Recommendations for Multimodality Imaging of Patients with Pericardial Diseases

Steven A. Goldstein  MD  FACC  FASE
Professor of Medicine
Georgetown University Medical Center
MedStar Heart Institute
Washington Hospital Center
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DISCLOSURE

I have NO relevant financial relationships
Introduction
Must Reading . . .
ASE EXPERT CONSENSUS STATEMENT

American Society of Echocardiography Clinical Recommendations for Multimodality Cardiovascular Imaging of Patients with Pericardial Disease

Endorsed by the Society for Cardiovascular Magnetic Resonance and Society of Cardiovascular Computed Tomography

Allan L. Klein, MD, FASE, Chair, Suhny Abbara, MD, Deborah A. Agler, RCT, RDCS, FASE, Christopher P. Appleton, MD, FASE, Craig R. Asher, MD, Brian Hoit, MD, FASE, Judy Hung, MD, FASE, Mario J. Garcia, MD, Itzhak Kronzon, MD, FASE, Jae K. Oh, MD, FASE, E. Rene Rodriguez, MD, Hartzell V. Schaff, MD, Paul Schoenhagen, MD, Carmela D. Tan, MD, and Richard D. White, MD, Cleveland and Columbus, Ohio; Boston, Massachusetts; Weston, Florida; Scottsdale, Arizona; Rochester, Minnesota; Bronx and New York, New York

Klein J Am Soc Echocardiogr 2013;26:965-1012
European Association of Cardiovascular Imaging (EACVI) position paper: multimodality imaging in pericardial disease

Bernard Cosyns\textsuperscript{1*}, Sven Plein\textsuperscript{2}, Petros Nihoyanopoulos\textsuperscript{3}, Otto Smiseth\textsuperscript{4}, Stephan Achenbach\textsuperscript{5}, Maria Joao Andrade\textsuperscript{6}, Mauro Pepi\textsuperscript{7}, Arsen Ristic\textsuperscript{8}, Massimo Imazio\textsuperscript{9}, Bernard Paelinck\textsuperscript{10}, and Patrizio Lancellotti\textsuperscript{11} On behalf of the European Association of Cardiovascular Imaging (EACVI) and European Society of Cardiology Working Group (ESC WG) on Myocardial and Pericardial diseases
2015 ESC Guidelines for the diagnosis and management of pericardial diseases

The Task Force for the Diagnosis and Management of Pericardial Diseases of the European Society of Cardiology (ESC)

Endorsed by: The European Association for Cardio-Thoracic Surgery (EACTS)

Authors/Task Force Members: Yehuda Adler* (Chairperson) (Israel), Philippe Charron* (Chairperson) (France), Massimo Imazio† (Italy), Luigi Badano (Italy), Gonzalo Barón-Esquivias (Spain), Jan Bogaert (Belgium), Antonio Brucato (Italy), Pascal Gueret (France), Karin Klingel (Germany), Christos Lionis (Greece), Bernhard Maisch (Germany), Bongani Mayosi (South Africa), Alain Pavie (France), Arsen D. Ristić (Serbia), Manel Sabaté Tenas (Spain), Petar Seferovic (Serbia), Karl Swedberg (Sweden) and Witold Tomkowski (Poland)
Pericardium is a 2-layered sac

- **Parietal** → outer, thicker, fibrous layer
  → ≤ 2 mm (abnormal ≥ 4 mm
  → mostly acellular

- **Visceral** → thin, inner, serous layer

Normally contains ≈ 25 ml fluid
Anterior Portion of Pericardial Sac Removed

Note: Proximal portions of great vessels are intrapericardial

modified from Klein J Am Soc Echocardiogr 2013;26:965-1012
Iodinated contrast inadvertently injected into pericardial space during an attempted pulmonary angiogram.

Pericardial Syndromes

- Pericarditis
  - Acute pericarditis
  - Recurrent pericarditis
  - Incessant and chronic pericarditis
  - Myopericarditis

- Pericardial effusion

- Cardiac tamponade

- Constrictive pericarditis
  - Chronic constrictive pericarditis
  - Effusive-constrictive pericarditis
  - Transient pericarditis
Pericardial Diseases

- Wide spectrum of pericardial diseases
- Imaging essential for diagnosis, complications, management
- 3 main techniques: Echo, CT, MRI
- Each has strengths and limitations
- Often complementary: may need 1 or multiple
- TTE is first-line imaging modality
Why Echo is Firstline Imaging Test

• Readily, widely available, portable
• Low cost, safe
• Can be performed at bedside
• Can be performed in urgent situations
• Can be performed with respirometer
• Comprehensive → anatomy and physiology
Limitations of TTE

• Dependence on good windows
• Inability to image entire pericardium
• Limited tissue characterization
• Not accurate for pericardial thickness
  (CT and MRI superior for thickness)
Strengths of CT-scan

- Measurement of pericardial thickness
- Evaluation of associated/extracardiac disease (pleural effusions, postradiation fibrosis, malignancy, cirrhosis, ascites)
- Detection of pericardial calcification
- Pre-operative planning
CT-Scan for Pericardial Thickening

Thickening of pericardium
Bilateral pleural effusions

Otto Textbook of Clinical Echocardiography 6th ed; p284
CT-Scan for Pericardial Disease

- CT attenuation of peric. similar to myocardium
- Pericardium can only be seen when surrounded by fat
- Appears as thin line on anterior surface
- Esp. useful for detecting calcification

continued . . . .
CT-Scan for Pericardial Disease

- Useful for size of atria and vena cavae
- Character of pericardial fluid:
  - Pericardial effusion $\rightarrow$ 0-20 Hounsfield units
  - Hemorrhagic effusion $\rightarrow$ $\geq$ 30 Hounsfield units
  - Purulent effusion $\rightarrow$ $\geq$ 50 Hounsfield units
Limitations of CT-scan

- Ionizing radiation; iodinated contrast
- Functional evaluation
  (only possible with retrospective-gated studies)
- Difficult in cases of arrhythmias
- Need for breath hold
- Hemodynamically stable patients only
Cardiac MRI for Pericardial Effusion

• More detailed visualization than TTE (especially loculated or regional)

• May help differentiate transudate vs exudate

• Useful in myopericarditis
  - Myocardial edema
  - Hyperremia (capillary leak)
  - Myocardial fibrosis
Cardiac MRI for Pericardial Thickening

Thickening of pericardium
- At apex
- Around lateral LV wall
- Anterior to the RV

Otto  Textbook of Clinical Echocardiography  6th ed; p284
Limitations of MRI

• Time consuming, high cost
• Difficult in cases with arrhythmias
• Calcifications not well-visualized
• Gadolinium (not recommended if GFR < 30 mL/min)
• Need for breath hold
• Hemodynamically stable patients only
## Table 1: Comparison of multimodality imaging modalities in the evaluation of pericardial diseases

<table>
<thead>
<tr>
<th></th>
<th>Echocardiography</th>
<th>CT</th>
<th>CMR</th>
</tr>
</thead>
</table>
| **Main strengths**    | - First-line imaging test in the diagnostic evaluation of pericardial disease  
                        | - Readily available                                | - Second-line for better anatomic delineation    |
|                       | - Low cost                                            | - Evaluation of associated/extracardiac disease  | - Superior tissue characterization               |
|                       | - Safe                                                | - Preoperative planning                          | - Evaluation of inflammation                    |
|                       | - Can be performed at bedside or urgent situations    | - Evaluation of pericardial calcification        |                                                  |
|                       | - Portable                                            |                                                  |                                                  |
|                       | - TEE available for better evaluation                 |                                                  |                                                  |
|                       | - High frame rate                                     |                                                  |                                                  |
|                       | - Can be performed with respirometer                  |                                                  |                                                  |
| **Main weaknesses**   | - Limited windows, narrow field of view               | - Use of ionizing radiation                      | - Time-consuming, high cost                     |
|                       | - Technically limited with obesity, COPD, or postoperative setting | - Use of iodinated contrast                      | - Preferably stable heart rhythms               |
|                       | - Relatively operator dependent                        | - Functional evaluation only possible with retrospective gated studies (higher radiation dose, suboptimal temporal resolution) | - Relatively contraindicated in case of pacemaker or ICD |
|                       | - Low signal-to-noise ratio of the pericardium        | - Difficulties in case of tachycardia or unstable heart rhythm (particularly for prospective gated studies) | - Lung tissue less well visualized            |
|                       | - Limited tissue characterization                      | - Need for breath-hold                            | - Calcifications not well seen                  |
|                       |                                                      | - Hemodynamically stable patients only           | - Use of gadolinium contrast contraindicated in case of advanced renal dysfunction (glomerular filtration rate <30 mL/min) |
|                       |                                                      |                                                  | - Use of some breath-hold sequences             |
|                       |                                                      |                                                  | - Hemodynamically stable patients only          |
# Cardiac MRI for the Pericardium

## TABLE 1: MRI Sequences and Planes Used to Evaluate the Pericardium

<table>
<thead>
<tr>
<th>Sequence</th>
<th>Planes</th>
<th>Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scouts</td>
<td>Axial, sagittal, coronal</td>
<td>Localizing</td>
</tr>
<tr>
<td>HASTE FSE</td>
<td>Axial</td>
<td>Define anatomy and plan subsequent views</td>
</tr>
<tr>
<td>Cine SSFP</td>
<td>Vertical long-axis, horizontal long-axis, short-axis, four-chamber, LVOT</td>
<td>Evaluate function, volumes, masses</td>
</tr>
<tr>
<td>Myocardial tagging</td>
<td>LV short-axis × 3 (i.e., base, mid, distal), vertical long-axis, four-chamber, LVOT</td>
<td>Evaluate pericardial movement</td>
</tr>
<tr>
<td>T1 and T2 FSE</td>
<td>Vertical long-axis, short-axis, four-chamber, LVOT</td>
<td>Assess pericardial morphology</td>
</tr>
<tr>
<td>T2 FSE STIR</td>
<td>Vertical long-axis, short-axis, four-chamber, LVOT</td>
<td>Evaluate for pericardial edema due to inflammation</td>
</tr>
<tr>
<td>Velocity-encoded* phase-contrast</td>
<td>Mid ascending aorta</td>
<td>Assess aortic flow and flow pattern of SVC and pulmonary vein</td>
</tr>
<tr>
<td>Early contrast-enhanced T1-weighted FSE</td>
<td>Vertical long-axis, short-axis, four-chamber, LVOT</td>
<td>Evaluate for inflammation, masses</td>
</tr>
<tr>
<td>Delayed enhancement</td>
<td>Vertical long-axis, short-axis, four-chamber, LVOT</td>
<td>Evaluate for pericardial inflammation and fibrosis, masses</td>
</tr>
<tr>
<td>Real-time imaging</td>
<td>Short axis, mid ventricle</td>
<td>Evaluate for ventricular interdependence</td>
</tr>
</tbody>
</table>

Note—FSE = fast spin-echo, SSFP = steady-state free precession, LVOT = left ventricular outflow tract, SPAMM = spatial modulation of magnetization, LV = left ventricular, SVC = superior vena cava.

*Velocity encoding = 200 cm/s.
# Cardiac MRI for the Pericardium

## Features that Differentiate Thickening and Effusion

<table>
<thead>
<tr>
<th>Features</th>
<th>Effusion</th>
<th>Thickening</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signal in T1- and T2-weighted images</td>
<td>Signal void</td>
<td>Gray (except in calcification)</td>
</tr>
<tr>
<td>Signal in SSFP and GRE</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Margins</td>
<td>Smooth</td>
<td>Irregular or nodular</td>
</tr>
<tr>
<td>Location</td>
<td>Follows distribution typical of effusion</td>
<td>Does not follow typical distribution of effusion</td>
</tr>
<tr>
<td>Decubitus position</td>
<td>Change in configuration</td>
<td>No change in configuration</td>
</tr>
<tr>
<td>Tagging</td>
<td>Loss of tags with cardiac cycle</td>
<td>Persistent lines throughout cardiac cycle</td>
</tr>
<tr>
<td>Contrast enhancement</td>
<td>None</td>
<td>May be present if associated with inflammation</td>
</tr>
</tbody>
</table>

Rajiah  AJR 2011;197-Oct:W621-W634
What Do CT and MRI Add?

- Measurement of pericardial thickness
- Distribution of pericardial calcium
- Evaluation of pericardial inflammation
- Functional effects of the constrictive process
When to Utilize CT and/or MRI

- Inconclusive TTE and ongoing clinical concern
- Failure to respond promptly to anti-inflammatory rx
- Prior to pericardiectomy (pre-op planning)
- Search for a specific cause
- Suspicion of constrictive pericarditis
- Concern for transient constriction
- Acute pericarditis in the setting of acute MI, neoplasm, lung or infectious, or pancreatitis
Fat
Case 90

62 year-old obese male
STEMI

Epicardial and paracardial fat
Pericarditis
Acute Pericarditis

**Note:** Pericardial effusion present in only $\approx 50\%$ of patients
Acute Pericarditis

Incidence of Adverse Events

- Myocardial involvement: ~15%
- Cardiac tamponade: ~1-2%
- Recurrent pericarditis: ~15-30%
- Constrictive pericarditis: ~1-2%

Cremer J Am Coll Cardiol 2016;68(21):2311-28
Effusion
Ultrasound Diagnosis of Pericardial Effusion

Harvey Feigenbaum, MD, John A. Waldhausen, MD, and Lloyd P. Hyde, MD

The differentiation between a large, dilated heart and pericardial effusion is essential but frequently difficult. The clinician must often resort to diagnostic procedures which offer some hazard to the patient. The use of reflected ultrasound was found to be a highly effective and simple method of making this differential diagnosis. In five dogs with artificially produced pericardial effusion it was noted that without pericardial fluid only one ultrasound echo was produced in the vicinity of the posterior heart wall. When fluid was introduced, one detected two echoes, one which moved with cardiac action, the posterior heart wall, and another which moved only with inspiration, the pericardium. The space between the two signals represented the pericardial fluid. Subsequent clinical studies confirmed the accuracy, reliability, and simplicity of this diagnostic procedure.
Pericardial Effusion
Role of Echocardiogram

- Detection of pericardial effusion
  (distinguish from pleural effusion)
- Semiquantitation of pericardial effusion
- Determine hemodynamic significance
- Diffuse vs loculated
- Determine best site for pericardiocentesis
## Size of Pericardial Effusions

### Semiquantitative Grading

<table>
<thead>
<tr>
<th>Grade</th>
<th>Echo-free space Klein (ASE)</th>
<th>(end-diastole) Otto</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trivial</td>
<td>only in systole</td>
<td>-</td>
</tr>
<tr>
<td>Small</td>
<td>&lt; 1 cm</td>
<td>&lt;0.5 cm</td>
</tr>
<tr>
<td>Moderate</td>
<td>1 to 2 cm</td>
<td>0.5 – 2.0 cm</td>
</tr>
<tr>
<td>Large</td>
<td>&gt; 2 cm</td>
<td>&gt;2.0 cm</td>
</tr>
<tr>
<td>Very large</td>
<td>&gt; 2.5 cm</td>
<td>-</td>
</tr>
</tbody>
</table>

Klein ASE Consensus Statement J Am Soc Echocardiogr 2013;26:965-1012
Otto Textbook of Clinical echocardiography, 6th ed, 2018
### Estimation of Amount of Pericardial Effusion

*(perpendicular to ventricular walls in diastole)*

<table>
<thead>
<tr>
<th>Minimal pericardial effusion</th>
<th>Seen only in systole</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 1 cm</td>
<td>~ 300 mL</td>
</tr>
<tr>
<td>1 – 2 cm</td>
<td>~ 500 mL</td>
</tr>
<tr>
<td>&gt; 2 cm</td>
<td>typically &gt; 700 mL</td>
</tr>
</tbody>
</table>
Size of Pericardial Effusions

Arbitrary Partitions

<table>
<thead>
<tr>
<th>Size</th>
<th>Volume Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small</td>
<td>50 – 100 mL</td>
</tr>
<tr>
<td>Moderate</td>
<td>100 – 500 mL</td>
</tr>
<tr>
<td>Large</td>
<td>&gt; 500 mL</td>
</tr>
</tbody>
</table>

Klein ASE Consensus Statement  J Am Soc Echocardiogr 2013;26:965-1012
1 cm circumferential rim of pericardial effusion

\[ V = \frac{4}{3} \pi r^3 \]

285 cc

525 cc
Pericardial Effusion: Type of Fluid

- Transudate
- Exudate
- Blood
- Pus
- Partially organized fluid
  - Fibrin
  - Hematoma
Pericardial Effusion: Differential Diagnosis

1. Pleural effusion
2. Pericardial cyst
3. Mediastinal fluid
4. Pseudoaneurysm
5. Epicardial fat
6. Ascites
Case

SM - 51 year-old woman

Pericardial and pleural effusion
RC - 69 year-old woman

Pericardial effusion and thickened pericardium
Case

MLD - 74 year-old woman

Small pericardial effusion and RA collapse
No tamponade
Hydrodynamic compression of the right atrium: a new echocardiographic sign of cardiac tamponade

Linda D. Gillam, M.D., David E. Guyer, M.D., Thomas C. Gibson, M.D., Mary Etta King, M.D., Jane E. Marshall, B.S., and Arthur E. Weyman, M.D.

ABSTRACT The relationship of right atrial inversion, a previously undescribed cross-sectional echocardiographic sign, to the presence of cardiac tamponade was examined. We studied 127 patients with moderate or large pericardial effusions. Cardiac tamponade was present in 19 and absent in 104. Four patients with equivocal tamponade were excluded from analysis. Right atrial inversion was present in 19 of 19 patients with cardiac tamponade and 19 of 104 without cardiac tamponade (sensitivity, 100%; specificity, 82%; predictive value, 50%). The degree of inversion as quantitated by the area-corrected curvature did not improve the ability to discriminate between patients with and without cardiac tamponade. However, consideration of the duration of inversion by the right atrial inversion time index (duration of inversion/cardiac cycle length) and an empirically derived cut-off of 0.34 did improve the specificity and predictive value (100% and 100%, respectively) without a significant loss of sensitivity (94%). We conclude that right atrial inversion, particularly if prolonged, is a useful echocardiographic marker of cardiac tamponade that may be of particular diagnostic value when the clinical picture is unclear.

Case

RD - 77 year-old man
Massive pericardial effusion
Case

GR - 53 year-old man
“Swinging Heart”
Case

LAA surrounded by fluid
Case

Moderate size effusion

RA invagination relatively short
Case

TEE
Tamponade
Tamponade *not* all-or-none phenomenon
Cardiac Tamponade
Definition

Accumulation of fluid in the pericardium in an amount sufficient to cause restriction to filling
Pathophysiology of Tamponade

Accumulation of fluid in pericardial sac

Rise in intrapericardial pressure

Increase in ventricular filling pressures
Greater interdependence of ventricles when heart constrained by fluid

Filling of one ventricle influences filling of the other
Inspiratory increase in RV volume occurs at expense of LV cavity

Septum shifts toward LV

Reduces LV filling

Reduces stroke volume
Tamponade (in inspiration)

Inspiration: pericardial pressure falls from 20 to 18 mmHg
venous return increases (arrows)
right heart volume increases (septal bulging)
Extrapericardial venous pressure falls more than intracardiac pressure during inspiration

Reduces LV filling

Reduces stroke volume
Development of Tamponade Depends On:

- Distensibility of the pericardium
- Amount of fluid
- Speed of fluid accumulation
Pericardial Pressure-Volume Curves

Rapid Pericardial Effusion

- Cardiac Tamponade
- Limit of pericardial stretch
- Pericardial reserve volume

Slow Pericardial Effusion

- Cardiac Tamponade
- Limit of pericardial stretch
- Pericardial reserve volume
Cardiac Tamponade
2D-Echo Features

- RA diastolic collapse (>one third of systole)
- RV diastolic collapse
- Reciprocal variation in ventricular chamber size throughout respiratory cycle
- LA end-diastolic collapse
- Lack of IVC inspiratory collapse
- Swinging heart
- LV pseudohypertrophy
RA Systolic Collapse

- Inversion/collapse RA free wall
- Longer duration of inversion likely tamponade
- Inversion > 1/3 systole — 94% Sensitive
  100% Specific
RV Diastolic Collapse

- Intrapericardial pressure > RV diastolic pressure
- Sensitivity: 60-90%
- Specificity: 85-100%
Cardiac Tamponade
Doppler Features

- Exaggerated inspiratory decrease in mitral inflow velocity
- Exaggerated inspiratory increase in tricuspid inflow velocity
- IVC/SVC: decrease in flow velocity with exp’n
Cardiac Tamponade
Mitral Inflow Pattern
Cardiac Tamponade
Diastolic Collapse of Right Ventricle
Cardiac Tamponade
Right Atrial Collapse
Hydrodynamic compression of the right atrium: a new echocardiographic sign of cardiac tamponade

LINDA D. GILLAM, M.D., DAVID E. GUYER, M.D., THOMAS C. GIBSON, M.D., MARY ETTA KING, M.D., JANE E. MARSHALL, B.S., AND ARTHUR E. WEYMAN, M.D.

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# Right Atrial Inversion

<table>
<thead>
<tr>
<th></th>
<th>Cardiac tamponade</th>
<th>No cardiac tamponade</th>
</tr>
</thead>
<tbody>
<tr>
<td>RA inversion</td>
<td>19</td>
<td>19</td>
</tr>
<tr>
<td>No RA inversion</td>
<td>0</td>
<td>85</td>
</tr>
</tbody>
</table>

- **Sensitivity**: 100%
- **Specificity**: 82%
- **Pred Value**: 50%
- **Accuracy**: 85%

Gillam, Circulation 1983;68:294-301  
$P < 0.001$
Duration of RA Collapse

Gillam  Circulation 1983;68:294-301
## Separation of Groups by RA Inversion Time Index

<table>
<thead>
<tr>
<th></th>
<th>Cardiac tamponade</th>
<th>No cardiac tamponade</th>
</tr>
</thead>
<tbody>
<tr>
<td>RAITI &gt;0.34</td>
<td>17</td>
<td>0</td>
</tr>
<tr>
<td>RAITI &lt;0.34</td>
<td>1</td>
<td>18</td>
</tr>
</tbody>
</table>

- Sensitivity: 94%
- Specificity: 100%
- Pred Value: 100%
- Accuracy: 97%

Gillam, Circulation 1983;68:294-301  

$P < 0.0005$
Case

Tamponade
Cardiac Tamponade
Diastolic Collapse of Right Ventricle
Case

AR - 24 year-old woman

Tamponade
Exaggerated Respiratory Variation

- Cardiac tamponade
- Constricive pericarditis
- COPD
- Pulmonary embolus
- Hypovolemia
- Obesity
- Labored respiration
Constriction

Consider in all patients with unexplained right heart failure, esp when LVF normal
Structural Heart Disease

Echocardiographic Diagnosis of Constrictive Pericarditis
Mayo Clinic Criteria

Terrence D. Welch, MD; Lieng H. Ling, MBBS, MD; Raul E. Espinosa, MD; Nandan S. Anavekar, MBBCh; Heather J. Wiste, BA; Brian D. Lahr, MS; Hartzell V. Schaff, MD; Jae K. Oh, MD

Background—Constrictive pericarditis is a potentially reversible cause of heart failure that may be difficult to differentiate from restrictive myocardial disease and severe tricuspid regurgitation. Echocardiography provides an important opportunity to evaluate for constrictive pericarditis, and definite diagnostic criteria are needed.

Methods and Results—Patients with surgically confirmed constrictive pericarditis (n=130) at Mayo Clinic (2008–2010) were compared with patients (n=36) diagnosed with restrictive myocardial disease or severe tricuspid regurgitation after constrictive pericarditis was considered but ruled out. Comprehensive echocardiograms were reviewed in blinded fashion. Five principal echocardiographic variables were selected based on prior studies and potential for clinical use: (1) respiration-related ventricular septal shift, (2) variation in mitral inflow E velocity, (3) medial mitral annular e' velocity, (4) ratio of medial mitral annular e' to lateral e', and (5) hepatic vein expiratory diastolic reversal ratio. All 5 principal variables differed significantly between the groups. In patients with atrial fibrillation or flutter (n=29), all but mitral inflow velocity remained significantly different. Three variables were independently associated with constrictive pericarditis: (1) ventricular septal shift, (2) medial mitral e', and (3) hepatic vein expiratory diastolic reversal ratio. The presence of ventricular septal shift in combination with either medial e'≥9 cm/s or hepatic vein expiratory diastolic reversal ratio ≥0.79 corresponded to a desirable combination of sensitivity (87%) and specificity (91%). The specificity increased to 97% when all 3 factors were present, but the sensitivity decreased to 64%.

Conclusions—Echocardiography allows differentiation of constrictive pericarditis from restrictive myocardial disease and severe tricuspid regurgitation. Respiration-related ventricular septal shift, preserved or increased medial mitral annular e' velocity, and prominent hepatic vein expiratory diastolic flow reversals are independently associated with the diagnosis of constrictive pericarditis. (Circ Cardiovasc Imaging. 2014;7:526-534.)
Constrictive Pericarditis

Definition

An abnormally thickened* and rigid pericardium which causes restriction to diastolic filling

* note: up to 20% of pts have normal pericardial thickness
Pathophysiology of Constrictive Pericarditis

Thickened, scarred, and sometimes calcified pericardium

Layers become adherent

Limits diastolic distensibility ("imprisons" the heart)

Elevated and equal diastolic pressures:

Dissociation of intrathoracic and intracardiac pressures with respiration

Increased LV and RV interdependence

RA and JVP may increase with insp’n (Kussmaul’s)
Constrictive Pericarditis
Hemodynamic Characteristics

- Pericardial resistance in later 2/3 diastole
- Elevation and equalization of diastolic pressures
- Venous return biphasic: prominent “X” and “Y”
  - ↓ intracardiac volume, SV, CO
- Insp augmentation of venous return blunted
- Kussmaul’s sign
- Pulsus paradoxus uncommon (33%)
- Ventricular discordance
Constrictive Pericarditis
Pathophysiology

2 keys

1. Dissociation of intrathoracic and intracardiac pressures

2. Enhanced ventricular interaction
Constriction (in inspiration)
Normal Physiology

Inspiratory decrease in intrathoracic pressure is transmitted to the heart

IT = intrathoracic
PV = pulm veins
IP = intrapericardial

Inspiratory decrease in intrathoracic pressure is transmitted to the heart
Inspiration results in a ↓LV filling pressure gradient due to smaller pressure decrease in the pericardium and LV compared to PCWP
These dynamic changes can be used to diagnose constrictive pericarditis and to differentiate CP from restrictive CM.
Constrictive Pericarditis

**Diagnosis**

- Dx can be straightforward when clinical, hemo-dynamic, and echo-Doppler findings typical

- But dx often elusive, even after extensive evaluation

- **Echo-Doppler** → initial and key test
Constrictive Pericarditis

Echo is the cornerstone
Constrictive Pericarditis
M-Mode Echo

- Ventricular dimensions usually normal
- Ventricular function is preserved
- Pericardial thickening (only up to 40%)
- Left atrial enlargement (75%)
- Premature pulmonic valve opening (≤10%)
- Paradoxic septal motion - "diastolic septal bounce"
- Diastolic flattening of LV posterior wall motion
Constrictive Pericarditis
Constrictive Pericarditis
2D-Echo

- Ventricular dimensions usually normal
- Ejection fraction usually preserved
- Biatrial enlargement
- Diastolic "septal bounce"
- IVC usually dilated
Constrictive Pericarditis

The encasement of the heart with a rigid and noncompliant pericardial sac (thickened, inflamed, or adherent and sometimes calcified) results in a fixed intrapericardial volume resulting in impaired diastolic function. M-mode echo, 2D echo, Doppler, and tissue Doppler provide key information.

1. **Pericardial thickness.** Because the pericardium is usually more echogenic than other cardiac structures, it can be difficult to distinguish thickened from normal pericardium. But look carefully in both PLAX and subcostal views for absence of pericardial slippage which may be present due to tethering of the thickened and/or inflamed pericardium to the heart.

2. **Septal bounce.** Usually the size and contractility of the left ventricle are normal; however, an abrupt early diastolic posterior motion of the ventricular septum (septal bounce) is usually present. Remember that the septal bounce is related to respiration. Therefore, in order to appreciate the septal bounce, several 5-10 beat loops should be acquired. With 2D echo this is often best demonstrated in apical four-chamber view. In addition, this is often well illustrated by M-mode echocardiography from PLAX view. Therefore, get several strips of M-mode echo with reduced sweep speed to include 1 or 2 respiratory cycles.

3. **Ventricular interaction.** Identification of exaggerated respiratory variations in diastolic filling and ventricular outflow showing evidence of enhanced ventricular interaction are very useful in supporting the diagnosis of constrictive pericarditis (CP). Therefore, obtain PW Doppler of mitral and tricuspid flow patterns with respirometer to show these variations. Decrease sweep speed to show many beats and take several clips. Mitral inflow pattern typically shows a prominent E-wave, rapid early diastolic deceleration slope, and a small A-wave. Respiratory variations of greater than 25-30% in mitral E-wave velocity are expected. Also take several clips of Ap-4 chamber view with 6-10 beats per clip (to look for ventricular interaction).

4. **Annulus reversus.** In the normal individual, the lateral e’ velocity is higher than the septal (medial) e’ velocity. However in CP, the lateral e’ velocities are lower than the medial e’ velocity. As this is reversed of what is normally seen, the term *annulus reversus* has been coined. Therefore perform carefully done TDI of septum and lateral walls.

5. **Annulus paradoxus.** The transmitral E to TDI e’ ratio (E/e’) has a positive relationship with left ventricular filling pressures; that is, the higher the E/e’ ratio, the higher the left ventricular filling pressures. However, in constrictive pericarditis the medial TDI e’ velocity is usually preserved or even increased, despite the presence of elevated left ventricular filling pressures. Therefore, in patients with constrictive pericarditis, there is an inverse relationship between E/e’ ratio and left ventricular filling pressures. That is, despite high left ventricular filling pressures, the E/e’ ratio is normal or low. This is "paradoxic" to what is expected and for this reason the term "annulus paradoxus" has been proposed to describe the relationship between a low E/e’ ratio and the elevated left ventricular filling pressures in patients with CP.

6. **IVC** – obtain long clips to look for distension and inspiratory collapse

7. **Hepatic vein flow** - Obtain hepatic vein flow with decreased sweep speed (multiple clips)

**Note:** Strongly suggest that you speak to MD supervisor prior to study for instructions.
Case
Constrictive Pericarditis

Annulus Reversus

Medial velocity greater than lateral velocity

(≈ 75% constriction cases)
With CHF, consider constriction if septal $e' > 8$ cm/s
CP vs RCM $\rightarrow e' < 7$ cm/s supports RCM

modified from Mayo Clinic
Constrictive Pericarditis

Diastolic Hepatic Vein Reversal

Prominent diastolic flow reversals in expiration
Global longitudinal strain is nearly normal (-17.8%). Lateral strain is reduced compared to septal strain (Due to the tethering effect of the diseased pericardium)

Otto Textbook of Clinical Echocardiography 6th ed; p284
Summary
Consider Constrictive Pericarditis

- Abnormal septal motion → "bounce"
- Dilated IVC and hepatic veins
- Restrictive filling pattern
- Exaggerated respiratory variation
- Normal tissue Doppler in CHF
- Expiratory diastolic reversal in hepatic veins
Pericardiocentesis

Discussed later - Interventional echo
Cardiac Tamponade

Echo-Guided Pericardiocentesis

1. Selection of puncture site

2. Confirmation of needle position by contrast injection

3. Ascertain completeness of drainage

*The position of the actual needle tip can rarely be ascertained*