JACC: CARDIOVASCULAR IMAGING
VOL. 4, NO. 6, 2011
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ISSN 1936-878X/$36.00
PUBLISHED BY ELSEVIER INC.
DOI:10.1016/j.jcmg.2010.08.022

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IMAGING VIGNETTE

Contemporary Imaging of the Pericardium

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AS A THIN, ELASTIC STRUCTURE THAT SURROUNDS THE HEART, PERICARDIUM has an important contribution to cardiac physiology, dictating the diastolic interaction between the 2 ventricles. When diseased, the restraining effect of the pericardial apparatus can lead to significant morbidity and culminate in life-threatening situations. Advanced imaging modalities have brought novel insights and refinement in the diagnosis of pericardial disease. Herein, we present a comprehensive pictorial essay of pericardial syndromes beginning with a historical perspective (Figs. 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10).

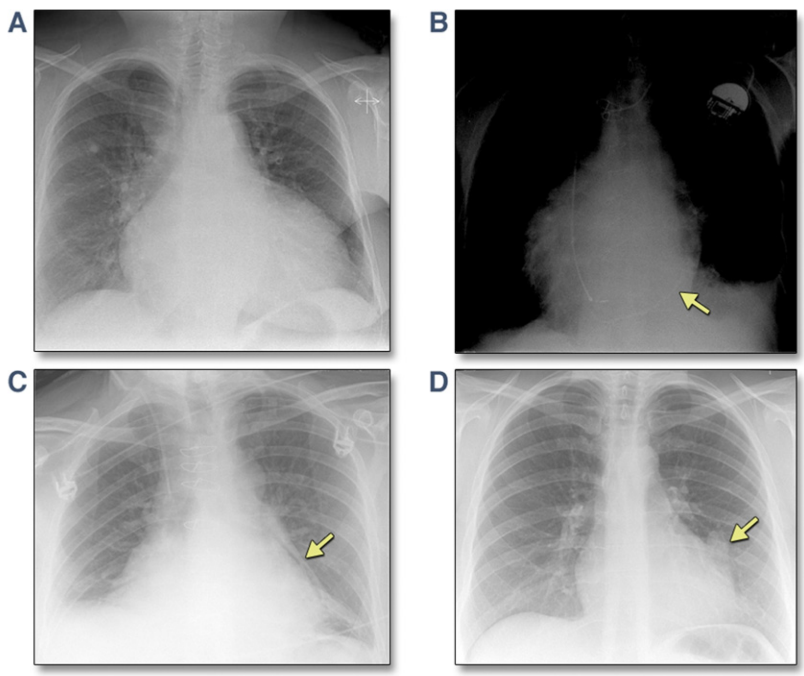

Figure 1. Chest Skiagram

Normal pericardium is hardly definable on the chest x-ray (CXR) but a globular heart may be seen with a large pericardial effusion (PEff) **(A)**. Pericardium may be visible on CXR when calcified, which may be associated with constriction: **(B)** demonstrates a rim of pericardial calcification **(arrow)** 15 years after coronary artery bypass graft (CABG). **(C)** Shows pneumopericardium **(arrow)** after thoracic surgery. Pericardial cysts, absent pericardium, and tumors may have characteristic appearances: **(D)** shows a low-grade malignant spindle-cell tumor **(arrow)**.

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Figure 2. CMR Imaging of Acute Pericarditis

Structural/tissue characterization cardiac magnetic resonance (CMR) imaging of a patient presenting with acute pericarditis is presented. **(A)** Demonstrates thickening of both visceral and parietal layers **(arrow)** with a small PEff and large right pleural effusion on balanced steady state free precession (b-SSFP) (Online Video 1). **(B)** Early gadolinium enhancement where both pericardial layers enhance, suggesting pericardial inflammation **(arrow)**. **(C)** The pericardium appears as bright signal on T2-weighted short tau inversion recovery (T2-W STIR) **(arrow)**, suggesting an edematous, inflammatory process. Abbreviations as in Figure 1.

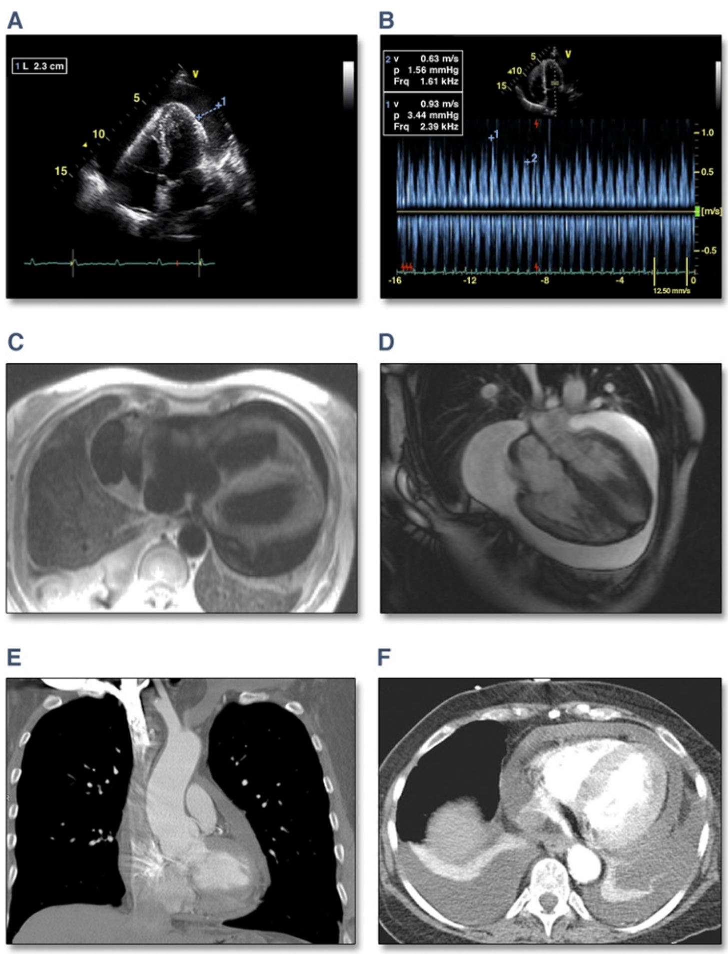

Figure 3. Multimodality Imaging of PEff

PEff is most often diagnosed by bedside echocardiography. **(A)** Shows a large PEff on 2-dimensional echocardiography (Online Video 2). **(B)** Depicts the respiratory variation in mitral inflow seen with pulsed wave Doppler. **(C)** Shows a T1-weighted turbo spin echo (T1-W TSE) transverse image of PEff—which appears as low intensity signal due to black blood preparation (pericardial fluid also moves). **(D)** Is a large PEff seen on b-SSFP cine CMR (a flow independent sequence, therefore an effusion appears as high signal intensity): note a swinging heart in Online Video 3 and the early right ventricle diastolic collapse and septal shudder in Online Video 4. **(E)** Coronal computed tomography reconstruction showing a small PEff. **(F)** Axial computed tomography view of a moderate PEff and bilateral pleural effusions. Abbreviations as in Figures 1 and 2.

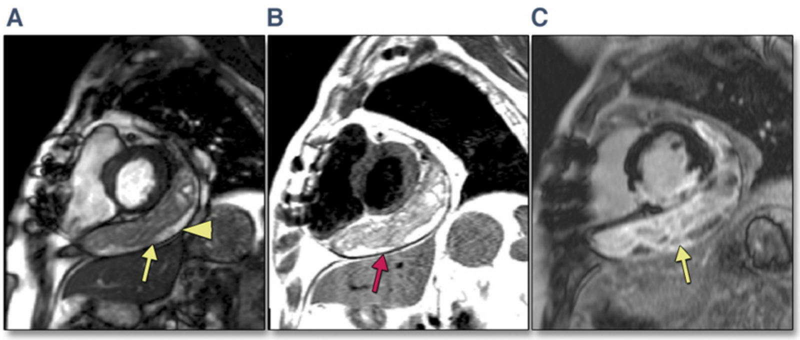

Figure 4. CMR Imaging of Hemopericardium

CMR has been used to characterize the type of effusion depending on the signal intensity: on T1-W TSE transudates most likely appear black, whereas exudates or fresh hemorrhagic content appear of higher signal intensity. On T2-W TSE both have high signal intensity. An older hemorrhagic PEff should appear to have lower signal on T2-W due to the shortening of T2 relaxation time by particulate Iron. **(A)** Short axis b-SSFP demonstrating a partially clotted hemopericardium **(arrow)** within a PEff **(arrowhead)** following CABG. **(B)** T2-W TSE showing intermediate signal intensity of the intrapericardial clot **(arrow)**. **(C)** Late gadolinium enhancement demonstrating contrast enhancement of the intrapericardial clot **(arrow)**. Abbreviations as in Figures 1, 2, and 3.

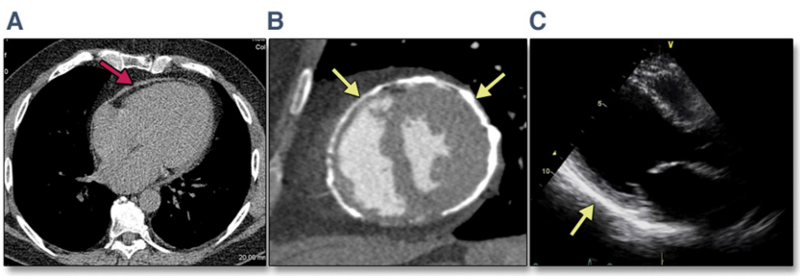

Figure 5. Multimodality Imaging of Pericardial Thickening and Calcification

The diagnosis of pericardial constriction can be challenging and requires careful clinical assessment as well as use of most available imaging techniques. Thickening and calcification of the pericardium are highly specific, whereas their absence does not rule out the diagnosis (normal pericardial thickness is 4 mm on CMR and 2 mm on computed tomography [CT]). They can be focal (typically in the atrioventricular groove) and have a ragged appearance. **(A)** Pericardial thickening seen on noncontrast CT **(arrow)**. **(B)** Extensive pericardial calcification on CT **(arrows)**. **(C) C**alcification on echocardiography **(arrow)** (Online Video 5). Abbreviations as in Figures 2 and 3.

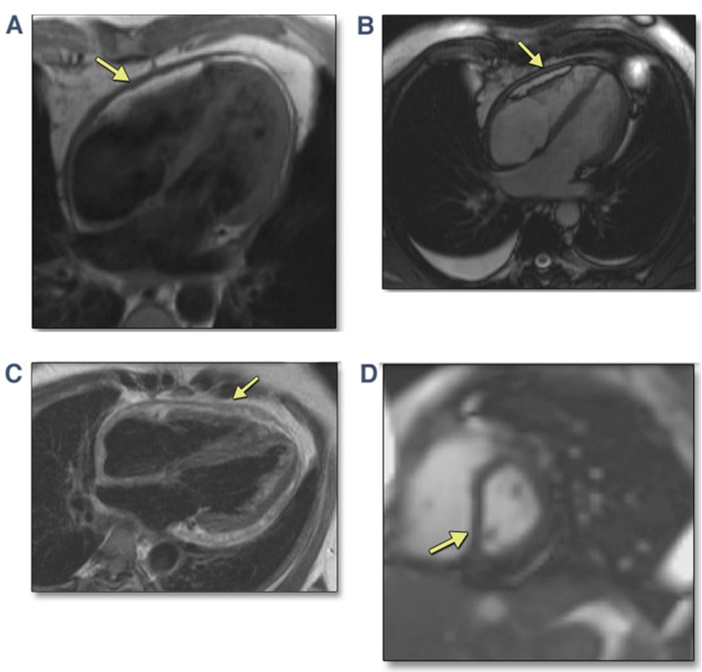

Figure 6. CMR in Pericardial Constriction

Any disease that limits the normal compliance of the pericardium (inflammation, thickening ± calcification, or effusion) prevents the transmission of the intrathoracic pressures to the pericardium and intracardiac cavities (1). This creates a large respiratory-dependent variation in the left-sided filling gradient (between pulmonary capillaries and left atrium). With inspiration the intrathoracic pressure falls but this is not transmitted to the intrapericardial space, therefore, the driving gradient decreases. With expiration, the intrathoracic pressure increases, encouraging more return. As the intrapericardial space is fixed, the phenomenon of ventricular interdependence dictates that less left ventricular filling occurs during early inspiration. As a result, the interventricular septum moves towards the left. In expiration, the left ventricle fills better and the septum returns to a normal position (2). This characteristic septal motion is known as a septal "bounce" or "shift." In addition, there is also a discrete septal "shudder" that is seen independent of breathing. This occurs due to the differential filling rates of the 2 ventricles during diastole, resulting in a septal movement first towards the right, then towards the left. **(A)** T1-W TSE demonstrating a thickened pericardium in a patient with constriction **(arrow)**. **(B)** Shows thickened pericardium seen on b-SSFP **(arrow)**. Please see Online Video 6 for septal shudder. **(C)** Enhancing pericardium on T2-W STIR denoting ongoing inflammatory process in a patient with sarcoidosis **(arrow)**. **(D)** Free breathing real-time frame demonstrating septal bounce **(arrow)** (Online Video 7). Abbreviations as in Figures 2 and 3.

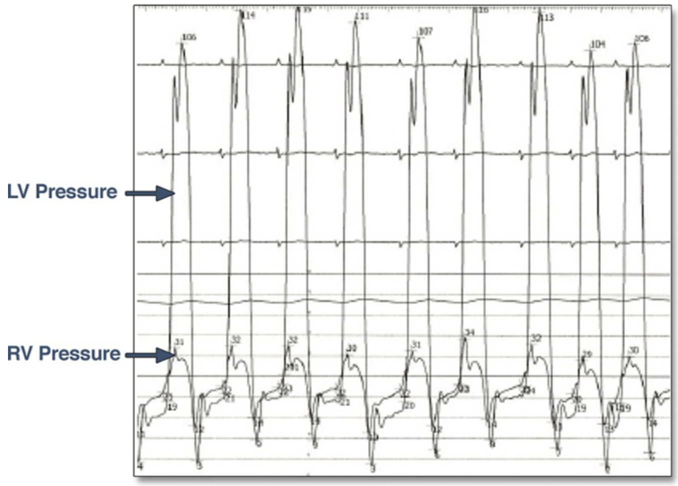

Figure 7. Invasive Pressure Recordings in Pericardial Constriction

Catheterization allows simultaneous right ventricular and left ventricular pressure recordings, demonstrating equalization of pressures at end-diastole which gives the typical "square root" or "dip and plateau" sign. Although not specific to constriction, this may add to the diagnosis in concert with other findings.

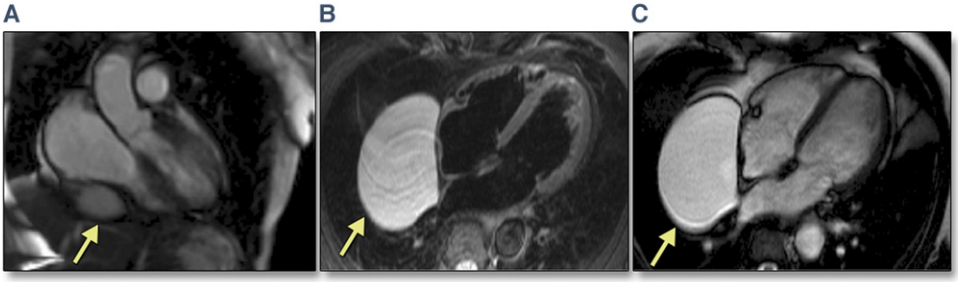

Figure 8. CMR Imaging of Pericardial Cyst

Pericardial cysts are usually incidental findings and typically occur in the right cardiophrenic sulcus. They are not connected to the pericardial space, have medium intensity on T1-W TSE but high signal on T2-W TSE or b-SSFP, and do not enhance with contrast. **(A)** b-SSFP coronal view of a small cyst in the right costophrenic location (Online Video 8). **(B)** T2-STIR and **(C)** b-SSFP axial views of a large cyst in a similar location **(arrows)**. Abbreviations as in Figures 1, 2, 3, and 4.

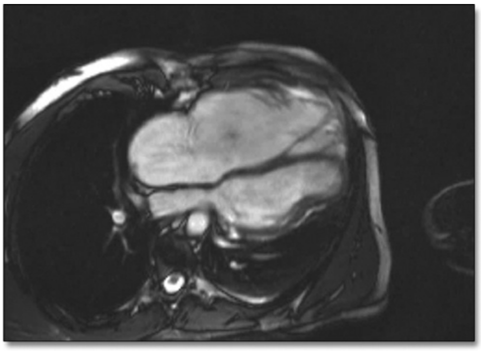

Figure 9. CMR Imaging of Pericardial Absence

b-SSFP frame of total pericardial absence, which shows as a shift of the entire heart to the left and enlargement of the right heart, with significant tricuspid regurgitation (Online Video 9). Abbreviations as in Figure 2.

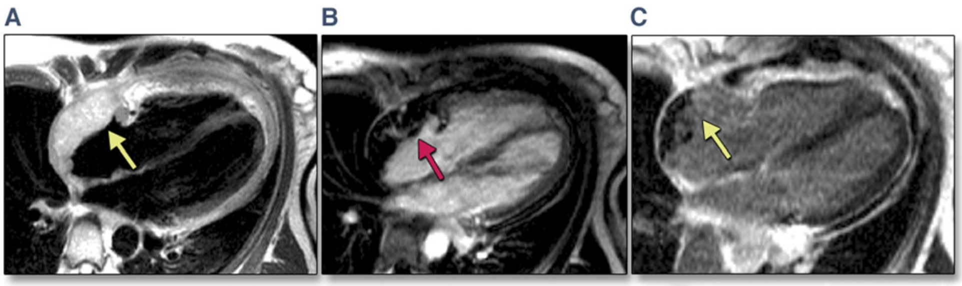

Figure 10. CMR Imaging of Pericardial Tumor

Primary malignant pericardial tumors are rare (mesothelioma, fibrosarcoma, angiosarcoma, teratoma). Metastases are much more common and secondary to lung or breast carcinoma or lymphoma; they are often associated with hemorrhagic PEff. Tissue characterization of tumors can be difficult with the exception of liposarcomas. **(A)** Shows a T2-W TSE of a pericardial angiosarcoma as a right atrial mass **(arrow)**. **(B and C)** Show late gadolinium enhancement images acquired after 1 min and 15 min, respectively, indicating increased vasculature and necrosis/scarring, respectively **(arrows)**. Abbreviations as in Figures 1, 2, and 3.

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Key Words: cardiac computed tomography ■ cardiac magnetic resonance ■ constriction ■ echocardiography ■ pericarditis ■ pericardium ■ tamponade.

APPENDIX

For accompanying videos 1 to 9, please see the online version of this article.