CT and MRI of the Pericardium

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Outline

- Normal Anatomy
- Congenital variants (Embryology)
- Pitfalls
- Pericardial effusions and pericarditis
- Pericardial masses
- Constrictive pericarditis
- Summary
- CME question

Anatomy and Function of the pericardium

- Normal Anatomy
  - Normal thickness = 2 mm
    - Space between visceral and parietal pericardial surfaces
  - Normal fluid ≤ 50 mL

- Normal Function
  - Maintain position of heart
  - Lubricated surface between stationary chest wall and moving heart
  - Barrier to infection
  - Restrains cardiac chamber volumes
    - "negative systolic pericardial pressure"

Anatomy and function of the pericardium

- Two layers
  - Visceral – serous membrane consisting of single layer of mesothelial cells adherent to epicardial surface of heart
  - Parietal – acellular, fibrous membrane consisting of collagen and elastin fibers surrounding most of the heart

- Pericardium extends superiorly to cover proximal portions of the great vessels
  - Left atrium predominately outside of the pericardium

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Pericardial defects

- DDx =
  - Congenital
  - Trauma
  - Iatrogenic

- Congenital absence of the pericardium
  - Partial vs. complete
  - Most commonly affects left side of pericardium
    - Heart is more mobile
    - Leftward shift of heart
    - Lung between aorta and main pulmonary artery
  - Associated with other congenital heart disease (ASD, PDA)
Post Surgical Pericardial absence

Rajiah P and Kanne J. J Cardiovasc Comp Tomogr, Vol 4, Issue 1 ; 3-18

Congenital absence of pericardium (2)


Pitfalls

Pericardial recesses

Knowledge of location important in distinguishing normal pericardial recesses from mediastinal lymphadenopathy and masses


Normal Variants that Simulate Disease

1. Fluid in recesses
   a. Superior aortic pericardial recess (may mimic aortic dissection)


Normal Variants that Simulate Disease

1. Fluid in recesses
   b. Pulmonary Vein Serosal sleeve (may simulate mass or LN)

Normal Variants that Simulate Disease

1. Fluid in recesses
c. Oblique Sinus (may simulate mass or LN)

Truong MT et al AJR 2003;181:4:1109-1113

1. Fluid in recesses
d. Transverse sinus (simulates LN)


Pericardial Cysts

Pericardial cysts

Formed from persistence of a blind ending parietal pericardial recess
60% Asymptomatic
May communicate with the pericardial space

Location
70% Right CPA
22% Left CPA
8% Mediastinal

Pericardial Cysts

Asymptomatic Pericardial cyst adjacent to LV

Well circumscribed fluid density and fluid signal mass adjacent to LV. This is a less common location. Cross-sectional imaging is needed to establish the Dx.

Slide Courtesy of Christopher J François, M.D.
Pericardial effusions and pericarditis

- **Pericardial effusions**
  - **Presentation**
    - Often asymptomatic
    - Chest pain
      - When present, usually due to tamponade
    - Dyspnea
    - Physical examination
      - Elevated jugular venous pressure
    - ECG – reduced voltage
  - **Causes**
    - Idiopathic
    - Infectious
      - Viral, bacterial, mycobacterial, fungal
    - Inflammatory
      - Connective tissue disease
    - Post-myocardial infarction
    - Trauma
      - Iatrogenic, non-iatrogenic, radiation
    - Drugs
    - Neoplastic
      - Primary or secondary
    - Other
      - Hypothyroidism, Amyloidosis, hemodialysis/uremic
      - Hemorrhage
  - **Presentation**
    - Often asymptomatic
    - Chest pain
      - When present, usually due to tamponade
    - Dyspnea
    - Physical examination
      - Elevated jugular venous pressure
    - ECG – reduced voltage
  - **Echocardiography**
    - Less sensitive than CT and MR for detecting small effusions
    - Tamponade
      - Early diastolic collapse of RV and RA
      - Exaggerated respiratory variation in R and L venous and valvular flow
  - **Chest x-ray**
    - Usually normal
    - With moderate and larger pericardial effusions, change in size of cardiac silhouette
    - Finding suggestive of etiology

- **Pericardial effusions**
  - **Symptomatic Pericardial cyst adjacent to LV**
  - 49 yo female with shortness of breath and altered diastolic filling of left ventricle at echocardiography
Pericardial effusion - Uremic

CXR
Globular CV Silhouette
Mild PV HTN
Azgyous not

Pericardial effusions

- CT and MRI
- More sensitive than echocardiography for small effusions
- Better characterization of fluid
- Cine MRI motion (bSSFP) and flow (phase contrast) analysis similar to echocardiography

Pericardial effusion

At time of presentation
5 months prior

Cine MRI of Pericardial effusion

Pericardial effusion in acute STEMI

SSFP 4-chamber Cine MRI showing epicardial fat (short arrow) and pericardial fluid (long arrow). MI is shown as increased T2* signal (lightening bolt).

DCE 4-chamber MRI showing pleural fluid enhancement (arrow) without pericardial enhancement with the enhancing MI (lightening bolt) with subendocardial no-reflow zone.

Pericardial hematoma from RCA graft after CABG causing tamponade

Severe compression of right atrium and ventricle.
Pericardial hemorrhage due to aortic rupture

High density pericardial fluid = hemorrhage

Pericarditis

- Causes of pericarditis
  - Idiopathic
  - Infectious
    - Viral, bacterial, mycobacterial, fungal
  - Inflammatory
    - Connective tissue disease
    - Post-myocardial infarction
  - Trauma
    - Iatrogenic, non-iatrogenic, radiation
  - Drugs
  - Neoplastic
    - Primary or secondary

Pericarditis

- Presentation
  - Chest pain
    - Often sharp and pleuritic
    - Substernal
    - Relieved by leaning forward
  - Dyspnea
  - Fever

- Physical examination
  - Pericardial rub with auscultation

Pericarditis

- Chest x-ray
  - Usually normal
  - With moderate and larger pericardial effusions, change in size of cardiac silhouette
  - Pneumopericardium suggests gas-producing organism or fistula

- Echocardiography
  - Usually normal
  - Effusions unusual with idiopathic pericarditis

Infected Pericardial effusion

- CT and MRI
  - Pericardial thickening
  - Pericardial enhancement
  - Cine imaging may show decreased pericardial mobility

26 yo Male with staphylococcus aureus pyopericarditis.
Note heterogeneous density of pericardial fluid and the thickened and enhancing visceral pericardium (arrow).
Pneumopericardium from purulent pericarditis

Pericardial defect caused by pancreatico-pericardial fistula

Pericardial defect caused by pancreatico-pericardial fistula


MRI of Infectious Pericarditis

Axial cine SSFP Axial post-contrast FSPGR SA delayed CE

Pericardial thickening Pericardial enhancement

The Continuum from Calcific pericarditis to Constrictive pericarditis

Calcific pericarditis

Calcific pericarditis – CXR and CT

Pericardium is immobile and may limit diastolic filling of LV
Constrictive pericarditis

• End-stage of any inflammatory process affecting the pericardium
  • Most common causes in US include infection, post-surgical, and radiation
  • TB was most common cause
• Can occur months to years after initial incident
• Patients present with right sided heart-failure and normal LV systolic function
  • DDx = restrictive cardiomyopathy

Causes of Constrictive Pericarditis

- Post acute pericarditis
- Post heart surgery (CABG)
- Uremia
- Connective Tissue Ds
- Post Traumatic
- Drug toxicity (procarbamide, hydralazine, methylergide)
- XRT
- Malignant (melanoma)
- Infection (TB, Histoplasmosis, Coccidiomycosis, Puralent)
- Post MI/ post Dressler’s Syndrome
- Asbestosis

Common Clinical Findings of Constrictive Pericarditis

- Increased Jugular venous distension
- Hepatomegaly
- Dyspnea
- Edema
- Ascites
- Pleural Effusion
- Fatigue

Imaging Findings of Constrictive pericarditis

- Chest x-ray
  • DDx = calcification of LV aneurysm
  • Right atrial enlargement
  • Pulmonary vascular congestion and redistribution when LV pressures are increased
  • Pleural Fluid
  • Distended Azygous Vein (>1cm)
- Echocardiography
  • Pericardial thickening and immobility
  • Interventricular septal “bounce” at inspiration
  • Dilated HV and IVC

Constrictive pericarditis

- CT and MRI
  • Pericardial thickening (> 4mm)
  • Global or focal
  • Calcifications (CT > MRI)
  • Cine:
    • Septal “bounce” reflecting abnormal RV filling (> 85%)
    • Real-time cine imaging can be helpful to elicit abnormal septal motion with Valsalva.
  • Ancillary findings:
    • Atrial enlargement, dilated HV and IVC, ascites

Real time MRI of a patient with constrictive pericarditis showing straightening of the interventricular septum with inspiration due to the increased volume entering the right heart.
Constrictive pericarditis

Cine MRI of a patient with calcific constrictive pericarditis of the right atrium and right ventricle (RV) showing aneurysmal dilation of the noninvolved RV and bowing of the adjacent intraventricular septum.

Right atrial Pressure volume loop

late atrial filling of Rt ventricle -The “a” wave

Early atrial filling of Rt ventricle - The “e” wave

Power and Turf In Medicine

“The currency in medicine is patients and Radiology doesn’t have any. We (Radiologists) have to build extremely strong and close ties with our referring physicians or we will have nothing to offer.”

Carl Ravin, M.D.
Founding Member of STR
President, Private Diagnostic Clinic
Duke University

Take home point

You can measure inflow across the TV with MRI using breath hold 2D PC pulse sequences. Thus measurement of the “e to a” wave ratio is possible to do in less than 3 minutes.

With constrictive pericarditis the velocity of the atrial Kick (a-wave) is larger than the early diastolic filling (e-wave) filling which is opposite of the normal situation.
Physiology of Constrictive Pericarditis

Septal "bounce" reflecting abnormal diastolic RV filling (> 85%)

This is due to the fact that RV filling pressure in diastole exceeds LV diastolic filling pressure and thus as the higher pressure RV fills in diastole, it moves the septum towards the lower pressure LV.

This is not to be confused with septal straightening during systole, which is a sign of elevated RV pressures greater than systolic LV pressures. This occurs with pulmonary hypertension and PV stenosis.

Pericardial masses

- Pericardial tumors
  - Metastases >> primary pericardial tumors
  - Metastases to pericardium:
    - Direct extension from mediastinal malignancies
    - Lymphatic spread from thoracic malignancies
    - Hematogenous spread from any malignancy
    - May have hemorrhage

- Pericardial masses
  - Primary pericardial neoplasms can be benign or malignant
    - Benign: lipoma, teratoma, fibroma, hemangioma
    - Malignant: mesothelioma, lymphoma, angiosarcoma
  - Malignant neoplasms tend to be larger, more ill-defined, and heterogeneous
    - Melanoma, Adenocarcinoma (lung, breast, gastric)
Primary Pericardial Lymphoma (rare)

Irregular, long $T_2$, infiltrating, heterogeneous mass in AV groove surrounding aorta and main pulmonary artery

Myocardial tagging

Can be performed with many types of pulse sequences.

Gridded (waffle Iron) or single plane saturation bands started at each $R$ wave (electrical systole).

Evolution of bulk myocardial motion can be ascertained over the $R-R'$ interval.

Adherent myocardium to the pericardium or a pericardial mass is shown by tag persistence between the two areas

Myocardial tagging

Early systole Mid systole

Pericardial tumor mass is not adherent to ventricle as shown by sheer in the myocardial taglines

Primary pericardial lymphoma

Irregular, heterogeneously dense, mass surrounding aorta and left main coronary artery and invading main pulmonary artery

Pericardial metastases from lung cancer

Irregular, lobular isodense, intense, hypermetabolic intracavitary RV mass extending into RVOT

Primary pericardial undifferentiated sarcoma

Large, heterogeneous, pericardial mass adjacent to LA appendage and main pulmonary artery

Slide Courtesy of Christopher J. Francois, M.D.
Summary

- Normal pericardium made up of two layers and is ≤2mm in thickness
- CXR, CT, and MRI have very important roles in diagnosis and evaluation of patients with pericardial disease
- Pericardial effusions have many causes
  - Etiology may or may not be evident on CT/MRI
- Pericarditis presents as pericardial thickening and enhancement
  - Pericardial effusion may or may not be present

• Constrictive pericarditis can be distinguished from restrictive cardiomyopathy with CT or MRI
  - Pericarditis (± calcification)
  - Septal bounce with cine imaging
  - Real-time cine SSFP with inspiration/expiration
  - Pericardial masses
  - Metastases ≠ primary pericardial neoplasms
  - Pericardial cysts most common @ right cardiophrenic angle
  - Congenital absence of pericardium is usually partial rather than complete
    - Left > right

CME QUESTION: PERICARDIAL DISEASE

1. Constrictive pericarditis is best shown by which MRI sequence:
   a. Arterial Spin Labeling
   b. Double Inversion Recovery
   c. Fast Spin Echo T2
   d. Short Time Inversion Recovery (STIR)
   f. bSSFP Cine images with myocardial tagging

Thank you

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CT and MRI of the Pericardium

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This syllabus will provide an overview of the current state of the art of CT and MRI of the pericardium with current pertinent references from the literature. We will begin with a discussion of the embryology and the normal appearance of this ancillary but important structure in the chest and then we will discuss the various imaging appearances of the common diseases that affect this structure. We will discuss how MRI can be used to determine the presence and physiological significance of constrictive pericarditis. We will conclude with a review of the common pitfalls associated with the various pericardial recesses.

Anatomy

The normal pericardial sac can be envisioned in a very simplistic manner as a bursal like structure that is draped like a ball of dough applied to the anterior surface of the heart and rolled to the posterior surface leaving a bare area at the left atrium. The pericardium has two components: an outer fibrous layer providing structure and a serous layer that is responsible for fluid production. The serous layer has both a visceral and parietal surface that is a single cell layer thick. This visceral lining on the epicardial surface is not visible by imaging methods. The parietal layer composed of the parietal serous layer and a second fibrous component usually measures a <2mm thick on imaging. Often what can be seen by CT and MRI is material or fluid in the pericardial space between the two layers. There is normally around 15-50 ml of a clear serous plasma ultra-filtrate present. Pericardial thickening is defined as any area greater than 4mm in AP dimension on CT or MRI. This “pericardial thickening” is in fact the summation of visceral layer, material or fluid in the pericardial space and also the parietal fibrous layer.

Function

The function of the pericardium is multifactorial: 1) provide a barrier to infection from mediastinal and pleural surfaces, 2) provide a lubricated space (like a bursa for a tendon) for the heart to contract in that is sheltered from the (reasonably) stationary chest wall, 3) provide a defined space for the atria to be filled while the ventricles contract, acting as a backbone to prevent atrial collapse and allowing for blood to be “pulled into” the atria. The atria can act like individual bellows that fill with new blood as their respective ventricles empty in systole because of the “negative systolic pericardial pressure”, 4) fixation of the heart in the mediastinum, 5) limits acute dilation of the chambers, 6) prevent acute atrioventricular valve (AV) annular stretching in the setting of acute left or right ventricular end diastolic pressure overload, thus limiting potential acute AV regurgitation, 7) coordinate, in the short term, right and left ventricular stroke volumes when there is elevated peripheral vascular resistance (e.g. elevated systemic blood pressure).

Embryology

The embryology of the pericardium is important in understanding the common congenital variants that the clinical imager is likely to encounter. Congenital absence most commonly is partial and on the left. Complete congenital absence is rare. This is thought to be related to regression of the left common cardinal vies, which in turn devascularizes the pleuropericardial membrane, resulting in loss of that portion of the pericardium. This disorder may also be associated with many intra-cardiac defects that include: Atrial septal defects, patent ductus arteriosus, Tetralogy of Fallot, and mitral stenosis. Partial absence of the pericardium can be seen as a lack of the normal thin pericardial membrane at CT or MRI over those regions that have enough epicardial fat. For the left atrial appendage and portions of the left ventricle that are not perpendicular to the plane of imaging, the pericardium may be difficult to see. Clues to this diagnosis includes shift of the mediastinal structures, focal bulging of a structure (e.g. the left atrial appendage or left ventricle), and interposition of lung either between the heart and the hemidiaphragm or between the pulmonary artery and aorta. Rarely, herniation of the left atrial appendage through a focal pericardial defect can result in torsion with subsequent strangulation. Surgical repair is usually indicated for significant torsion of the heart or an epicardial structure because of sizeable pericardial defect.
**Pericardial Diseases**

There are a number of pathologies that involve the pericardium. This presentation will highlight the common etiologies that affect this portion of the chest.

- Pericardial fluid
- Uremia
- Dressler syndrome
- Acute Right heart failure
- Infection: Viral and bacterial
- Malignant
- Pericardial cysts
- Non physiologically significant
- Physiologically significant

**Common Locations**

- Pericarditis (importance of DCMR in showing extent)\(^7\)-\(^8\)
- Viral
- Bacterial
- Malignancy
- Trauma
- Intra-Pericardial malignancy
- Common-Melanoma, Lung, Gastric, Breast
- Rare- Angiosarcoma, Synovial Cell
- Extra-Pericardial malignancy or Infection
- Adjacent lung masses

**Constrictive pericarditis (importance of MR showing location and physiological importance)**

- Old Infection - TB
- Prior surgery

**Utilization of CT and MR in Constrictive Pericarditis**

Constrictive pericarditis (CP) is defined as contact between the visceral and parietal surfaces of the pericardium such that there is a limitation in cardiac chamber movement. This is commonly an incomplete process and is typically associated with either thickening of the pericardium or calcification. While CT shows pericardial thickening and calcification\(^9\), motion of the heart will only be seen with retrospectively gated cCTA exams, which tend to have at least 10 mSv of radiation exposure. MRI in this setting is very useful. Cine tagged images show direct contact between the pericardium and ventricle by a lack of sheer between those two attached structures.\(^10\) In the normal situation, there will be motion present between the myocardial tag lines and the pericardial tag lines. In those regions of constrictive pericarditis, there is no sheer of the myocardial tags observed between the heart chambers involved and the adjacent pericardium. This is now seen as only one structure that moves in unison. While the pericardium does not mind this “marriage” too much, the heart complains bitterly about this “shotgun wedding” and may scream out loud about it the only way it knows how- by changing its output resulting in the classic but non-specific symptom of: shortness of breath that worsens with exercise. Depending on how much of the wall of each respective the chamber is involved, the lack of its ability to fully expand will frequently change the diastolic filling pressure of that portion of the heart.

For simplicity, consider a patient with CP involving both ventricles. With each inspiration, venous inflow to the right heart increases as the bellows of the diaphragm and intercostals muscles increase lung and pleural space volume with a concomitant decrease in the intrathoracic pressure. As there is now a concrete sac enclosing both ventricles, the ability to expand with this influx of volume from the Right Atrium and systemic venous system is limited; thus, the right ventricle (RV) pushes the intraventricular septum away from it.\(^11\) The diastolic filling pressure of the RV with CP now exceeds the diastolic pressure of the left ventricle (LV) leading to paradoxical motion (from right to left) of the interventricular septum.\(^12\)-\(^14\) Furthermore, limited filling (decrease in stroke volume) of the LV, when severe, can cause pulsus paradoxicus.\(^15\) In this situation, limited filling of the left heart causes systemic blood pressure to drop with a loss of a palpable peripheral pulse at inspiration. While this entity was first described with calcific pericarditis,\(^15\) there are many other causes including cardiac tamponade, acute pulmonary thromboembolism, and severe obesity.\(^15\)

**Key Point**

MRI (breath hold, phase contrast complex difference, flow imaging) is able to show changes in atrial filling patterns that are highly suggestive of constrictive physiology. Specifically the early atrial filling wave (e wave) is blunted in its flow and velocity, while the atrial kick or secondary wave (a wave) of atrial filling is enhanced. This is typically associated with an increase in the diastolic filling pressure of the right ventricle (RVEDP). It is this increase RVEDP that results in the change in septic movement that can be exaggerated with inspiration.
Common Pitfalls

A major issue when dealing with the pericardium is the errant diagnosis of lymphadenopathy that is simply related to fluid in a pericardial recess.\textsuperscript{1,16} Knowing the common locations where this can occur is very helpful in limiting this perceptual error and preventing needless intervention.

Transverse sinus—simulates LN\textsuperscript{17}  
High riding superior pericardial sinus\textsuperscript{18}—simulates LN  
Inferior sleeve of pulmonary veins—simulates LN\textsuperscript{19}  
Superior pericardial sinus—simulates aortic dissection or LN\textsuperscript{18,20-23}  
Oblique Sinus—simulates LN\textsuperscript{1}

Summary

The radiologist is able to make the initial diagnosis of pericardial disease with confidence using CT and MRI. While CT is excellent for routine screening of pericardial disorders and the detection of pericardial calcification; MRI is superior in quantifying the degree of adherent pericardium and can provide detailed functional information.

References for MR and CT of Pericardium