CLINICAL IMAGE

Computed Tomography and Magnetic Resonance Imaging of the Pericardium: Anatomy and Pathology

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The purpose of this article is to review the characteristics of computed tomography (CT) and magnetic resonance imaging (MRI) of the pericardium and pericardial diseases. Because patients with pericardial diseases usually present with nonspecific symptoms, these diseases may not be detected until they have reached an advanced stage. It is therefore important to distinguish between normal pericardial structure and disease. Multiplanar reconstruction images of CT and MRI are useful for evaluating faint changes of the pericardium. The specific pericardial diseases described in this article include pericardial cyst, constrictive pericarditis, pericarditis with radiation pericarditis, postoperative pericardial hematoma, and cardiac tamponade due to a paracardiac mass (lymphoma).

Keywords: *pericardium, pericardial disease, CT, MRI*

Introduction

Understanding the anatomy of the pericardium is key to detecting and assessing the distribution of pericardial diseases. Computed tomography (CT) and magnetic resonance (MR) imaging offer distinct advantages in the imaging of the pericardium. Both modalities provide a larger field of view than does echocardiography, thus allowing the examination of the entire chest and detection of associated abnormalities in the mediastinum and lungs.¹ This article describes the anatomy of the pericardium and pericardial space and reviews the appearance of pericardial diseases in CT and MR images.

Anatomy

The pericardial complex encloses the heart and comprises fibrous and serous components. The tough fibrous outer parietal layer has attachments to the diaphragm, sternum, and costal cartilage. The serous layer is a thin mesothelial layer adjacent

to the surface of the heart. The pericardial sac lies between variable amounts of epicardial and pericardial adipose tissue.² Discrimination of the pericardium from the myocardium in radiological images requires the presence of epicardial fat or pericardial fluid. The amount of epicardial fat normally increases with age. Excessive fat accumulation is most common in older, obese, diabetic patients, usually women, and may be observed in patients with exogenous or endogenous steroid excess.³ In CT imaging of the pericardium, occasional difficulty is encountered in differentiating fluid from thickened pericardial tissue.¹ MRI is superior to CT in differentiating fluid from thickened pericardium.²

The normal pericardium is seen as a very thin linear density surrounding the heart but is often not visualized over much of the left ventricle (Fig. 1A), where very little pericardium—usually less than 2 mm (measured by CT)—may be present.⁴ With MRI, the normal pericardium appears as a low-intensity signal between the high-intensity mediastinal and subepicardial fat (Fig. 1B). The thickness ranges between 1 mm and 3 mm on average, being 1.2 mm in diastole and 1.7 mm in systole.⁵

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Fig. 1. Normal pericardium

The pericardium is visible as a very thin linear density surrounding the heart (arrows) but is not visualized over much of the left ventricle in an axial nonenhanced CT scan (**A**: 52-year-old male). An axial ECG-gated spin-echo (SE) T_1 -weighted MR image (T_1 WI) of a subject (**B**: 60-year-old male with mitral regurgitation) shows a pericardium with normal thickness (arrows).

The potential space between the two levels normally contains a small amount of clear fluid, typically between 15 and 50 ml.⁶ The presence of a normal pericardium can also be detrimental in situations where fluid rapidly fills the small potential space when the ability to distend quickly is limited. Slowly accumulating effusions cause the pericardium to stretch and can exceed a liter in volume.²

At the reflections of the serous pericardium between the great vessels at the base of the heart, the pericardial cavity forms the pericardial sinuses, which are not separate compartments but represent extensions of the pericardial cavity.⁷ The *Nomina Anatomica* labels them as the transverse sinus and oblique sinus.⁸ The transverse pericardial sinus (Fig. 2), which surrounds the ascending aorta, is sometimes mistaken for an aortic dissection or lymphadenopathy.⁹ The oblique pericardial sinus, which is situated behind the left atrium, may be misinterpreted as esophageal lesions or bronchogenic cysts.¹ Recognizing the appearance of these normal variations is extremely important to avoid mistaking them for lymphadenopathy and other mediastinal disease processes.⁷

Many disease processes can affect the pericardium, including infection, neoplasm, trauma, primary myocardial diseases, and congenital disease.¹

Pericardial Cysts

Pericardial cysts are rare remnants of defective embryological development of the pericardium.

They are clinically indistinguishable from pericardial diverticula and exist as unilocular, thin-walled structures that may be attached intimately or by a pedicle to the pericardium.¹⁰ They occur in the pericardiophrenic angle, much more commonly on the right, but can be located throughout the mediastinum.² The appearance of this disease in CT and MRI is as a nonenhanced, well-circumscribed, ovoid mass adjacent to the pericardium. The content shows water density and signal (Figs. 3, 4A and 4B). Any cyst containing transudate fluid (nonhemorrhagic and with low protein concentration) appears as low intensity in T_1 -weighted spin-echo (SE) images (Fig. 5A) and as high and homogeneous intensity in T_2 -weighted SE images.⁵ On short TI inversion recovery image (Fig. 5B), the water content of the cyst also shows high signal intensity. Occasionally, a cyst may contain highly proteinaceous fluid, which may have a high signal intensity in T_1 -weighted images.¹ A discriminative feature is their common tendency to change in size or shape with respiration or body position (Figs. 5C and 5D).

Constrictive Pericarditis

The causes of constrictive pericarditis are numerous, including postsurgical, postradiation, posttraumatic, and postinfectious presentations.¹¹ Often the cause is labeled idiopathic. Normal pericardial thickness is less than 3 mm. A thickness exceeding 6 mm indicates pericardial thickening, and in the proper clinical setting, it can be a diag-

Fig. 2. Normal transverse pericardial sinus
Axial nonenhanced CT scan (A: 65-year-old female) and ECG-gated SE T₁WI (B: 77-year-old male, C, D: 49-year-old male) show the superior aortic recesses (arrows) in a normal position, anterior or posterior to the ascending aorta.

Fig. 3. Pericardial cyst in an asymptomatic 39-year-old female

An axial enhanced CT scan shows a nonenhanced, low-attenuated, well-circumscribed, ovoid mass adjacent to the right side of the pericardium and consistent with a pericardial cyst.

nostic finding in constrictive pericarditis. However, the presence of pericardial thickening by itself does not indicate constriction.⁵ The presence of any calcification in an individual suspected of constriction should be considered significant. CT will detect minute amounts of pericardial calcium, and MRI can miss significant deposits (Fig. 6).²

Additional findings seen with constriction include distorted contours of the ventricles, tubular-shaped ventricles (Fig. 7), hepatic venous congestion, ascites, pleural effusions, and occasionally some pericardial effusion. Dilatation of the atria, coronary sinus, inferior vena cava, and hepatic veins are common.²

Constriction is localized in some cases on the right side of the heart or even at the right atrioventricular groove only. In many circumstances, pericardial thickening is observed only over the right atrium and the right ventricle.⁵

Thickening of the pericardium, often with (Fig. 6A) and sometimes without calcifications (Figs. 7 and 8A), can be clearly depicted, as seen in the figure legends.

Fig. 4. Pericardial cyst in an asymptomatic 65-year-old female

A well-circumscribed, ovoid pericardial cyst (arrows) adjacent to the right side of the pericardium shows a low signal intensity in a T₁WI (**A**) and a high signal intensity in a short TI inversion recovery image (**B**).

Fig. 5. Pericardial cyst in an asymptomatic 44-year-old female

This subject was revealed to have an abnormality in a chest X-ray for health screening. The cyst (arrow) shows a low signal in an axial ECG-gated SE T₁WI (**A**) and a high signal in a T₂WI (**B**) in the sagittal plane. It appears to be pulmonary effusion. An axial nonenhanced CT scan taken with the subject in a supine position (**C**) show fluid collection (arrow) resembling pulmonary effusion. An axial nonenhanced CT scan taken with the subject in a prone position (**D**) reveals the fluid collection (arrow) appearing in the higher level and with a changed shape. Such changes are consistent with pericardial cyst.

Fig. 6. Constrictive pericarditis in a 41-year-old female with symptoms of heart failure

An axial enhanced CT scan (**A**) and ECG-gated SE T_1 WI (**B**) demonstrate pericardial calcification and thickening (arrows). The dilated right atrium, in contrast to the normal-sized right and left ventricles, is suggestive of pericardial constriction.

Fig. 7. Constrictive pericarditis in a 77-year-old male with symptoms of heart failure

An axial enhanced CT scan shows diffuse pericardial thickening (arrows) without calcification and with tubular-shaped ventricles.

Pericardial Defects

Pericardial defects are uncommon. The majority of cases are congenital, but defects can result from surgery (Fig. 8B) or trauma. A spectrum of abnormalities exists, ranging from small defects to total absence of the pericardium. The most common defect is an absence of the entire left side of the pericardium. Left-sided absence of the pericardium allows interposition of lung tissue between the

aorta and the main segment of the pulmonary artery, and occasionally, bulging of the left atrial appendage through the defect. Because of these abnormalities, the heart usually rotates toward the left.¹ CT and MRI may be helpful in determining the presence or absence of a segment of pericardium, but the lack of visualization of the pericardium over the left ventricle and atrial appendage in normal makes diagnosis difficult.²

Pericarditis and Pericardial Effusion

Pericarditis is an inflammatory response by the pericardium associated with a wide variety of clinical conditions.¹² With CT, simple effusions usually have attenuation of water. Nonhemorrhagic fluid exhibits a low signal intensity in T_1 -weighted SE images and a high intensity in GRE cine images (Figs. 9A and 9B).¹ Transudate pericardial effusions are often even more intense than epicardial fat in GRE images (Fig. 9B).

CT attenuation measurements and analysis of MR signals also enable the initial characterization of pericardial fluid. Attenuation greater than that of water suggests malignancy, hemopericardium (Fig. 10), purulent exudates or effusion-associated hypothyroidism.¹³ Conversely, hemorrhagic effusion is characterized by high signal intensity in T_1 -weighted SE images and low intensity in GRE cine images.¹⁴ With inflammatory pericarditis, the patient usually has an effusion and pericardial thickening. The effusion may be loculated (Fig. 10). Pericardial effusion originates in the obstruction of venous or lymphatic drainage from the heart.

Fig. 8. Constrictive pericarditis in a 40-year-old male with symptoms of constriction

An enhanced paracoronal multiplanar reformatted (MPR) image (A) shows diffuse pericardial thickening (arrows). An MPR image after pericardectomy clearly shows that most of the pericardium, except for the bottom (arrow), has been resected (B).

Fig. 9. Pericardial effusion in a 60-year-old female with congestive heart failure

Axial ECG-gated SE T₁WI (A) and gradient echo (GRE) cine image (B) show diffuse pericardial effusion (arrows) and bilateral pulmonary effusion due to congestive heart failure. Note that pericardial effusion shows a higher signal than epicardial and subcutaneous fat in the GRE cine image (B).

Common causes of pericardial effusion include heart failure, renal insufficiency, infection (bacterial, viral, or tuberculous), neoplasm (carcinoma of lung or breast or lymphoma), and injury (from trauma or myocardial infarction).¹ Radiation pericarditis (Fig. 11) is also an example of the above.

The magnitude of the pericardial effusions also may be assessed quantitatively by MRI with volume methods. Effusions that are classified semiquantitatively as moderate by MRI are associated with a pericardial space exceeding 5 mm anterior to the right ventricle.⁵ MRI is superior to CT in differentiating fluid from thickened pericardium.²

Primary Pericardial Tumors

The pericardium is more commonly involved by metastatic disease than is the myocardium. Primary pericardial tumors are rare, with mesotheliomas and sarcomas being the more “common” among them.¹⁴ Benign pericardial tumors include lipoma, teratoma, fibroma, and hemangioma; malignant tumors include mesothelioma, lymphoma, sarcoma, and liposarcoma.¹ Cohen has classified primary pericardial tumors as developmental, stromal, vascular, and miscellaneous.¹⁵ Primary malignant mesothelioma of the pericardium may manifest as pericardial effusion, occasionally accompanied

by pericardial nodules or plaques. Lymphoma (Fig. 12), sarcoma, and liposarcoma typically appear as large heterogeneous masses frequently associated with serosanguineous pericardial effusion. Biopsy and histopathologic analysis are necessary to achieve a definitive diagnosis of most

pericardial tumors.¹

Metastatic Pericardial Disease

Pericardial metastases are much more common than primary pericardial tumors and are discovered at autopsy in 10%–12% of all patients with malignancy.^{16,17} Carcinomas of the lung and breast are the tumors most likely to metastasize to the pericardium. Melanoma and lymphoma are two other common sources of pericardial metastases. Imaging reveals that pericardial involvement caused by direct extension of pulmonary and mediastinal malignancies is a common occurrence.⁴ Metastatic involvement of the pericardium may be suggested by CT findings of effusion and irregularly thickened pericardium or pericardial mass. With MRI, an intact pericardial line may be observed if an adjacent tumor extends to the pericardium but not through it.¹ If the effusion is hemorrhagic, extension is certain. This is easily seen with MRI with high signal intensity in SE imaging.⁹

Conclusion

Various imaging characteristics of pericardial diseases have been demonstrated. We conclude that CT and MR imaging can clearly depict and characterize the pericardium and pericardial diseases.

Fig. 10. Pericardial hematoma in a 59-year-old male with recent mitral valve replacement. An axial nonenhanced CT scan shows localized fluid collection (arrow) within the pericardial space. The center of the fluid shows a slightly higher attenuation, which is compatible with hematoma.

Fig. 11. Radiation-induced pericarditis in a 39-year-old male with thymic carcinoma

An axial unenhanced CT scan (A) shows partial pericardial thickening and pericardial effusion. The patient suffered from thymic carcinoma and was given radiation therapy. Note the range of the pericardial thickness (arrow) is limited in the field of irradiation. Radiation osteomyelitis of the sternum (arrow) is also shown in the upper slice (B).

Fig. 12. Malignant lymphoma in a 70-year-old female with heart failure due to cardiac tamponade

An axial enhanced CT scans show pericardial (A) and intracardiac (B) masses (arrows). Massive pericardial effusion and pulmonary effusion are also shown. The patient has progressive cardiac failure due to cardiac tamponade. Pericardiocentesis reveals the tumor to be malignant lymphoma.

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