Recommendations for Multimodality Imaging of Patients with Pericardial Diseases

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DISCLOSURE

I have NO relevant financial relationships
Introduction
European Association of Cardiovascular Imaging (EACVI) position paper: multimodality imaging in pericardial disease

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Eur Heart J – Cardiovasc Imaging 2015;16:12-31
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)

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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

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Klein J Am Soc Echocardiogr 2013;26:965-1012
Normal Pericardium

- Fibroserous sac
- Visceral and parietal layers
- Normally contains $\approx 25$ ml fluid
- Normal pericardium $\leq 2$ mm thick
- Abnormal $\rightarrow \geq 4$ mm thick
Pericardium is a 2-layered sac

- **Parietal** → outer, thicker, fibrous layer
- **Visceral** → thin, inner, serous layer
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
CT “Pericardiogram”

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
Specific Etiologies of Pericardial Syndromes

- Viral pericarditis
- Bacterial pericarditis (purulent pericarditis and Tbc)
- Pericarditis in renal failure
- Pericardial involvement in autoimmune and autoinflammatory disease
- Post-cardiac injury syndromes
- Traumatic pericardial effusion and hemopericardium
- Pericardial involvement in neoplastic diseases
- Misc: - Radiation pericarditis
  - Drug-related pericarditis and pericardial effusion
  - Pericardial effusion in pulmonary hypertension
Initial Assessment

- Careful history
- Physical exam
- ECG
- Chest X-ray

Imaging

- Echo (first-line)
- CT-scan
- CMR
Pericardial Diseases

- Wide spectrum of pericardial diseases
- Imaging essential for dx, complications, mgt
- 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 \(\rightarrow\) 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 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
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>
<tbody>
<tr>
<td><strong>Main strengths</strong></td>
<td>● First-line imaging test in the diagnostic evaluation of pericardial disease</td>
<td>● Second-line for better anatomic delineation</td>
<td>● Second-line for better anatomic delineation</td>
</tr>
<tr>
<td></td>
<td>● Readily available</td>
<td>● Evaluation of associated/extracardiac disease</td>
<td>● Superior tissue characterization</td>
</tr>
<tr>
<td></td>
<td>● Low cost</td>
<td>● Preoperative planning</td>
<td>● Evaluation of inflammation</td>
</tr>
<tr>
<td></td>
<td>● Safe</td>
<td>● Evaluation of pericardial calcification</td>
<td></td>
</tr>
<tr>
<td></td>
<td>● Can be performed at bedside or urgent situations</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>● Portable</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>● TEE available for better evaluation</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>● High frame rate</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>● Can be performed with respirometer</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Main weaknesses</strong></td>
<td>● Limited windows, narrow field of view</td>
<td>● Use of ionizing radiation</td>
<td>● Time-consuming, high cost</td>
</tr>
<tr>
<td></td>
<td>● Technically limited with obesity, COPD, or postoperative setting</td>
<td>● Use of iodinated contrast</td>
<td>● Preferably stable heart rhythms</td>
</tr>
<tr>
<td></td>
<td>● Relatively operator dependent</td>
<td>● Functional evaluation only possible with retrospective gated studies (higher radiation dose, suboptimal temporal resolution)</td>
<td>● Relatively contraindicated in case of pacemaker or ICD</td>
</tr>
<tr>
<td></td>
<td>● Low signal-to-noise ratio of the pericardium</td>
<td>● Difficulties in case of tachycardia or unstable heart rhythm (particularly for prospective gated studies)</td>
<td>● Lung tissue less well visualized</td>
</tr>
<tr>
<td></td>
<td>● Limited tissue characterization</td>
<td>● Need for breath-hold</td>
<td>● Calcifications not well seen</td>
</tr>
<tr>
<td></td>
<td></td>
<td>● Hemodynamically stable patients only</td>
<td>● Use of gadolinium contrast contraindicated in case of advanced renal dysfunction (glomerular filtration rate &lt;30 mL/min)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>● Use of some breath-hold sequences</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>● Hemodynamically stable patients only</td>
</tr>
</tbody>
</table>
# 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 3: MRI 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>
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 infection, or pancreatitis
After a two year loan to the United States, Michelangelo’s David is being returned to Italy.
His proud sponsors were:

- McDonald's
- Starbucks
- Burger King
Fat
Pericardial Effusion vs Fat

**Epicardial Fat**

- Increases with age and obesity
- Usually present only anteriorly
- Slightly higher echo-density than effusion
- CT is more definitive
Parietal Pericardium

Parapericardial fat

Epicardial fat over RV

modified from Klein J Am Soc Echocardiogr 2013;26:965-1012
Wm. C. Roberts  Chief Editor  Formaldehyde

1983  $\rightarrow$  5% hearts floated
2016  $\rightarrow$  52% hearts floated
Case

62 year-old obese male
STEMI

Epicardial and paracardial fat
Case

VW - 71 year-old woman
64” 186 lbs
BP 170/88

Epicardial fat within pericardial fluid
Pericarditis
Acute Pericarditis

Note: Pericardial effusion present in only ≈ 50% of patients
### Acute Pericarditis with Small or No Effusion (non-complicated effusion)

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>TTE to confirm clinical diagnosis</td>
<td>Recommended</td>
</tr>
<tr>
<td>CMR to confirm clinical diagnosis if clinical context of myocarditis</td>
<td>Recommended</td>
</tr>
<tr>
<td>CT/CMR to confirm clinical diagnosis if echo inconclusive</td>
<td>Not recommended</td>
</tr>
<tr>
<td>TEE if poor TTE quality of imaging</td>
<td>Not recommended</td>
</tr>
<tr>
<td>TTE for follow-up</td>
<td>Not recommended</td>
</tr>
</tbody>
</table>

Cosyns  EACVI Position Paper  Eur Heart F – CV Img 2015;16:12-31
### Acute Pericarditis with Complicated Course and/or Moderate-to-Severe Effusion and No Tamponade

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>TTE to confirm clinical diagnosis</td>
<td>Recommended</td>
</tr>
<tr>
<td>TEE if poor TTE quality</td>
<td>Recommended</td>
</tr>
<tr>
<td>TTE to indicate, contraindicate pericardiocentesis</td>
<td>Recommended</td>
</tr>
<tr>
<td>TTE to guide and for f/u of pericardiocentesis</td>
<td>Recommended</td>
</tr>
<tr>
<td>CT/CMR to confirm clinical diagnosis in case of high suspicion of aortic dissection</td>
<td>Reasonable</td>
</tr>
<tr>
<td>CT/CMR to confirm clinical diagnosis in case of trauma or associated disorders</td>
<td>Reasonable</td>
</tr>
<tr>
<td>CT/MRI to confirm clinical diagnosis if echo inconclusive</td>
<td>Reasonable</td>
</tr>
<tr>
<td>CMR to confirm clinical diagnosis of myocarditis</td>
<td>Recommended</td>
</tr>
<tr>
<td>CMR for f/u of pericardiocentesis</td>
<td>Reasonable</td>
</tr>
<tr>
<td>TTE for follow-up</td>
<td>Reasonable</td>
</tr>
</tbody>
</table>

Cosyns EACVI Position Paper  Eur Heart F – CV Img 2015;16:12-31
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
- Semiquantitation of pericardial effusion
- Determine hemodynamic significance of pericardial effusion
- Determine best site for pericardiocentesis
## Estimation of Amount of Pericardial Effusion

(perpendicular to ventricular walls in diastole)

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

### Semiquantitative Grading

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

Klein ASE Consensus Statement  J Am Soc Echocardiogr 2013;26:965-1012
### Size of Pericardial Effusions

**Arbitrary Partitions**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></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
## Classification of Pericardial Effusion

### 2015 ESC Guidelines

<table>
<thead>
<tr>
<th>Onset</th>
<th>Acute Subacute Chronic (&gt; 3 months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>Mild &lt; 10 mm Moderate 10-20 mm Large &gt; 20 mm</td>
</tr>
<tr>
<td>Distribution</td>
<td>Circumferential Loculated</td>
</tr>
</tbody>
</table>
1 cm circumferential rim of pericardial effusion

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

SM - 51-year-old woman

Pericardial and pleural effusion
Case

RC - 69 year-old woman

Pericardial effusion and thickened pericardium
Case

MLD - 74 year-old woman

Small pericardial effusion and RA collapse
No tamponade
Case

RD - 77 year-old man
Massive pericardial effusion
Case

GR - 53 year-old man

“Swinging Heart”
GR - 53 year-old man, longtime cigarette smoker
July, 2011 → pain in “neck muscles”
PMD → Chest X-ray → suspicious mass
Chest CT → bilat. nodules & hilar lymphadenopathy
Fine needle aspiration supraclavic node → cancer
Squamous cell lung cancer
Began cisplaten/pemetrexed chemotherapy
2D-echo performed
Case

LD - 70 year-old woman
Fluid around LA-appendage
Case

LAA surrounded by fluid
Case

Moderate size effusion

RA invagination relatively short
Case
Left pleural effusion - Tiger claw left
Right pleural effusion  -  Tiger claw right
Case
Which of the following is the best explanation for this echo-free space?

A. Pericardial effusion
B. Pleural effusion
C. Ascites
D. Mediastinal fluid
E. Pericardial cyst
The Falciform Ligament in the Echocardiographic Diagnosis of Ascites

Frank Patrick Cardello, MD, Dong-Hi Anthony Yoon, MD, Robert E. Halligan Jr, MD, and Herschel Richter, MD, Phoenix, Arizona

**Objective:** The purpose of this study was to show that the falciform ligament (FL) is an important finding on transthoracic echocardiography (TTE) in patients with ascites.

**Background:** It is difficult to determine the cause of echo-free spaces around the heart. When an echo-free space is seen anterior to the right ventricle, the identification of the FL helps to distinguish ascites from pericardial effusions, pleural effusions, and pericardial cysts.

**Methods:** TTE was performed with a 3-MHz multiplane transducer connected to an ultrasound system. Standard TTE and Doppler flow measurements were performed following the American Society of Echocardiography guidelines. A total of 32 patients with ascites were studied.

**Results:** In all 32 patients with ascites noted on clinical examination and documented with abdominal ultrasound, magnetic resonance imaging, computerized tomography, paracentesis, or a combination of these, the FL was identified in the subdiaphragmatic view on TTE examination.

**Conclusion:** The FL can be readily visualized on TTE in the subdiaphragmatic view and can aid in the differential diagnoses of translucent space around the right heart border and the liver. The presence of the FL in this echoluent space denotes ascites. (J Am Soc Echocardiogr 2006;19:1074.e3-e4.)
The Falciform Ligament in the Echocardiographic Diagnosis of Ascites

Conclusions: The FL can be readily visualized on TTE in the subdiaphragmatic view and can aid in the differential diagnoses of translucent space around the right heart border and the liver. The presence of the FL in this echolucent space denotes ascites.

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(J Am Soc Echocardiogr 2006;19:1074.e3-e4.)
Falciform Ligament

- Falciform ligament
- Coronary ligament
- Round ligament
- Diaphragm
- Gall bladder
Tamponade
Tamponade not all-or-none phenomenon
Pericardial effusion
Severity of tamponade
Echo tamponade
Clinical tamponade
Hemodyln tamponade
Pericardial effusion
Tamponade
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

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

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

- RA diastolic collapse
- 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
Cardiac Tamponade
Diastolic Collapse of Right Ventricle
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

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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.  

# 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%              | Pred Value           | 50%               |
| Specificity    | 82%               | 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
Case

AR - 24 year-old woman

Tamponade
Cardiac Tamponade after Cardiac Procedures

Coronary interventions 0.2%

EP procedures 0.2 – 0.5%

Cardiac surgery 1.5 – 2.0%
Constriction
Structural Heart Disease

Echocardiographic Diagnosis of Constrictive Pericarditis
Mayo Clinic Criteria

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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
Constrictive Pericarditis

Pathophysiology

- Thickened, scarred, and sometimes calcified pericardium
- Impairs diastolic filling of heart ("imprisons" the heart)
- Elevated and equal diastolic pressures in all 4 chambers
- RA and JVP may increase with inspiration (Kussmaul's sign)
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
Etiologies (1985 to 1998)
n = 212

- Idiopathic: 27%
- Cardiac surgery: 22%
- Radiation: 16%
- Infection: 12%
- Collagen: 7%
- Others: 5%
- Pericarditis: 11%

Ling Circulation 100:1380(1999)
Constrictive Pericarditis
Constrictive Pericarditis
Pathophysiology of Constrictive Pericarditis

CP results from thickening of pericardium

Layers become adherent

Limits diastolic distensibility

Dissociation of intrathoracic and intracardiac pressures with respiration

Increased LV and RV interdependence

Hinders diastolic filling
Constrictive Pericarditis Pathophysiology

2 keys

1. Dissociation of intrathoracic and intracardiac pressures

2. Enhanced ventricular interaction
Inspiratory decrease in intrathoracic pressure is transmitted to the heart.

IT = intrathoracic
PV = pulm veins
IP = intrapericardial

Normal Physiology
Inspiration results in a ↓LV filling pressure gradient due to smaller pressure decrease in the pericardium and LV compared to PCWP.
Constriction  (in inspiration)
Thickened pericardium
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, hemodynamic, and echo-Doppler findings typical

- But dx often elusive, even after extensive evaluation

- **Echo-Doppler → initial and key test**
Constrictive Pericarditis
Echo-Doppler Findings
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
Phonocardiogram and JVP Tracing

K

JVP

a

x

v

y

h

S1

S2

K
Early opening of pulmonic valve c/w elevated RVEDP (eg constr peri, TR)
Constrictive Pericarditis
2D-Echo

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

1. More than 2-beats-per clip for all images (minimum of 6 beats/clip)

2. M-mode of LV
   a. PLAX → Obtain several strips (at 50 mm/sec and 25 mm/sec) – to look for septal bounce and for ventricular independence

3. Apical-4 → several clips with 6-10 beats per clip

4. Mitral inflow careful to look for exaggerated respiratory variation of E-wave (use respirometer); also decrease sweep speed to look for resp variation

5. Carefully done TDI of septum and lateral walls

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

7. Hepatic vein flow with decreased sweep speed (multiple clips)

Strongly suggest that you speak to MD prior to study for instructions
Case
Constrictive Pericarditis
Constrictive Pericarditis
Echo-Doppler

Miranda and Oh  Prog Cardiovasc Dis 2017;59(4):369-379
Annulus Reversus

Lateral < Medial: 75% of constriction cases

Latera l
E’ = 9

Medial
E’ = 14

Circ CV Img 4: 399, 2011

from Mayo Clinic
Constrictive Pericarditis

Annulus Reversus

Medial velocity greater than lateral velocity
Constrictive Pericarditis

Annulus Reversus

Septal $e'$: 14 cm/sec
Lateral $e'$: 11 cm/sec

Medial velocity greater than lateral velocity
Annulus Paradoxus

- Normal
- Impaired Relaxation (Cardiomyopathy)
- Constrictive Pericarditis

*With CHF, consider constriction if $E' > 8 \text{ cm/s}$

from Mayo Clinic
Constrictive Pericarditis

Diastolic Hepatic Vein Reversal

Prominent diastolic flow reversals in expiration
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
The End