Assessment of Tamponade Physiology

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- The space between the two layers holds normally 5 – 15 ml of fluid.
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- The inner part consists of a single layer serous membrane.
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**Pericardium Anatomy**

- **Outer layer**
  - Fibrous structure
  - Parietal pericardium

- **Inner layer**
  - Visceral pericardium

**Normally 5 – 15 ml fluid**
Pericardium Anatomy

- Attachment to
  - Greater vessels
  - Diaphragm

- First fluid $\rightarrow$ oblique sinus (posterior left ventricle)

- $> 100$ ml $\rightarrow$ becomes circumferential

McMinn. Schattauer Verlag 1977

- The pericardium has two main functions: reduction of friction between heart and mediastinum and even distribution of the pressure to the heart. It is attached to the greater vessels and the diaphragm.
- At first fluid collects in the oblique sinus lying posteriorly to the left ventricle.
- When the fluid exceeds about 100 ml, it will extend to the entire pericardial space.
Echo-Anatomy

† Oblique sinus

† Pericardial fluid lies anterior to descending Aorta (pleural effusion dorsal)

- The best view of the oblique sinus (most sensitive location for fluid accumulation) is the parasternal long axis.
- The fluid lies posteriorly to the left ventricle and anteriorly to the descending aorta. Fluid posterior to the aorta corresponds to left pleural effusion.
• On the basis of the definition of cardiac tamponade we will discuss the pathophysiology. The pathophysiology will help to understand the main echo features.
Pericardial Tamponade

- Intrapericardial pressure increases and compromises systemic venous return to the right atrium
- Myocardial transmural pressure = intracardiac pressure – intrapericardial pressure
Pericardial Tamponade

- Increased pericardial pressure equalizes with RA systolic pressure or RV diastolic pressure

Chronic vs Acute Pericardial Effusion

– Chronic
  – Large amounts of fluid that accumulate slowly take longer to cause tamponade
  – Pericardial compliance increases and the pericardium stretches

– Acute
  – Small amounts of fluid that accumulate rapidly cause tamponade acutely
  – Acute increases in pericardial fluid are too rapid to allow change in pericardial compliance

The chronicity of the pericardial effusion determines whether tamponade occurs acutely with small pericardial effusions, or later with large pericardial effusions.
Graph from the NEJM review article on cardiac tamponade.
55 yo male with shock on dopamine, history of idiopathic capillary leak syndrome

This is a large pericardial effusion that was causing tamponade and shock. This effusion likely accumulated over time.
55 yo male with shock on dopamine, history of idiopathic capillary leak syndrome

This is a large pericardial effusion that was causing tamponade and shock. This effusion likely accumulated over time.
Acute Pericardial Effusion: 30 yo female with viral myocarditis and hx of scleroderma

This is the parasternal long axis view of a young woman with progressively worsening shock requiring vasopressors and a small to moderate pericardial effusion that occurred acutely. The cardiac cath lab tracings showed ventricular interdependence and her hemodynamics improved significantly with drainage of the pericardial effusion.
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Apical four chamber view of the same patient.
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A non-collapsing IVC consistent with tamponade, and suggesting that further volume infusion might not be helpful. Do not use the term pre-load, use IVC dilation or IVC plethora.
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Simultaneous right and left heart catheter tracings showing ventricular interdependence
(RA=22 mm Hg, PCWP=21 mm Hg)

Tracing is from right and left heart catheterization during pericardial drainage in the 30 yo female with viral myocarditis and hx of scleroderma
• Before going over the echocardiographic findings it is important to understand that tamponade is a clinical diagnosis and not an echocardiographic one.
• The echo, however, can help you with understanding the physiology.
Clinical Diagnosis of Cardiac Tamponade

- Pericardial effusion observed with echocardiography does not define tamponade
- Tachycardia
- Tachypnea
- Hypotension
- Pulsus paradoxus > 10 mm Hg decrease in systolic blood pressure during inspiration
- Electrical alternans on EKG

Emphasize that cardiac tamponade is a clinical diagnosis that requires evaluation of clinical signs, EKG, pulsus paradoxus, and echocardiography. Pulsus paradoxus of <10 mm Hg is a normal finding.
Clinical Presentation

- Hypotension (shock)
- Distended neck veins
- Muffled heart sounds

Beck’s triad (rare!!)

- Kussmaul sign (distension of neck veins during inspiration) is uncommon

The clinical features of cardiac tamponade are shock, distended neck veins (in patients who are not hypovolemic), muffled heart sounds (rare sign), pulsus paradoxus (i.e. drop of systolic pressure of > 10 mmHg during inspiration) and pulsus alternans/low voltage in the ECG.

Beck triad consists of hypotension, distended neck veins and muffled heart sounds.

The Kussmaul sign (distension of neck veins during inspiration) is only seen in complicated cardiac tamponade.
EKG electrical alternans

Chronic Pericardial Effusion: 20 yo male presenting with a mediastinal mass, tachycardia, and weakness

Emphasize that electrical alternans occurs because of the swinging of the heart in the pericardial fluid.
EKG electrical alternans

Chronic Pericardial Effusion: 20 yo male presenting with a mediastinal mass, tachycardia, and weakness

Emphasize that electrical alternans occurs because of the swinging of the heart in the pericardial fluid.
The movie demonstrates the swinging of the heart (clockwise rotation) in a large circumferential pericardial effusion.
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Pericardial Tamponade: Main Echo Findings

- RA inversion/collapse in late systole
  - Atrial diastole
  - Very sensitive sign

- RV inversion/collapse in early diastole
  - Less sensitive, more specific

- Reciprocal respiratory changes in right ventricular and left ventricular inflow velocities

- Distended, non-compliant IVC

In this lecture we’ll go over only 2D findings. In the advanced course we’ll also talk about Doppler evaluation for the diagnosis of tamponade physiology.

Right atrial compression should occur before right ventricular compression when intrapericardial pressure increases, since right atrial pressure is lower than right ventricular pressure during most of the cardiac cycle.

First we will discuss the 4 two-dimensional echocardiographic findings:

1. **Right atrial inversion/collapse** begins in the late diastole, persists into early systole and is a very sensitive sign.
   - Exaggerated right atrial collapse is seen, which is an indication of impeded right atrial filling
   - This occurs with timing opposite that of right ventricular collapse, it is identifiable on two-dimensional echocardiography, typically from the subcostal or apical four-chamber view. Because the right atrium normally contracts in volume with atrial systole, the degree of right atrial collapse must be quantified with respect to either the magnitude of collapse or the duration for which it remains collapsed. Right atrial collapse occurs immediately after normal atrial systolic contraction.

2. **Right ventricular inversion/collapse** begins in the early diastole. It is more specific, but less sensitive than right atrial inversion/collapse. In early diastole, immediately after closing of the pulmonary valve, at the time of opening of the tricuspid valve, the right ventricular outflow tract will paradoxically collapse inward. This is indirect evidence that intrapericardial pressure has exceeded right ventricular diastolic pressure at this time point, and hence the underlying substrate for tamponade is likely to be present. When collapse extends from the more compressible outflow tract to the body of the right ventricle, this is evidence that intrapericardial pressure is elevated more substantially.

3. A third sign is the **swinging heart**, i.e. a clockwise rotation of the heart around the great vessels which translates into a danse-like motion. (Detection of a swinging heart is simply a marker of a large pericardial effusion in which the four cardiac chambers are free to float within the pericardial space in a phasic manner. A large pericardial effusion is more likely than a small effusion to be associated with intrapericardial pressure elevation, and hence the relationship between a swinging heart and hemodynamic compromise is indirect rather than direct evidence of elevated pressure)

4. The last feature is a **distended inferior vena cava (≥ 2 cm)** and a decreased or no collapse during inspiration.
74 year old male with ground level falls and hypotension, echo guided pericardiocentesis of 850 ml of blood resulted in hemodynamic improvement.

Right atrial systolic collapse
74 year old male with ground level falls and hypotension, echo guided pericardiocentesis of 850 ml of blood resulted in hemodynamic improvement.
RA systolic inversion/collapse

- Describe the features of late right atrial diastolic inversion/compression on this slide (apical 4 chamber view).
- Explain that atrial diastole occurs during cardiac cycle systole.
- Talk about the pericardial effusion seen and the swinging of the heart in this image.
- Explain that by just looking at the live 2D clip it is sometimes difficult to figure out if the RA wall inversion occurs during cardiac systole, and it is always helpful to freeze the picture or slow it down on the u/s machine.
- Show that by freezing the image one can see that during cardiac systole (show the red mark on ECG tracing) the RA wall is inverted securing the diagnosis of tamponade physiology.
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Early RV diastolic inversion and collapse

- Parasternal short axis view at the level of the valves (3-in-1 view)
- Describe the valves and chambers
- Similar to previous slide, the message here is that by just looking at the live 2D clip one cannot know if the RV free wall collapse occurs during cardiac systole or diastole.
- Again here, by freezing the picture it is clear that RV free wall collapse occurs during cardiac diastole (red mark on ECG tracing)
- Another nice trick is M-mode, which allows you very clearly and accurately look at wall motion over time. In this example we see RV free wall movement during diastole, and another nice sign here is LA inversion during the beginning of systole (the wall at the bottom of the picture closest to the ECG wave)
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Right atrial collapse occurs in late diastole after emptying of the atrial chamber and in early systole.
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Right atrial collapse occurs in late diastole after emptying of the atrial chamber and in early systole.
RV Collapse - Caution!

- May not occur when:
  - RV hypertrophy
  - Significant ↑ RV end-diastolic pressure
  - ↑PA pressure
  - Mechanical compression (clot)

- Go over the limitations of RV collapse
Reciprocal Respiratory Changes of Doppler Velocity During Spontaneous Respiration
(RV inflow > 40% and LV inflow > 25%)

Explain the difference in respiratory changes in LV inflow as compared to RV inflow.
Reciprocal spontaneous respiratory changes in RV and LV filling

Spontaneously breathing 55 year old male with idiopathic capillary leak syndrome and shock on dopamine
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Distended, non-compliant IVC

- The last sign is a distended inferior vena cava (≥ 2cm) with no collapse during inspiration.
- On the live 2D clip on the left you can see a distended IVC. It is always good to refer to the cm scale on the side (left side of the pie). In this example you can see that the IVC diameter is roughly 2.5 cm and that there is no respiratory variation indicating higher CVP.
- The image on the right is of an M-mode interrogation of the IVC clearly demonstrating a severely dilated IVC (>5cm) with no respiratory variation, again, indicating a very high CVP.
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Summary: Cardiac Tamponade

- Pericardial tamponade is a clinical diagnosis
- Pulsus paradoxus > 10 mm Hg
- Electrical alternans or low voltage EKG
- Echocardiography findings of
  - right atrial systolic collapse
  - right ventricular diastolic collapse
  - > 25% variation in LV inflow velocity
  - > 40% variation in RV inflow velocity
  - IVC plethora
• Summarize all 2D signs that were just reviewed
• Go over RA and RV collapse in relation to the position of the QRS
• No real tamponade exists without a caval plethora.
Caution!!

Cardiac tamponade despite no echo features

- Localized clot (post-cardiac surgery)
- Prolonged ↑↑ PA pressures
- Thickened RV wall

- Under certain conditions absence of traditional echocardiographic features cannot rule out cardiac tamponade. These conditions are abnormal cardiac physiology and localized fluid accumulation, mostly after cardiac surgery.
Summary

- Cardiac Tamponade is primarily a clinical diagnosis!!

- Echo – the standard method for pericardial fluid detection

- RA systolic collapse ➔ RV diastolic collapse ➔ LA systolic collapse

- Echocardiography is pivotal for decision-making and management of pericardial effusion. Emergency pericardiocentesis cannot wait for a specialist. In such an extreme situation echocardiography helps to make the procedure safe and simple.