Metastasis to the Heart and Pericardium: A Radiological Approach

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Goals and Objectives

- Review epidemiology and clinical features of cardiac metastatic disease
- Define routes of tumor spread to the heart and pericardium
- Explain the strengths of various imaging modalities for examining cardiac metastasis
- Identify key imaging features of cardiac metastasis
Background

- Much more common than previously recognized
- Any tumor with metastatic potential can spread to the heart
- Can involve any structure of the heart as well as the pericardium and proximal great vessels
- Here, we will refer to metastatic spread to any of these sites as “cardiac metastases”

Patients With Known Malignancy

~9% Have Cardiac Metastases

Thymic carcinoma invading the pericardium and proximal great vessels.

Tumor invasion of multiple cardiac structures with a small pleural effusion.
Epidemiology

• Most cardiac neoplasms are metastases
• Incidence of detected cardiac metastasis was previously very low (<1%)
• As cancer therapy has improved and life span increased, the incidence of cardiac metastasis has also increased
• Incidence estimated by autopsy series is 2-18% in patients with known malignancy
• True incidence is probably 9-10%
• No sex predilection

Cardiac Tumors

- Primary 2%
- Secondary 98%

H&E stain demonstrating nodular sclerosis classical Hodgkin lymphoma invading the pericardium in an autopsy specimen.
Epidemiology:
Sites of Primary Neoplasms

Incidence depends on:
- Overall prevalence in the general population
- Proximity to the heart
- Degree of aggressiveness

Some tumors commonly metastasize to the heart:
- Mechanism is not well understood
- Repeatedly documented in the literature

Lung cancer:
- By far the most common
- High prevalence
- Multiple routes of spread
- Often aggressive

Breast cancer:
- High prevalence in general
- Often aggressive

Hematologic malignancies:
- High propensity for cardiac metastasis

Other:
- Melanoma
- Mesothelioma
- Mediastinal Malignancies
- Renal cell carcinoma
- Pancreatic carcinoma
- Ovarian carcinoma
- Gastric carcinoma
- Other

35% 38%
16% 11%

Mechanism is not well understood
Repeatedly documented in the literature
Epidemiology

Certain tumors have a predilection for cardiac metastasis

Most common cardiac mets:
- Lung
- Breast
- Lymphoma

Highest rates of metastasis:
- Melanoma
- Mesothelioma
- Mediastinal Malignancies

All cardiac mets

- Other: 35%
- Lung: 65%
- Breast: 35%
- Lymphoma

Patients with melanoma

- Cardiac mets: 50%
- No cardiac mets: 50%
Clinical Features

- Depends on location and tumor burden
- 90% are clinically silent (discovered only at autopsy)
- Most have nonspecific cardiac symptoms
- Can mimic other forms of cardiac disease
- Elevated cardiac biomarkers
- Some present with life-threatening emergencies

Most common:
- Dyspnea
- Chest pain
- Palpitations
- Atrial flutter/fibrillation
- Lower extremity edema

Most severe:
- Tamponade
- Heart block
- Arrhythmias
- Outflow tract obstruction
- Cardiogenic shock

Any new cardiac symptom in a patient with carcinoma should raise the concern for cardiac metastases
Clinical Outcomes

• Most are rapidly fatal
• Very limited data on survival
  – Small series describe average survival of 5 months from time of diagnosis, **overall mortality of 80%**
  – Mesothelioma: 6-12 months
  – Lymphoma: 5 years with treatment, 1 month untreated
• Treatment:
  – Address underlying malignancy
  – Surgical resection
  – Radiotherapy
  – Chemotherapy
  – Cardiac Transplant

Axial nongated CECT demonstrates a large pleural effusion with indistinct borders of the pericardium, concerning for pericardial invasion in this patient with mesothelioma.

Representative H&E stain image from an autopsy specimen demonstrating of a focus of epithelioid mesothelioma invading the pericardial surface.
Sites of Disease and Clinical Features

- **Pericardium (64-69%)**
  - Pericardial effusion
  - Pericarditis
  - Tamponade

- **Epicardium (25-34%)**
  - Arrhythmias
  - Heart block

- **Myocardium (29-32%)**
  - Arrhythmias
  - Heart block
  - Myocardial destruction
  - \( \downarrow \) Cardiac output
  - Can mimic MI

- **Endocardium (3-5%)**
  - Outflow tract obstruction
  - Cardiogenic shock
  - Embolic phenomena

*Cardiac metastasis to any location can be FATAL*
Routes of Spread

Metastatic tumors can reach the heart in 4 ways:
1. Hematogenous spread
2. Lymphatic spread
3. Transvenous extension
4. Direct invasion
Hematogenous Spread

- **Common Primaries:**
  - Melanoma, lymphoma, sarcoma

- **Mechanism:**
  - Tumor cells disseminated in the blood stream

- **Sites of disease:**
  - Myocardial or endocardial (end arterial supply)

Complications:
- Conduction abnormalities
- Outflow tract obstruction
- Myocardial destruction
- Embolization

Short axis myocardial delayed enhancement MRI through the mid left ventricle demonstrates an enhancing **myocardial** mass in a patient with malignant **melanoma**
Axial CECT of the chest demonstrates an enhancing **intracardiac mass centered in the anterior atrioventricular groove** invading the adjacent myocardium (pink arrow) though sparing the right coronary artery in a patient with **lymphoma**. **Intrachamber component** of the mass is also present (yellow arrow).

H&E stain from an **autopsy specimen** of the heart demonstrating tumor with nodular growth pattern, broad surrounding collagen bands, population of inflammatory cells, and scattered **Reed-Sternberg cells** (arrows) in this patient with **Hodgkin lymphoma**.
Lymphatic Spread

- **Common primaries:**
  - Lung, breast (epithelial tumors)

- **Mechanism:**
  - Retrograde spread through lymphatic channels

- **Sites of disease:**
  - Pericardial
  - Epicardial

**Complications:**
- Pericardial effusion
- Tamponade
- Conduction abnormalities

Axial contrast-enhanced CT (CECT) of the heart demonstrates a large pericardial effusion, **pericardial nodularity and enhancement** (blue arrows) and **epicardial masses** (orange arrow) indicating metastases to the heart in a patient with **breast cancer**
Lymphatic Spread

Axial CECT with cardiac gating (left) and long axis balanced SSFP CMR (right) demonstrates enhancing intrapericardial mass invading the epicardium in a patient with synovial sarcoma.
Transvenous Spread

- **Common primaries:**
  - HCC, RCC, lung, ovarian, sarcoma
- **Mechanism:**
  - Tumor thrombus propagates along venous channels
- **Sites of disease:**
  - Endocardial

**Complications:**
- Venous obstruction
- Embolization
- Outflow tract obstruction
- Myocardial destruction

Coronal CECT of the heart and liver demonstrates tumor thrombus **invading the right atrium** via the IVC in a patient with **leiomyosarcoma**
Axial CECT of the abdomen and pelvis demonstrates a lobulated intracardiac mass ascending to the right atrium from the pelvis through the IVC in this patient with pelvic leiomyosarcoma.
Direct Invasion

- **Common primaries:**
  - Aggressive thoracic malignancies
  - Lung, thymoma, mesothelioma

- **Mechanism:**
  - Aggressive thoracic neoplasm invades pericardium or great vessels

- **Sites of disease:**
  - Any

**Complications:**
- Embolization
- Obstruction
- Conduction abnormalities
- Myocardial destruction
- Tamponade

Axial CECT of the chest demonstrates a left lung mass with direct invasion of the pericardium and epicardium in a patient with lung cancer. Additional metastatic focus is present in the anterior mediastinum (blue arrow).
Direct Invasion

Axial CECT with cardiac gating demonstrates a mediastinal mass with direct invasion of the pericardium (blue arrow) and broad contact with the pulmonary artery in a patient with thymic carcinoma.

H&E stain from an autopsy specimen demonstrates pericardial invasion in this patient with mesothelioma.
New chest symptoms

- Clinical evaluation by oncologist, ER physician
- Cardiac biomarkers often abnormal
- Radiographs for initial evaluation
- May have nonspecific abnormalities

Cardiologic Evaluation

- Echocardiography
- May see effusion or mass
- Exclude other causes of cardiac chest pain (CHF, MI, valve pathology)

Radiography

- May see intracardiac mass, pericardial effusion, pleural effusion, adenopathy
- Exclude mimickers (pulmonary embolism, etc.)

Imaging Modalities

- Radiographs for initial evaluation
- Cardiac biomarkers often abnormal
- May have nonspecific abnormalities

Echo

- Nonspecific findings or concern for acute extracardiac chest pathology?
- Obtain CT +/- cardiac gating

MRI

- Confirm cardiac neoplasm
- Evaluate extent of disease
- Evaluate cardiac function

Signs of cardiac metastases

- Signs of cardiac metastases
Radiography

- Often the first imaging test obtained in the setting of new cardiac symptoms
- Radiographic findings:
  - Pericardial effusion
  - Pleural effusion
  - Mediastinal adenopathy
  - Unusual cardiac contour
- Any of these findings should raise suspicion for cardiac metastasis in a patient with known malignancy.

Frontal chest radiograph demonstrates a bulging right heart border as a sign of pericardial effusion (blue arrows). There is also a left pleural effusion (yellow arrows) and an abnormal contour of the left heart border (pink arrow) in this patient with melanoma.
Echocardiography

- Can rapidly confirm pericardial effusion
- Can evaluate for tamponade
- Can identify intracardiac or pericardial masses
- Low cost
- No Radiation
- Evaluate for mimickers

![Short axis grey scale echocardiogram of the left ventricle demonstrates an echo free space of 10-20 mm consistent with a moderate pericardial effusion (PE).]
CT

- High sensitivity for pericardial effusions and masses
- Best modality for evaluation of calcifications
- Low sensitivity for myocardial invasion or intracardiac masses
- Cardiac gating is needed unless disease burden is severe
- DDx of new pericardial effusion or thickening in a patient with known malignancy:
  - Malignant pericardial effusion
  - Pericarditis
  - Radiation fibrosis

Axial CECT demonstrates pericardial thickening and enhancement (blue arrows) a small epicardial mass (orange arrow), and an intra-atrial mass (yellow arrow) in a patient with metastatic pancreatic adenocarcinoma.
• Best imaging modality to evaluate extent of cardiac involvement
• Functional data and valve disturbance
• Most cardiac metastases are low T1, high T2, with heterogeneous enhancement
• Enhancement may differentiate from thrombus
• Can evaluate for pericardial motion
• Can differentiate from mimickers

Four-chamber double inversion recovery T2 CMR image demonstrates T2 hyperintense tumor infiltration of the right and left ventricular myocardium (pink arrows) with endocardial nodularity (yellow arrows).
MRI vs. CT

Improved tissue resolution with MRI

CECT (right) without cardiac gating demonstrates a subtle area of low attenuation (orange arrow) within the right ventricular chamber in a patient with history of melanoma. Axial myocardial delayed enhancement CMR image (left) demonstrates an enhancing mass (pink arrow) along the interventricular septum near the right ventricular apex, confirming metastatic disease.
Key imaging features

**Most Specific:**

**Intracardiac mass**
- Can involve any structure in the heart
- Enhancement typically differentiates from thrombus

**Most Common:**

**Pericardial abnormalities**
- Effusion
- Nodules
- Thickening
- Enhancement

Mass invading right atrium via IVC in a patient with hepatocellular carcinoma

**Common but Nonspecific:**

**Pleural effusion**
- Up to 80% of patients

**Mediastinal adenopathy**
- Up to 50% of patients

Both are commonly seen in patients with underlying malignancy
Pericardial Effusion

- By far the most common imaging finding
- Site of disease in 40% at presentation
- 15% of cytologically examined pericardial effusions are malignant
- Most common symptom is dyspnea

Mild Effusion

Moderate Effusion

Severe Effusion

<10 mm

10-20 mm

> 20 mm
Pericardial Tamponade

- **Tamponade** can occur if effusion develops rapidly
- A true emergency
- **Imaging features:**
  - Collapse of RA or RV during diastole
  - “Septal bounce” (also seen in constrictive pericarditis)
- **Treatment:**
  - Surgical pericardial window
  - Percutaneous drainage
  - Sclerotherapy
  - Radiotherapy

Short axis cine FIESTA SSFP clip from cardiac MR (CMR) demonstrates a characteristic “septal bounce”. The interventricular septum is initially directed **towards-then paradoxically away**-from the left ventricle during diastole.
Pericardial Abnormalities

Frequency of Occurrence
In Patients with Known Pericardial Metastases

- Most patients with proven pericardial metastases:
  - DO have pericardial effusion
  - DO NOT have nodules, thickening, or enhancement
  - An uncomplicated-appearing effusion does not indicate a benign effusion!
Intracardiac Mass

- The **most specific** indicator of cardiac metastasis
- Most are RIGHT sided
- Most enhance
- MR: low T1, high T2 signal
- Calcification is rare
  - Usually only in osteosarcoma or angiosarcoma

Axial T1 (left) and T2 (right) DIR cardiac MR (CMR) images of a patient with **plasmacytoma** demonstrate a right sided **intracardiac mass** with **low T1** and **high T2** signal. A pericardial effusion is also present.
Axial balanced SSFP (left) and delayed enhancement CMR images (right) demonstrate a non-enhancing mass (arrows) within the right atrium near the tricuspid valve in this patient with intracardiac thrombus.
Pitfalls

Most common **benign** intracardiac neoplasm?

**MYXOMA**

4 chamber balanced SSFP CMR image demonstrates a mass (asterisk) **prolapsing through the mitral valve plane** (arrows) during diastole in a patient with cardiac **myxoma**.
Pitfalls

Must consider all differentials

MYOPERICARDITIS

Short-axis myocardial delayed enhancement MRI demonstrates a large pericardial effusion (asterisks) and diffuse visceral and parietal pericardial enhancement (blue arrows) in this patient with myopericarditis.
Summary

**Primaries:**
- Most common: Lung, breast, lymphoma
- Highest propensity: Melanoma & mesothelioma

**Key imaging features:**
- Pericardial effusion
- Intracardiac mass
- Pleural effusion
- Adenopathy

**Routes of spread:**
- Hematogenous
- Lymphatic
- Direct invasion
- Transvenous

**Complications:**
- Embolization
- Obstruction
- Conduction abnormalities
- Myocardial destruction
- Tamponade
References