
- Val ∆E/A ≥ 0.5

Grade III
- E/A ≥ 2
- DT < 160 ms
- Av. E/e ≥ 13
- Ar-A ≥ 30 ms
- Val ∆E/A ≥ 0.5

Septal e’ ≥ 8
- Lateral e’ ≥ 10
- LA < 34 ml/m2

Septal e’ ≥ 8
- Lateral e’ ≥ 10
- LA ≥ 34 ml/m2

Septal e’ < 8
- Lateral e’ < 10
- LA ≥ 34 ml/m2

Normal function

Normal function, Athlete’s heart, or constriction

Nageuh et al JASE 2009
Constrictive Pericarditis and Atrial Fibrillation

Tabata et al. JACC 2001;37:1936-42
Diastolic Function in Patients with Atrial Fibrillation

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- Physiologic Issues
- Filling Pressures
- Prognosis
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Diastolic Function in Patients with Atrial Fibrillation

Physiologic Issues

• Loss of mechanical atrial function
• Variable cycle length
• Left atrial enlargement
Determinants of LV Diastolic Function in Atrial Fibrillation

Determinants of LV diastolic function during atrial fibrillation: beat-to-beat analysis in acute dog experiments

Longer RR intervals associated with improved filling and increased LV EDV that leads to increase in the peak LV systolic pressure in the studied beat in Afib resulting in improved subsequent LV relaxation

Diastolic Filling Parameters

**LV Filling**

**Left Ventricular Inflow**
- Peak E (cm/sec)
- Peak A (cm/sec)
- E/A
- DT (msec)

**Pulmonary Vein**
- Forward Flow
  - Peak S (cm/sec)
  - Peak D (cm/sec)
- Reverse Flow
  - Peak AR (cm/sec)

**Color M-Mode**

**Tissue Doppler Echo**

**RV Filling**

**Right Ventricular Inflow**
- Peak E (cm/sec)
- Peak A (cm/sec)
- E/A
- DT (msec)

**Hepatic Vein**
- Forward Flow
  - Peak S (cm/sec)
  - Peak D (cm/sec)
- Reverse Flow
  - Peak AR (cm/sec)

**Inferior Vena Cava Size (cm)**

www.escardio.org/EAE
MV Inflow
Physiologic Issues
Cycle Length

www.escardio.org/EAE
PV Flow
Tissue Doppler Imaging
Color M-Mode
New Diastole Rules in Atrial Fibrillation

- Average 5-10 beats *(more the better)*
- Cycle length equivalent to HR from 60-80 and an interval $\geq 70$ msec between end of mitral inflow and onset of QRS
- $\text{RRp/RRpp}=1$
- Absence of marked variation in E wave may suggest increased LV filling pressures
Diastolic Function in Patients with Atrial Fibrillation

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Diastolic Function Variables
LV Filling Pressures

- Mitral DT (≤ 150 msec)
- TDI E/e’ (≥ 11)
- Color M-Mode E/Vp (≥ 1.4)
- PV Diastolic flow DT (≤ 220 msec)
- IVRT (≤ 65 msec)
- Peak Accel of E wave (≥ 1900 cm/s²)
- IVRT/T E-e’ < 5.59

Nagueh et al. JASE 2009;22:108-133
Al-Omari et al Am J Cardiol 2008; 101:1759-1765
## Diastolic Function Variables

### LV Filling Pressures

**Echocardiographic assessment of diastolic filling pressure in AF**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>First Author</th>
<th>Study population (N)</th>
<th>Age (y)</th>
<th>LVEF (%)</th>
<th>Correlation with LVFP (r)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mitral DT</td>
<td>Nagueh et al.(^{17})</td>
<td>ICU, cardiac catheterization or OR patients (60)</td>
<td>69 ± 9</td>
<td>48 ± 17</td>
<td>−0.42</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>Chirillo et al.(^{25})</td>
<td>In-hospital patients (35)</td>
<td>66 ± 7</td>
<td>41 ± 13</td>
<td>−0.50</td>
<td>F ratio = 11.1</td>
</tr>
<tr>
<td></td>
<td>Temporelli et al.(^{27})</td>
<td>Patients admitted with CHF (35)</td>
<td>69 ± 9</td>
<td>22 ± 5</td>
<td>−0.95</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td></td>
<td>Sohn et al.(^{18})</td>
<td>Patients undergoing a clinically-indicated cardiac catheterization (27)</td>
<td>62.9 ± 10.8</td>
<td>53 ± 10.5</td>
<td>Did not correlate</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>Traversi et al.(^{28})</td>
<td>Patients admitted with CHF (65)</td>
<td>57 ± 6</td>
<td>25 ± 7</td>
<td>−0.60</td>
<td>0.000</td>
</tr>
<tr>
<td></td>
<td>Matsukida et al.(^{26})</td>
<td>Patients with various cardiac conditions (37)</td>
<td>65 ± 13</td>
<td>FS = 29 ± 4</td>
<td>−0.65</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>E/e’</td>
<td>Sohn et al.(^{18})</td>
<td>Patients undergoing a clinically-indicated cardiac catheterization (27)</td>
<td>62.9 ± 10.8</td>
<td>53 ± 10.5</td>
<td>0.79</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>e’</td>
<td>Sohn et al.(^{18})</td>
<td>Patients undergoing a clinically-indicated cardiac catheterization (27)</td>
<td>62.9 ± 10.8</td>
<td>53 ± 10.5</td>
<td>*0.51</td>
<td>0.007</td>
</tr>
<tr>
<td>E</td>
<td>Nagueh et al.(^{17})</td>
<td>ICU, cardiac catheterization, or OR patients (60)</td>
<td>69 ± 9</td>
<td>48 ± 17</td>
<td>0.42</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>Temporelli et al.(^{27})</td>
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<td>22 ± 5</td>
<td>0.23</td>
<td>0.21</td>
</tr>
<tr>
<td></td>
<td>Sohn et al.(^{18})</td>
<td>Patients undergoing a clinically-indicated cardiac catheterization (27)</td>
<td>62.9 ± 10.8</td>
<td>53 ± 10.5</td>
<td>0.61</td>
<td>0.01</td>
</tr>
</tbody>
</table>

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Al-Omari, et al, Am J Cardiol 2008;101:1759 –1765

www.escardio.org/EAE
Estimation of Pulmonary Wedge Pressure by Transmitral Doppler in Patients With Chronic Heart Failure and Atrial Fibrillation

DT <120 ms predicts LVP 20 mmHg
Sensitivity of 100%
Specificity of 96%

Temporelli et al Am J Cardiol 1999;83:724-727
Mitral Inflow

- $DT \leq 100$ ms predict LV filling pressures $\geq 18$ mmHg
- Sensitivity of 80%
- Specificity of 85%
- Superior to BNP

Matsukida et al. JASE 2001;14: 1080-1987
Pulmonary Vein Flow DT
(\leq 150 \text{ MSEC})

Matsukida et al. JASE 2001;14: 1080-1987
Tissue Doppler Imaging
TDI

Septal E/e' Ratio in AF

LVFP (mmHg)

Sens. = 75% (9 of 12)
Spec. = 93% (14 of 15)

Color M- Mode Doppler
Non-invasive assessment of left ventricular relaxation during atrial fibrillation using mitral flow propagation velocity†

Junko Asada-Kamiguchi1, Tomotsugu Tabata2, Zoran B. Popovic1, Neil L. Greenberg1, Yong Jin Kim1, Mario J. Garcia1, Don W. Wallick1, Kent A. Mowrey1, Shaowei Zhuang1, Youhua Zhang1, Todor N. Mazgalev1, James D. Thomas1, and Richard A. Grimm1

†Section of Cardiovascular Imaging, Department of Cardiovascular Medicine, The Cleveland Clinic Foundation, Cleveland, OH 44195, USA and 1Department of Internal Medicine, Division of Cardiology, Second Hospital of the Fujita Health Science University, 3-6-10 Otabashi, Nagakawa, Nagoya 454-8509, Japan

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Aims To elucidate the usefulness of the early diastolic mitral flow propagation velocity (Vp) obtained from colour M-mode Doppler for non-invasively assessing left-ventricular (LV) relaxation during atrial fibrillation (AF).

Methods and results Ten healthy adult dogs were studied to correlate Vp with the invasive minimum value of the first derivative of LV pressure decay (dP/dtmin) and the time constant of isovolumic LV pressure decay (τ) at baseline, during rapid and slow AF, and during AF after inducing myocardial infarction. There were significant positive and negative curvilinear relationships between Vp and dP/dtmin and τ, respectively, during rapid AF. After slowing the ventricular rate, the average value of Vp increased, while dP/dtmin decreased and τ increased. After inducing myocardial infarction, the average value of Vp decreased, while dP/dtmin decreased and τ increased.

Conclusion The non-invasively obtained Vp evaluates LV relaxation even during AF regardless of ventricular rhythm or the presence of pathological changes.

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Restrictive physiology as defined by Doppler echocardiography (DT ≤130 msec) appears to predict a similar poor prognosis with atrial fibrillation as with normal sinus rhythm.
Kaplan Meier Survival
NSR and AFib

Kaplan Meier Survival
EF $\geq$ 50% vs < 50% in Afib

Diastolic Function in Patients with Atrial Fibrillation

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- New Approaches
Clinical Utility of Single-Beat E/e’ Obtained by Simultaneous Recording of Flow and Tissue Doppler Velocities in Atrial Fibrillation With Preserved Systolic Function

Kenya Kusunose, MD, Hirotsgu Yamada, MD, PhD, Susumu Nishio, RMS, Noriko Tomita, MD, PhD, Toshiyuki Niki, MD, Koji Yamaguchi, MD, PhD, Kunihiko Koshiba, MD, PhD, Shusuke Yagi, MD, PhD, Yoshio Taketani, MD, Takashi Iwase, MD, PhD, Takeshi Soeki, MD, PhD, Tetsuzo Wakatsuki, MD, PhD, Masashi Akaike, MD, PhD, Masataka Sata, MD, PhD
Tokushima, Japan

CONCLUSIONS The single-beat lateral E/e’ correlated with plasma BNP level and PCWP in AF patients with preserved systolic function. In addition, the single-beat lateral E/e’ (≥11) was a good predictor of elevated PCWP (≥15 mm Hg). Dual Doppler echocardiography offers an advantage of providing the single-beat lateral E/e’ correctly even in AF patients, for the evaluation of left ventricular diastolic function. (J Am Coll Cardiol Img 2009;2:1147–56) © 2009 by the American College of Cardiology Foundation
Simultaneous Transmitral Flow and Mitral Annular Velocity

Preceding RR/pre-preceding RR=1

Kusunose et al. J Am Coll Cardiol Img 2009; 2: 1147-56
Single-Beat vs Conventional E/e’

Kusunose et al. J Am Coll Cardiol Img 2009; 2: 1147-56
Dual Doppler System
Color M-Mode E/Vp

- E/Vp correlated with LV filling pressures ($r=0.63$) with mean E/Vp $\geq 1.7$ predicting a BNP $\geq 200$ pg/ml with sensitivity of 80% and specificity of 84%

Oyama et al Circ J 2004;68:1132-1138
E/e’ could be useful in identifying symptomatic diastolic HF and evaluating the functional state in the process of HF in patients with Afib. E/e’ is able to assess the improvement of diastolic HF in Afib and is superior to BNP or LAA.

E/SR during Isovolumic Relaxation

Wang et al., Circulation. 2007;115:1376-1383
Summary

• Assessment of Diastology in Afib is challenging but feasible
• Multiple beats averaging using mitral, PV and E/e’ variables
• Cycle length is key!!
• Dual Doppler Echo with Single Beat E/e’ is best.
• Role of SR imaging in Afib ?
EDITORIAL COMMENT

Cracking the Mysteries of Diastolic Function in Atrial Fibrillation

New Technology for an Old Problem*

Zoran B. Popović, MD, PHD, Allan L. Klein, MD

Cleveland, Ohio

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Cleveland Clinic

14th Diastology and New Echo Technologies Summit

Featuring Heart Valve and Contrast Echo Mini-Symposium

Key Topics:

Heart Valve Disease
- State-of-the-Art Imaging
- Quantification of Valvular Regurgitation
- Robotic Surgery
- Percutaneous Techniques/Partner Trial

Diasstology
- New ASE Guidelines
- Tissue Doppler Imaging and Strain
- Specific Diseases Assessment
- Therapy and Clinical Trials

New Echocardiography Technologies
- Real Time 3D TTE and TEE
- Speckle Tracking, Tissue
- Cardiac Resynchronization Therapy
- Appropriateness Criteria

Contrast Echocardiography
- Black Box Warning and Safety
- ASE Guidelines
- LVO, EBD, and Stress Echo
- Myocardial Perfusion

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