Diastologie

André Denault MD PhD FRCPC, CSPQ, ABIM-CCM, FASE
President of the CVT section of the CAS
Professeur agrégé de clinique
Département d’anesthésiologie
Institut de Cardiologie de Montréal
Service des soins intensifs
Centre Hospitalier Universitaire de Montréal

10th annual perioperative TEE symposium
Toronto, November 3rd 2012
Objectifs du Collège Royal

• 1-Describe the determinants of normal diastolic function and understand its importance in the normal function of the heart, as well as describe conditions associated with abnormal diastolic function

• 2-Left sided CHF from diastolic and/or systolic dysfunction
Est-ce que l’œdème pulmonaire est secondaire à la dysfonction diastolique ?
Plan

- Is it important to evaluate diastolic function?
- Can we monitor LV diastolic function intraoperatively or in the intensive care unit?
- Echocardiographic and non-echocardiographic bedside indices of diastolic function.
- Is left more important than right ventricular diastolic function evaluation?
- How we approach it in the operating room and in the intensive care unit?
- How to treat diastolic function?
Practical diastology

André Denault MD PhD, Pierre Couture MD

Department of Anesthesia
Montreal Heart Institute, Montréal Canada
Division of critical care medicine
Centre Hospitalier de l’Université de Montréal, Montréal, Canada

andre.denault@umontreal.ca
Plan

• Is it important to evaluate diastolic function?
  • Can we monitor diastolic function intraoperatively or in the intensive care unit?
  • Echocardiographic and non-echocardiographic bedside indices of diastolic function.
  • Is left more important than right ventricular diastolic function evaluation?
  • How we approach it in the operating room and in the intensive care unit?
  • How to treat diastolic function?
Patients at risk

- Elderly patients
- Chronic hypertension with LV hypertrophy
- Chronic renal failure patients
- Hypertrophic cardiomyopathy
  - young and elderly
- Aortic stenosis
- Secondary diastolic dysfunction in CAD
1452-1519

“The lower chamber filled with blood from the upper chambers”
When the old man’s heart relaxes slowly, his capacity for physical exertion is still limited... even though the systolic contractions were still like those of youth. »
Right Ventricular Dysfunction in Low Output Syndrome After Cardiac Operations: Assessment by TEE

- RV Dysfunction (n = 17)
- RV and LV Dysfunction (19)
- LV Dysfunction (n = 18)
- Normal (n = 21)

N = 75

Davila-Roman VG, Ann Thorac Surg 1995;60:1081-6
Evaluation of diastolic filling of left ventricle in health and disease: Doppler echocardiography is the clinician's Rosetta Stone

Nishimura RA JACC 1997;30:8-18
The hemodynamically unstable patient in the intensive care unit: Hemodynamic vs. transesophageal echocardiographic monitoring

Tudor Costachescu, MD, FRCPC; André Denault, MD, FRCPC; Jean-Gilles Guimond, MD, FRCPC; Pierre Couture, MD, FRCPC; Stéphane Carignan, MD, FRCPC; Peter Sheridan, MD, FRCPC; Gisèle Hellou, MD, FRCPC; Louis Blair, MD, FRCPC; Louis Normandin, MD, FRCPC; Denis Babin, MSc; Martin Allard; François Harel, MSc; Jean Buithieu, MD, FRCPC
The hemodynamically unstable patient in the intensive care unit: Hemodynamic vs. transesophageal echocardiographic monitoring

<table>
<thead>
<tr>
<th></th>
<th>Admission</th>
<th>SICU 2hr</th>
<th>SICU 4hr</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Kappa</strong></td>
<td>0.33</td>
<td>0.47</td>
<td>0.28</td>
</tr>
</tbody>
</table>
Limitations of the Swan-Ganz catheter

Hypovolemia

LV dysfunction

Low PaP

Elevated PaP

Echographic diagnosis
48 evaluations had 2 causes of hemodynamic instability or more (82%)
72% diastolic dysfunction
45% RV systolic dysfunction
38% LV systolic dysfunction
29% hypovolemia
Diastolic Dysfunction is Predictive of Difficult Weaning from Cardiopulmonary Bypass

Francis Bernard, MD*, André Denault, MD, FRCPC†, Denis Babin, MSc†, Caroline Goyer, MD†, Pierre Couture, MD, FRCPC†, André Couturier, MSc†, and Jean Buithieu, MD, FRCPC*†

Departments of *Medicine and †Cardiology, CHUM, Notre-Dame Hospital; and ‡Department of Anesthesia, Montreal Heart Institute Montreal, Quebec, Canada
Diastolic Dysfunction is Predictive of Difficult Weaning from Cardiopulmonary Bypass

Table 3. Multivariate Backward Logistic Regression of Inotropic Support 0–12 Hours After Surgery

<table>
<thead>
<tr>
<th>Variable</th>
<th>Odds ratio</th>
<th>Unit</th>
<th>95% CI</th>
<th>P value&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female sex</td>
<td>8.44</td>
<td>1</td>
<td>(2.088–42.085)</td>
<td>0.004</td>
</tr>
<tr>
<td>Diastolic dysfunction</td>
<td>4.315</td>
<td>1</td>
<td>(1.021–19.849)</td>
<td>0.04</td>
</tr>
<tr>
<td>CPB time (min)</td>
<td>3.403</td>
<td>33</td>
<td>(1.496–9.413)</td>
<td>0.008</td>
</tr>
</tbody>
</table>

N = 92
Left and right ventricular diastolic dysfunction as predictors of difficult separation from cardiopulmonary bypass

André Y. Denault MD FRCP,∗ Pierre Couture MD FRCP,∗ Jean Buithieu MD FRCP,¶ Francois Haddad MD FRCP,∗ Michel Carrier MD FRCP,¶ Denis Babin MSc,* Sylvie Levesque MSc,§ Jean-Claude Tardif MD FRCP†

Left Ventricular Diastolic Function Evaluation

Right Ventricular Diastolic Function Evaluation

CAN J ANESTH 2006 / 53: 10
Diastolic Heart Failure — No Time to Relax

There are 4.6 million people in the United States with heart failure today, and 550,000 new cases are being reported annually.\(^1\) Approximately 30 to 50 percent of patients with heart failure have a normal or nearly normal left ventricular ejection fraction.\(^2\) In these patients heart failure is usually due to left ventricular diastolic dysfunction. Yet despite the high prevalence of diastolic heart failure, it has received far less attention than its systolic counterpart.
# Prognostic Implications of Preoperative E/e’ Ratio in Patients with Off-pump Coronary Artery Surgery

Eun-Ho Lee, M.D.,* Sung-Cheol Yun, Ph.D.,† Ji-Hyun Chin, M.D.,‡ Dae-Kee Choi, M.D.,* Hyo-Jung Son, M.D.,§ Wook-Chong Kim, M.D.,* Seong-Soo Choi, M.D.,∥ Jun-Gol Song, M.D.,* Kyung-Don Hahn, M.D.,# Ji-Yeon Sim, M.D.,** In-Cheol Choi, M.D.††

## Table 3. Association between E/e’ ratio and 30-day and 1-yr MACE

<table>
<thead>
<tr>
<th></th>
<th>E/e’ ≤15</th>
<th>E/e’ &gt;15</th>
<th>Unadjusted</th>
<th>Multivariable Adjusted</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>30-day MACE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall</td>
<td>43/744 (5.8)</td>
<td>37/304 (12.2)</td>
<td>2.6 (1.4–3.6)</td>
<td>2.4 (1.4–3.9)</td>
</tr>
<tr>
<td>LVEF ≥50%</td>
<td>34/621 (5.5)</td>
<td>22/214 (10.3)</td>
<td>2.0 (1.1–3.5)</td>
<td>2.3 (1.3–4.3)</td>
</tr>
<tr>
<td>LVEF &lt;50%</td>
<td>9/123 (7.3)</td>
<td>15/90 (16.7)</td>
<td>2.5 (1.1–6.1)</td>
<td>3.7 (1.1–11.9)</td>
</tr>
<tr>
<td><strong>1-yr MACE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall</td>
<td>55/744 (7.4)</td>
<td>45/304 (14.8)</td>
<td>2.1 (1.4–3.1)</td>
<td>2.1 (1.4–3.1)</td>
</tr>
<tr>
<td>LVEF ≥50%</td>
<td>45/621 (7.3)</td>
<td>26/214 (12.2)</td>
<td>1.7 (1.1–2.8)</td>
<td>1.5 (1.1–4.5)</td>
</tr>
<tr>
<td>LVEF &lt;50%</td>
<td>10/123 (8.1)</td>
<td>19/90 (21.1)</td>
<td>2.7 (1.3–5.9)</td>
<td>2.3 (1.1–5.2)</td>
</tr>
</tbody>
</table>

N = 885
Prognostic Implications of Preoperative E/e’ Ratio in Patients with Off-pump Coronary Artery Surgery
Perioperative Diastolic Dysfunction in Patients Undergoing Noncardiac Surgery Is an Independent Risk Factor for Cardiovascular Events

A Systematic Review and Meta-analysis

Ashraf Fayad, M.D., M.Sc., F.R.C.P.C., F.A.C.C., F.A.S.E.,
Mohammed T. Ansari, M.B.B.S., M.Med.Sc., M.Phil., Homer Yang, M.D., F.R.C.P.C.,
Terrence Ruddy, M.D., F.R.C.P.C., F.A.C.C., George A. Wells, B.Sc., M.Sc., Ph.D.
Enough literature to...
Heart failure

Diastolic

Systolic
Plan

• Is it important to evaluate diastolic function?
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• How we approach it in the operating room and in the intensive care unit?
• How to treat diastolic function?
Effects of anesthetic induction in patients with diastolic dysfunction

Les effets de l’induction de l’anesthésie chez les patients souffrant de dysfonction diastolique

Pierre Couture, MD · André Y. Denault, MD · Yanfen Shi, MD · Alain Deschamps, MD, PhD · Mariève Cossette, Msc · Michel Pellerin, MD · Jean-Claude Tardif, MD
After induction of anesthesia...
Plan

• Is it important to evaluate diastolic function?
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• How to treat diastolic function?
Adapted from Bettex D. Échocardiographie transoesophagienne en anesthésie-réanimation 1997
Fonction diastolique

Fonction systolique

Pression

Volume

B1

B2

B3

B4
Pressure-volume loop

Pressure

Volume

EKG
Arterial pressure
LA pressure
LV pressure

Adapted from Bettex D. Échocardiographie transoesophagienne en anesthésie-réanimation 1997
Diastolic dysfunction
Diastolic dysfunction

LVED area

Wedge = 5 mmHg
## Echocardiographic Classification of Diastolic Dysfunction

<table>
<thead>
<tr>
<th></th>
<th>Normal Diastolic Function</th>
<th>Stage 1 Impaired Relaxation</th>
<th>Stage II Pseudonormal Restrictive</th>
<th>Stage III Reversible Restrictive</th>
<th>Stage IV Fixed Restrictive</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mitral Inflow</strong></td>
<td>0.75 &lt; E/A &lt; 1.5, DT &gt; 140 ms</td>
<td>E/A &lt; 0.75, DT &gt; 140 ms</td>
<td>0.75 &lt; E/A &lt; 1.5, DT &gt; 140 ms</td>
<td>E/A &gt; 1.5, DT &lt; 140 ms</td>
<td>E/A &gt; 1.5, DT &lt; 140 ms</td>
</tr>
<tr>
<td><strong>Pulmonary Venous Flow</strong></td>
<td>S ≥ D, AR dur &lt; A dur</td>
<td>S &gt; D, AR dur &lt; A dur + 30 ms</td>
<td>S ≥ D, AR dur &gt; A dur + 30 ms</td>
<td>S &lt; D or AR dur &gt; A dur + 30 ms</td>
<td></td>
</tr>
<tr>
<td><strong>Color M-Mode Propagation Velocity</strong></td>
<td>Vp &gt; 45</td>
<td>Vp &lt; 45</td>
<td>Vp &lt; 45</td>
<td>Vp &lt; 45</td>
<td>Vp &lt; 45</td>
</tr>
<tr>
<td><strong>Doppler Tissue Imaging of Mitral Annular Motion</strong></td>
<td>E/Em &lt; 10</td>
<td>E/Em &lt; 10</td>
<td>E/Em ≥ 10</td>
<td>E/Em ≥ 10</td>
<td>E/Em ≥ 10</td>
</tr>
</tbody>
</table>

### LV Relaxation
- Normal
- Impaired
- Impaired
- Impaired
- Impaired

### LV Compliance
- Normal
- Normal to ▼
- ▼▼▼
- ▼▼▼▼
- ▼▼▼▼

### Atrial Pressure
- Normal
- ▲▲
- ▲▲▲
- ▲▲▲▲
Isovolumic contraction time

Isometric relaxation time

Isovolumic phase indices

Adapted from Bettex D. Échocardiographie transoesophagienne en anesthésie-réanimation 1997
Isovolumic relaxation time

1 2 3 4 5 6 7

Systole

Diastole

Rapid filling

Diastasis

Atrial contraction

Adapted from Bettex D. Échocardiographie transoesophagienne en anesthésie-réanimation 1997
Pulse wave Doppler

Systole  Diastole

Adapted from Bettex D. Échocardiographie transoesophagienne en anesthésie-réanimation 1997
Normal

Tissue Doppler

Adapted from Bettex D. Échocardiographie transoesophagienne en anesthésie-réanimation, 1997.
Doppler Tissue Imaging: A Noninvasive Technique for Evaluation of Left Ventricular Relaxation and Estimation of Filling Pressures

SHERIF F. NAGUEH, MD, KATHERINE J. MIDDLETON, RCT, HELEN A. KOPELEN, RDMS, WILLIAM A. ZOGHBI, MD, FACC, MIGUEL A. QUIÑONES, MD, FACC

Houston, Texas
If $E/Em$ values $> 10$
PAOP is $> 15$ mmHg
(sensitivity 97% specificity 78%)

$E/Em$ values $> 15$
$= \text{high filling pressure}$
Prognostic Implications of Preoperative E/e’ Ratio in Patients with Off-pump Coronary Artery Surgery

Patients with LVEF ≥ 50% (n=835)

P = 0.024

E/e’≤15 (n=45/621)
E/e’>15 (n=26/214)

MACE free survival

Follow up (months)

Anesthesiology 2012
Recommendations for the Evaluation of Left Ventricular Diastolic Function by Echocardiography

Sherif F. Nagueh, MD, Chair,† Christopher P. Appleton, MD, † Thierry C. Gillebert, MD,* Paolo N. Marino, MD,* Jae K. Oh, MD, † Otto A. Smiseth, MD, PhD,*
Alan D. Waggoner, MHS, † Frank A. Flachskampf, MD, Co-Chair,* Patricia A. Pellikka, MD, † and Arturo Evangelista, MD,* Houston, Texas; Phoenix, Arizona;
Ghent, Belgium; Novara, Italy; Rochester, Minnesota; Oslo, Norway; St. Louis, Missouri; Erlangen, Germany; Barcelona, Spain

Journal of the American Society of Echocardiography
February 2009
## Echocardiographic Classification of Diastolic Dysfunction

<table>
<thead>
<tr>
<th>Stage</th>
<th>Normal Diastolic Function</th>
<th>Stage I: Impaired Relaxation</th>
<th>Stage II: Pseudonormal</th>
<th>Stage III: Reversible Restrictive</th>
<th>Stage IV: Fixed Restrictive</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.75 &lt; E/A &lt; 1.5 DT &gt; 140 ms</td>
<td>E/A &lt; 0.75</td>
<td>0.75 &lt; E/A &lt; 1.5 DT &gt; 140 ms</td>
<td>E/A &gt; 1.5 DT &lt; 140 ms</td>
<td>E/A &gt; 1.5 DT &lt; 140 ms</td>
</tr>
</tbody>
</table>

### Mitral Inflow

- **Velocity (ms)**
- **Time (ms)**

### Pulmonary Venous Flow

- **Velocity (ms)**
- **Time (ms)**

### Color M-Mode Propagation Velocity

- **Velocity**
- **Time (ms)**

### Doppler Tissue Imaging of Mitral Annular Motion

- **Velocity (ms)**
- **Time (ms)**

### LV Relaxation
- Normal
- Impaired

### LV Compliance
- Normal
- Normal to ▼
- ▲▲

### Atrial Pressure
- Normal
- ▲▲▲
Grade I: relaxation abnormality

![Graph showing left ventricular pressure and volume changes during relaxation](image)
Relaxation abnormality

Adapted from Bettex D. Échocardiographie transoesophagienne en anesthésie-réanimation 1997
Diastolic pressure (mmHg) vs. Diastolic volume (mL/m²) for Angina and Control conditions. The graph shows an increase in diastolic pressure with diastolic volume in the Angina condition compared to the Control condition.
Transesophageal echocardiographic assessment of systolic and diastolic dysfunction during percutaneous transluminal coronary angioplasty
Tissue Doppler

Relaxation abnormality

Adapted from Bettex D. Échocardiographie transoesophagienne en anesthésie-réanimation, 1997
Anesthetic agents and rate of isovolumic relaxation

- Desflurane
- Isoflurane
- Halothane

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>1.0 MAC</th>
<th>1.5 MAC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desflurane</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Isoflurane</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Halothane</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Pagel Anesthesiology 1993
76 yo woman with aortic stenosis
62 yo man with post CABG:
How important is the atrial kick?
62 yo man with post CABG:
How important is the atrial kick?
Clinical implication of relaxation abnormality

- “A” wave >> v wave on wedge tracing
- Poor tolerance to atrial fibrillation
- Rx for atrial fibrillation = cardioversion if unstable
- LV filling is compromised by tachycardia
- Shortness of breath without angina with diastolic dysfunction worsened by ischemia
# Echocardiographic Classification of Diastolic Dysfunction

<table>
<thead>
<tr>
<th>Stage</th>
<th>Normal Diastolic Function</th>
<th>Stage 1 Impaired Relaxation</th>
<th>Stage II Pseudonormal</th>
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<th>Stage IV Fixed Restrictive</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0.75(&lt;E/A)&lt;1.5 DT(&gt;140\ ms)</td>
<td>E/A(&lt;0.75) DT(&gt;140\ ms)</td>
<td>E/A(&gt;1.5) DT(&lt;140\ ms)</td>
<td>E/A(&gt;1.5) DT(&lt;140\ ms)</td>
</tr>
</tbody>
</table>

## Mitral Inflow

### Pulmonary Venous Flow

### Color M-Mode Propagation Velocity

### Doppler Tissue Imaging of Mitral Annular Motion

### LV Relaxation

### LV Compliance

### Atrial Pressure
Grade III: Increased Chamber Stiffness

![Diagram showing left ventricular pressure volume relationship with increased stiffness](image-url)
Restrictive pattern

Adapted from Bettex D. Échocardiographie transoesophagienne en anesthésie-réanimation 1997
Abnormal pulmonary vein
Restrictive pattern

Adapted from Bettex D. Échocardiographie transoesophagienne en anesthésie-réanimation, 1997.
62 yo patient unstable after AVR
Right Ventricular Dysfunction in Low Output Syndrome After Cardiac Operations: Assessment by TEE

N = 75

Davila-Roman VG, Ann Thorac Surg 1995;60:1081-6
Pulmonary capillary wedge pressure
After CPB
Clinical implication of restrictive disorder

- “V” wave without significant regurgitation on wedge tracing
- Atrial fibrillation is often the consequence
- Tachycardia is often compensatory: BB can be dangerous
- Shortness of breath with pulmonary hypertension
- Poor prognosis
### Echocardiographic Classification of Diastolic Dysfunction

<table>
<thead>
<tr>
<th>Stage IV</th>
<th>Stage III</th>
<th>Stage II</th>
<th>Stage I</th>
<th>Normal Diastolic Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed</td>
<td>Reversible Restrictive</td>
<td>Pseudonormal</td>
<td>Impaired Relaxation</td>
<td>Normal</td>
</tr>
<tr>
<td>E/A&gt;1.5 DT&lt;140 ms</td>
<td>E/A&gt;1.5 DT&lt;140 ms</td>
<td>E/A&lt;1.5 DT&gt;140 ms</td>
<td>E/A&lt;0.75</td>
<td></td>
</tr>
</tbody>
</table>

#### Mitral Inflow

- **Velocity (ms)**
  - Normal: 0.75 < E/A < 1.5
  - Stage I: E/A < 0.75
  - Stage II: E/A < 1.5 DT > 140 ms
  - Stage III: E/A > 1.5 DT < 140 ms
  - Stage IV: E/A > 1.5 DT < 140 ms

#### Pulmonary Venous Flow

- **Velocity (ms)**
  - S ≥ D, AR dur ≤ A dur
  - S > D, AR dur ≤ A dur + 30 ms
  - S < D, AR dur > A dur + 30 ms

#### Color M-Mode Propagation Velocity

- **Velocity**
  - Vp > 45
  - Vp < 45

#### Doppler Tissue Imaging of Mitral Annular Motion

- **Velocity (ms)**
  - E/Em < 10
  - E/Em ≥ 10

#### LV Relaxation

- Normal
- Impaired

#### LV Compliance

- Normal
- Normal to ▼
- ▼▼▼▼

#### Atrial Pressure

- Normal
- ▲▲
- ▲▲▲▲
Doppler Mitral Flow Pattern

Carvedilol Therapy in CHF (EF <40%)

- Stable nonrestrictive MFP (n=49)
- Reversible restrictive MFP (n=31)
- Irreversible restrictive MFP (n=12)
### Echocardiographic Classification of Diastolic Dysfunction

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<th>Stage IV Fixed Restrictive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vp(m/s)</td>
<td>0.75 &lt; E/A &lt; 1.5 DT &gt; 140 ms</td>
<td>E/A &lt; 0.75 DT &gt; 140 ms</td>
<td>0.75 &lt; E/A &lt; 1.5 DT &gt; 140 ms</td>
<td>E/A &gt; 1.5 DT &lt; 140 ms</td>
<td>E/A &gt; 1.5 DT &lt; 140 ms</td>
</tr>
<tr>
<td>Time (ms)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

#### Mitral Inflow

- **Velocity (m/s)**
- Time (ms)

#### Pulmonary Venous Flow

- **Velocity (m/s)**
- Time (ms)

#### Color M-Mode Propagation Velocity

- **Velocity**
- Time (ms)

#### Doppler Tissue Imaging of Mitral Annular Motion

- **Velocity (m/s)**
- Time (ms)

#### LV Relaxation

- Normal
- Impaired

#### LV Compliance

- Normal
- Normal to ▼
- ▼▼▼

#### Atrial Pressure

- Normal
- Normal
- ▲▲▲▲▲
Grade II: Pseudo-normal
Pseudo-normal

Adapted from Bettex D. Échocardiographie transoesophagienne en anesthésie-réanimation 1997
Tissue Doppler

Pseudo-normal

Am
Em
Sm
73 yo woman with CAD
ORIGINAL ARTICLE

Early myocardial dysfunction following subarachnoid haemorrhage

N. MCLAUGHLIN¹, M. W. BOJANOWSKI¹ & A. DENAULT²,³

¹Department of Neurosurgery, and ²Intensive Care Unit, Centre hospitalier de l’Université de Montréal (CHUM), Hôpital Notre-Dame, and ³Department of Anesthesiology, Montreal Heart Institute, Montreal, QC, Canada
38 yo woman with SHA grade IV
Biventricular diastolic filling patterns after coronary artery bypass graft surgery

Yanfen Shi, MD, André Y. Denault, MD, Pierre Couture, MD, Ady Butnaru, MD, Michel Carrier, MD, and Jean-Claude Tardif, MD, FACC

The Journal of Thoracic and Cardiovascular Surgery • May 2006
Clinical implication of pseudonormal disorder

It depends whether they are related to relaxation abnormality or early restrictive disorders
Plan

• Is it important to evaluate diastolic function?
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Plan

• Is it important to evaluate diastolic function?
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• How we approach it in the operating room and in the intensive care unit?
• How to treat diastolic function?
Hypoxia and/or hemodynamic instability

Diastolic function evaluation?
Pulmonary edema: 7±1 mm between tails
Pulmonary edema: < 3mm between tails
Transesophageal lung ultrasonography: a novel technique for investigating hypoxemia

Yiorgos Alexandros Cavayas, MD • Martin Girard, MD • Georges Desjardins, MD • André Y. Denault, MD, PhD
86 yo ♂ pre-op cardiac surgery
Pulmonary venous flow

Transmitral flow

Mitral tissue Doppler velocities

Pulmonary venous flow
Clinical and echocardiographic determinants of ultrasound lung comets

Francesca Frassi\textsuperscript{a,c}, Luna Gargani\textsuperscript{a,c}, Suzana Gligorova\textsuperscript{b,c,d}, Quirino Ciampi\textsuperscript{a,c,e}, Gaetano Mottola\textsuperscript{b,c}, Eugenio Picano\textsuperscript{a,*},c
Clinical and echocardiographic determinants of ultrasound lung comets

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p<0.0001
Recommendations for Chamber Quantification: A Report from the American Society of Echocardiography’s Guidelines and Standards Committee and the Chamber Quantification Writing Group, Developed in Conjunction with the European Association of Echocardiography, a Branch of the European Society of Cardiology

Members of the Chamber Quantification Writing Group are: Roberto M. Lang, MD, FASE, Michelle Bierig, MPH, RDCS, FASE, Richard B. Devereux, MD, Frank A. Flachskampf, MD, Elyse Foster, MD, Patricia A. Pellikka, MD, Michael H. Picard, MD, Mary J. Roman, MD, James Seward, MD, Jack S. Shanewise, MD, FASE, Scott D. Solomon, MD, Kirk T. Spencer, MD, FASE, Martin St John Sutton, MD, FASE, and William J. Stewart, MD

<table>
<thead>
<tr>
<th>Atrial dimensions</th>
<th>Reference range</th>
<th>Mildly abnormal</th>
<th>Moderately abnormal</th>
<th>Severely abnormal</th>
</tr>
</thead>
<tbody>
<tr>
<td>LA volume, mL</td>
<td><strong>W</strong> 22-52</td>
<td>53-62</td>
<td>63-72</td>
<td>≥ 73</td>
</tr>
<tr>
<td></td>
<td><strong>M</strong> 18-58</td>
<td>59-68</td>
<td>69-78</td>
<td>≥ 79</td>
</tr>
<tr>
<td>LA volume/BSA, mL/m²</td>
<td><strong>W</strong> 22±6</td>
<td>29-33</td>
<td>34-39</td>
<td>≥ 40</td>
</tr>
<tr>
<td></td>
<td><strong>M</strong> 22±6</td>
<td>29-33</td>
<td>34-39</td>
<td>≥ 40</td>
</tr>
</tbody>
</table>

Red blood cell
Glucose + Hemoglobin
Glycohemoglobin

A4C
A2C
Abnormal LV systolic dysfunction
Abnormal RV systolic dysfunction
Normal LV systolic dysfunction

LA volume > 40 ml/m²
Diastolic dysfunction

Systolic function

Abnormal  Normal
Début diastole

Figure 1. Short-axis cine frames at different trigger delays (Td) during the cardiac cycle in a patient with PPH. In early diastole (Td = 320), the ventricular septum bows to the left.

Impaired Left Ventricular Filling Due to Right Ventricular Pressure Overload in Primary Pulmonary Hypertension* Noninvasive Monitoring Using MRI

*The term "Primary Pulmonary Hypertension" is often abbreviated as "PPH."
Diastolic dysfunction

\[ \text{Systolic function} \]

Abnormal

Systolic heart failure

Left

Right

Normal
Symptoms and signs of heart failure

Normal to mildly reduced LV systolic function
LVEF > 50%
LVEDVI < 97 ml/m²

Evidence of abnormal LV relaxation, distensibility and diastolic stiffness

Invasive hemodynamic measurements
Echocardiographic criteria
Biomarkers
Symptoms and signs of heart failure

Normal to mildly reduced LV systolic function
LVEF > 50%
LVEDVI < 97 ml/m²

Evidence of abnormal LV relaxation, distensibility and diastolic stiffness

Invasive hemodynamic measurements
PCWP > 12 mmHg
LVEDP > 16 mmHg
Tau > 48 msec

Echocardiographic criteria
E/Em > 15
15 > E/Em > 8

Biomarkers
BNP > 200 pg/ml
Symptoms and signs of heart failure

Normal to mildly reduced LV systolic function
LVEF > 50%
LVEDVI < 97 ml/m²

Evidence of abnormal LV relaxation, distensibility and diastolic stiffness

Invasive hemodynamic measurements
PCWP > 12 mmHg
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Echocardiographic criteria
E/Em > 15
15 > E/Em > 8

Biomarkers
BNP > 200 pg/ml

Doppler + 2D criteria:
E/A (>50yo) < 0.5
DT (>50yo) > 280 msec
Duration (A - AR) > 30 msec
LA volume > 40 ml/m²
LV mass index > 122 g/m² (female)
or > 149 g/m² (male)
Atrial fibrillation

Diastolic

Heart failure

With normal ejection fraction
Chamber Dilatation

Left Ventricular Pressure vs. Left Ventricular Volume

Diagram showing the relationship between left ventricular pressure and volume.
Systolic Failure

Normal diastolic chamber distensibility
Perioperative Assessment of Diastolic Dysfunction

Robina Matyal, MD,* Nikolaos J. Skubas, MD,† Stanton K. Sherman, MD,‡ and Feroze Mahmood, MD*

![Decision tree diagram showing the assessment of diastolic dysfunction based on E/E' ratio and associated hemodynamic parameters. The diagram illustrates the different outcomes including normal LAP and increased LAP based on specific criteria such as Ar-A, PAS, and ΔE/A.](image)
Perioperative Assessment of Diastolic Dysfunction

Robina Matyal, MD,* Nikolaos J. Skubas, MD,† Stanton K. Sherman, MD,‡ and Feroze Mahmood, MD*

Mitral E/A

E/A < 1 or E ≤ 50 cm/sec

E/A ≥ 1 - < 2 or E/A < 1 or E > 50 cm/sec

E/A ≥ 2, DT < 150 ms

E/E’ (avg) < 8
E/E’ ≥ 8

E/Vp < 1.4
E/Vp ≥ 2.5

S/D > 1
S/D < 1

Ar-A < 0 ms
Ar-A ≥ 30 ms

Valsalva Δ < 0.5
Valsalva Δ ≥ 0.5

PAS < 30 mm Hg
PAS > 35 mm Hg

Normal LAP

Increased LAP

Normal LAP

Increased LAP

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September 2011 • Volume 113 • Number 3
Heart rate and diastolic function

Kaplan Cardiac anesthesia 1998
Heart rate and diastolic function

Graph showing the relationship between pressure (mmHg) and volume (mL/m²) at two different heart rates: 110 bpm (green line) and 84 bpm (blue line). The graph indicates how diastolic function changes with varying heart rates.
Heart rate and diastolic function

Kaplan Cardiac anesthesia 1998
Pericardial Restraint

LVP

LVV
Pericardial Restraint
Volume

Pressure

Wedge = 5

Wedge = 10

Volume
Acute abdominal compartment syndrome

Nancy Deslauriers, MD · Renée Déry, MD · André Denault, MD
Diastolic dysfunction

↓

Systolic function

Abnormal

Systolic heart failure

Left

Secondary diastolic dysfunction

Normal

Diastolic heart failure

Right

Filling pressure

Reduced

Normal

Elevated
Plan

• Is it important to evaluate diastolic function?
• Can we monitor LV diastolic function intraoperatively or in the intensive care unit?
• Echocardiographic and non-echocardiographic bedside indices of diastolic function.
• Is left more important than right ventricular diastolic function evaluation?
• How we approach it in the operating room and in the intensive care unit?
• How to treat diastolic function?
Diastolic function: therapeutic approach
Hemodynamic Pressure Waveform Analysis in Predicting Fluid Responsiveness

Sébastien Roy, MD,* Pierre Couture, MD,* Baqir Qizilbash, MD,* Francis Toupin, MD,* Sylvie Levesque, MSc,† Michel Carrier, MD,‡ Jean Lambert, PhD,§ and André Y. Denault, MD, PhD*

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Responders (N=24)</th>
<th>Non-Responders (N=13)</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>△SV·post·bolus (%)*</td>
<td>33±16</td>
<td>8±6</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>CVP·(mm·Hg)*</td>
<td>9±3</td>
<td>9±3</td>
<td>0.6</td>
</tr>
<tr>
<td>PCWP·(mm·Hg)*</td>
<td>11±3</td>
<td>12±3</td>
<td>0.57</td>
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<tr>
<td>a/v·ratio·(CVP)*</td>
<td>1.16±0.14</td>
<td>1.18±0.09</td>
<td>0.67</td>
</tr>
<tr>
<td>a/v·ratio·(PCWP)*</td>
<td>1.07±0.07</td>
<td>0.96±0.1</td>
<td>0.0001</td>
</tr>
<tr>
<td>dp/dt·RV·(mm·Hg/s)*</td>
<td>4.70±2.21</td>
<td>5.83±2.05</td>
<td>0.32</td>
</tr>
</tbody>
</table>

JTCVA 2013
Diastolic function: therapeutic approach
Diastolic function: therapeutic approach
Diastolic function: therapeutic approach

Systolic function
- Abnormal
  - Systolic heart failure
    - Left
    - Right
  - Secondary diastolic dysfunction
- Normal
  - Diastolic heart failure
  - Filling pressure
    - Reduced
    - Normal
    - Elevated
  - Tachycardia
    - Congenital heart disease
    - Cardiac tumor
    - Cardiomyopathy hypertrophic
    - Valvular heart disease
- Other conditions
  - Extra-cardiac
    - Pericardial
    - Thoracic
    - Abdominal
Milrinone enhances systolic, but not diastolic function during coronary artery bypass grafting surgery

Pierre Couture MD FRCPC,* André Y. Denault MD FRCPC,* Michel Pellerin MD FRCPS,† Jean-Claude Tardif MD FRCPC‡
Uptodate 2016: HFpEF

• The treatment of HFpEF is largely governed by management of associated conditions and symptoms since trial data are limited.
  – control of pulmonary congestion and peripheral edema with diuretics,
  – treatment of systolic hypertension,
  – prevention of rapid heart rates, particularly in patients with atrial fibrillation
  – coronary revascularization in patients with coronary heart disease with ischemia judged to contribute to symptoms of HF
Diastolic function: therapeutic approach
Cardiac output monitor: capnography

\[ \text{Predicted PAQ}t = 5.1 \left( \text{P}_{et}\text{CO}_2 \right) / \left( 63 - \text{P}_{et}\text{CO}_2 \right) \]

Heart rate optimisation
Homme de 70 ans instable après RVA
Diastolic function: therapeutic approach
Summary..

- History and physical exam
- EKG: LVH and atrial waves
- Hemodynamic waveform analysis
- Response to volume and heart rate control
- 2D and Doppler echocardiography
- Chest ultrasound
- Treatment according to the grade and etiology of diastolic dysfunction
- Research needed +++
Summary

• Is it important to evaluate diastolic function?
• Can we monitor LV diastolic function intraoperatively or in the intensive care unit?
• Echocardiographic and non-echocardiographic bedside indices of diastolic function.
• Is left more important than right ventricular diastolic function evaluation?
• How we approach it in the operating room and in the intensive care unit?
• How to treat diastolic function?
“We are like children playing on the seashore and diverting ourselves now and then, finding a smoother pebble or a prettier shell than ordinary, whilst the greater ocean of truth lies all undiscovered before us”

Sir Isaac Newton
L’équipe de recherche:

Denis Babin
MSc Inh

Jean-Claude Tardif
MD FRCP

Jean Lambert PhD
Biostatistique

Alain Deschamps
MD FRCPC PhD

Louis P.Perrault
MD PhD FRCSC

Pierre Couture
MD FRCPC

Jean-Claude Tardif
MD FRCP
Limitations in the evaluation of diatolic function

- Sensitivity of non-echocardiographic diagnosis unknown?
- Doppler more sensitive but specificity unknown
- Value if tachycardia, MR, non-sinus rhythm, pacemaker?
- If not reversible: ischemia? Stunning? Hibernating myocardium?
- Significance during non-cardiac surgery?
Therapy in Diastolic dysfunction

- Beta-blockade: first choice if grade I
  - Increase E wave DT
- Calcium antagonist
  - Reduction in heart rate?
- ACE inhibitor
  - Reduction in LV mass
- Angiotensin II receptor blockade
- Others:
  - Anti-ischemic therapy
  - Synthroid
  - Nitroglycerine
  - Cardioversion
  - Exercice
• Hung et al Int J Clin Practice 2002 (2001 Echocardiography)
  – n = 15 heart failure class 2-3) Agent: verapamil 120 mg daily
• Torre-Amione Chest 2001
  – n = 8 Heart failure IV tezosentan vs placebo
  – Result: improved diastolic function
  – Result: improved systolic and diastolic function
• Monzani et al JCEM 2001
  – N = 20 subclinical hypothyroid patients with syntroid vs placebo
  – Result: improvement in both systolic and diastolic function
• Brilla et al Circulation 2000
  – N = 35 HBP with lisinipril vs HCTZ
  – Result: increased early filling, A velocity and reduced IVRT
• VISOR study Cardiovasc Drug Therapy 1999
  – N = 70 acute AMI thrombolysed verapamil or placebo (6 months)
  – Result: prevention of changes observed in diastolic function post AMI
• Ghaisas et al Am Heart J 1998
  – N = 24 in nitro in restrictive or non-restrictive group
  – Result: E to A ratio decreased in the restrictive group
• Grenberg Circulaiton 1995
  – N = 301 patients with LV dysfunction with enalapril or placebo
  – Result: reduction in E to A ratio in the enalapril group (ANF correlation)
• Gosse et al Jcardiovas pharm 1990
  – N = 56 HBP with ACE or bisoprolol
  – Result: improved E/A ration with bisoprolol
Effects of halothane and isoflurane on left ventricular diastolic function during surgical stress in patients with coronary artery disease.
L’équipe de recherche: