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Thoracic and Cardiac Imaging / Imagerie cardiaque et imagerie thoracique

Incidental Cardiac Findings on Thoracic Imaging

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Abstract

The cardiac structures are well seen on nongated thoracic computed tomography studies in the investigation and follow-up of cardiopulmonary disease. A wide variety of findings can be incidentally picked up on careful evaluation of the pericardium, cardiac chambers, valves, and great vessels. Some of these findings may represent benign variants, whereas others may have more profound clinical importance. Furthermore, the expansion of interventional and surgical practice has led to the development and placement of new cardiac stents, implantable pacemaker devices, and prosthetic valves with which the practicing radiologist should be familiar. We present a collection of common incidental cardiac findings that can be readily identified on thoracic computed tomography studies and briefly discuss their clinical relevance.

Résumé

Les structures cardiaques sont bien visibles sur les examens thoraciques par tomodensitométrie non synchronisée réalisés dans le cadre de l'investigation et du suivi de maladies cardiopulmonaires. Un large éventail de résultats peuvent par ailleurs être recueillis lors d'un examen attentif du péricarde, des cavités cardiaques, des valves et des gros vaisseaux. Certains de ces résultats peuvent représenter des variantes bénignes, alors que d'autres revêtent une plus grande importance clinique. De surcroît, l'expansion de la pratique interventionnelle et chirurgicale a entraîné le développement et l'utilisation de nouvelles endoprothèses cardiaques, de stimulateurs cardiaques internes et de prothèses valvaires, avec lesquels les radiologistes ont dû apprendre à se familiariser. Nous présentons une série de constatations cardiaques accessoires courantes qui peuvent être facilement établies lors d'examens thoraciques par tomodensitométrie et abordons brièvement leur pertinence clinique.

Key Words: Cardiac imaging; Cardiac computed tomography; Thorax; Incidental finding

Computed tomography (CT) imaging is a frequently performed radiologic study in the investigation of cardiopulmonary disease. Whereas radiologic features of noncardiac incidental findings, such as pulmonary nodules, are well recognized by interpreting radiologists and physicians in cardiac CT, less attention is often placed on searching for cardiac findings in noncardiac thoracic CT studies [1−3]. Cardiopulmonary diseases often overlap in their clinical manifestation, which makes careful evaluation of both pulmonary and cardiac structures of utmost importance in establishing a correct diagnosis to help guide further workup and management.

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Coronary Arteries

With the improvements in spatial and temporal resolution of multidetector CT scanners over the past decade, dedicated CT imaging of the coronary arteries has developed into a valuable clinical tool for noninvasive evaluation of coronary circulation [4]. Although nonelectrocardiographic-gated thoracic CT studies do not permit a dedicated evaluation of the coronary circulation, radiologic clues can often be found that can indicate the presence of congenital or acquired coronary disease. Calcification of the coronary arteries has been demonstrated to correlate well with formal coronary artery calcium scoring [5]. Calculation of the coronary calcium score is usually performed on noncontrast imaging of the heart reconstructed at 3-mm intervals by using the Agatston or volume methods, with scores of >400 being

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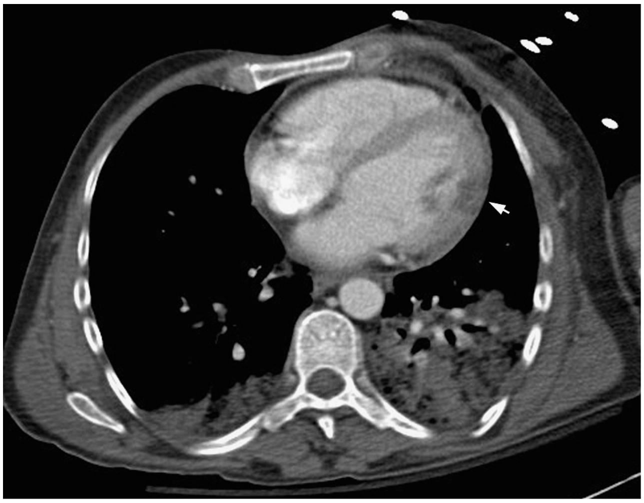

Figure 1. Axial contrast-enhanced computed tomography, showing an acute myocardial infarction that involves the lateral wall of the left ventricle (arrow) with adjacent mural thrombus. Low attenuation change is seen throughout the full thickness of the affected myocardium, in keeping with a transmural infarction. Intraventricular thrombus is typically seen in the apex of the ventricle in the setting of impaired left ventricular function or left ventricular aneurysm formation. The presence of thrombus adjacent to the lateral wall in this case is atypical and is secondary to the acute infarction in the adjacent segment of left ventricular myocardium.

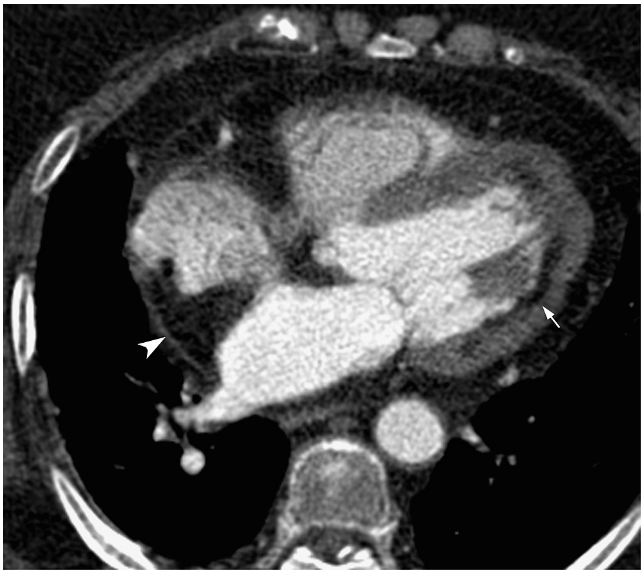

Figure 2. Axial contrast-enhanced computed tomography, showing an acute subendocardial infarction in the left anterior descending and diagonal territory that involve the mid-to-apical left ventricular free wall (arrow). The low attenuation myocardium infarction can be clearly distinguished from normal myocardium. Lipomatous hypertrophy of the interatrial septum is also present (arrowhead).

associated with an increased relative risk of cardiac events [6]. On regular noncardiac imaging, the presence of coronary calcium should be reported in younger patients (<55 years in men, <65 years in women) in whom it is an indicator of undiagnosed premature coronary artery disease. At the other end of the spectrum, evidence of previous coronary artery bypass surgery, percutaneous coronary intervention, and myocardial infarction can be seen in patients with known established coronary artery disease (Figures 1–3).

Less common findings include congenital coronary artery anomalies such as anomalous courses, aneurysms, and fistulas. Even on nongated imaging, it may be possible to identify a ‘‘malignant’’ anomalous course of the right coronary artery, which is associated with sudden death. The estimated incidence of sudden death is between 25% and 40% in patients with a malignant coronary course, particularly with physical exercise [7]. Abnormal aneurysmal dilatations of the coronary circulation, which are often caused by Kawasaki disease, atherosclerosis, or previous coronary intervention, can be identified. Similarly, it may be possible to visualize tortuous coronary artery fistulas, which often involve the right coronary artery and terminate in the right-sided cardiac chambers [8].

Coronary Artery Bypass Grafts

Coronary artery bypass grafts can be identified on CT imaging; common configurations include the use of saphenous vein grafts and the left internal mammary artery to bypass stenotic segments of the native coronary vessels. Less

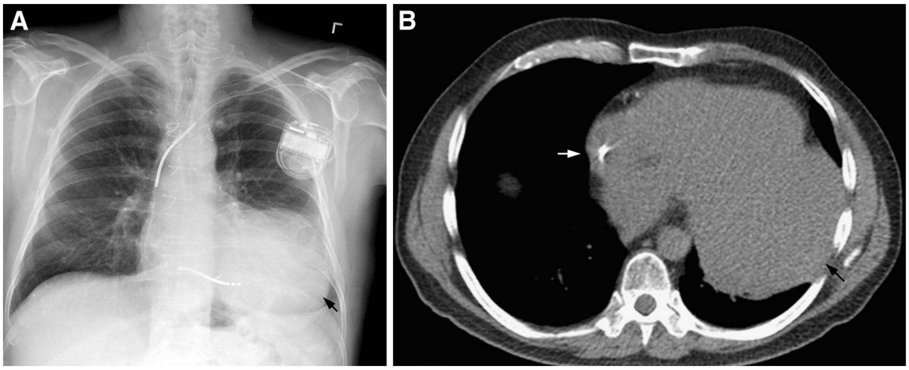

Figure 3. Large left ventricular aneurysm (black arrows) in a patient with previous lateral wall myocardial infarction. The aneurysm can be seen on the posteroanterior chest radiograph (A), and its dimensions are better appreciated on the axial noncontrast computed tomography image (B). A single-lead implantable cardiac defibrillator is also seen (white arrow), which is identifiable as a defibrillator device because the generator box is larger than a typical pacing device and a single lead with the location (right ventricular) and configuration as shown is the typical appearance of defibrillating leads.

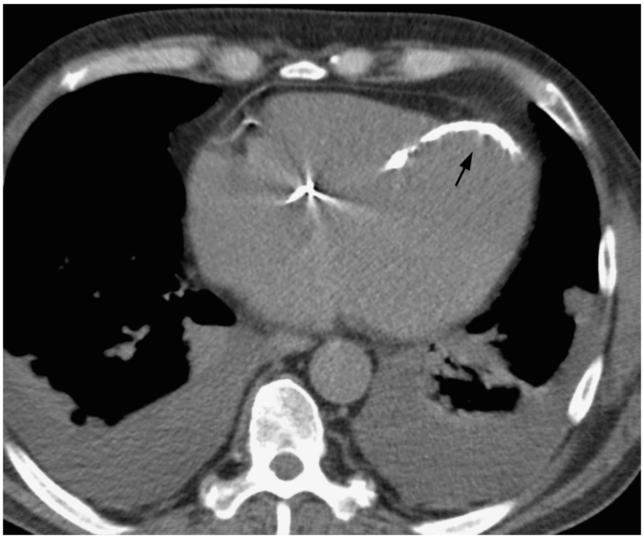

Figure 4. A 52-year-old man with ischemic cardiomyopathy undergoing chest computed tomography (CT) evaluation. An axial CT image, showing a rim of calcification in the nonviable left ventricular myocardium (arrow) from a previous extensive left anterior descending territory myocardial infarction with the presence of bilateral pleural effusions. A single lead pacing wire is seen crossing the tricuspid valve.

frequently, the right internal mammary and radial artery grafts can also be used. It is important to evaluate both the bypass grafts and the native vessels to look for complications, such as aneurysm formation and graft occlusion, particularly at sites where venous conduits are used. It is also increasingly common for stenotic grafts to undergo angioplasty and stenting. The position and course of the left internal mammary artery relative to the sternal suture wires is of relevance if a repeated coronary artery bypass graft is required because there is a risk of injury to a preexisting graft at sternal reentry [9].

Myocardial Disease

The myocardium can be evaluated on both contrast-enhanced and noncontrast studies for a variety of disease states, including previous myocardial infarction, myocardial hypertrophy, and aneurysm formation. Areas of low attenuation change in a segment of myocardium may indicate the presence of a prior infarction in that segment, and the thickness of myocardium involved can help to distinguish between subendocardial and transmural infarctions (Figures 1 and 2). Other changes of myocardial scarring from a prior infarction, such as wall thinning, left ventricular aneurysm formation (Figure 3), and calcification can be seen (Figure 4). Whereas nongated CT studies are not ideal for the evaluation of ventricular-wall thickness, because static images are typically not acquired at the diastolic phases of the cardiac cycle when the myocardium is most relaxed, gross asymmetry may still be identified in cases of hypertrophic cardiomyopathy. However, it is important for suspected abnormalities to be clarified with echocardiography or cardiac magnetic resonance imaging.

Pericardial Disease

CT evaluation of pericardial disease has the advantage of excellent spatial resolution compared with echocardiography to better depict pathology in this thin structure, which should normally be less than 2 mm in thickness [10,11]. Pericardial effusions are readily seen on nongated CT, and the attenuation value, in Hounsfield units (HU), of the effusion can help distinguish between simple effusions (smooth enhancing pericardium, effusion <20 HU, with no pericardial thickening, nodularity, or septation) and more sinister etiologies such as hemopericardium (60-80 HU) (Figure 5) or purulent exudative effusions (30-50 HU, with thickened pericardium and loculations). Metastatic pericardial disease can occur via direct spread from lung cancers or mediastinal tumours and also hematogenous spread commonly from, for example, breast cancer or melanoma. Of the cardiac structures, hematogenous spread of malignancy most commonly first involves the pericardium. Features of metastatic pericardial disease include complicated or hemorrhagic effusions, with nodular pericardial enhancement. In the setting of acute chest pain, a hemorrhagic pericardial effusion and clinical signs of shock

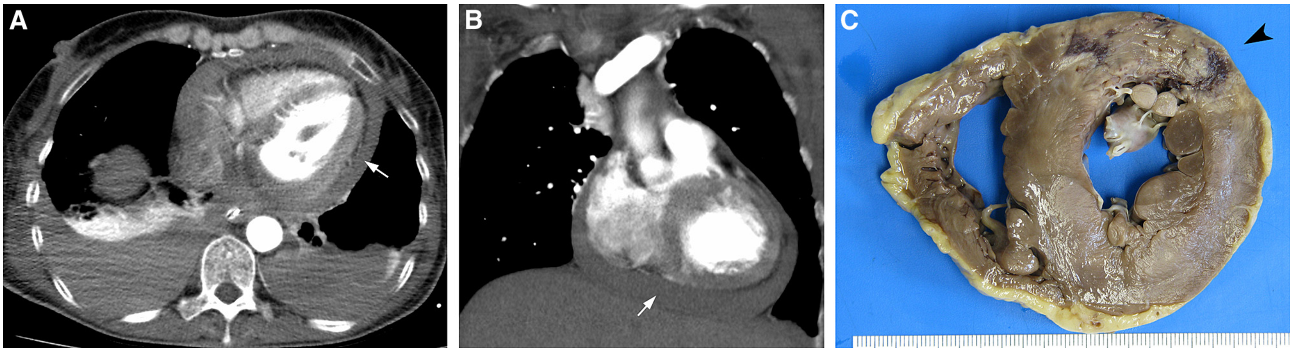

Figure 5. A 78-year-old man who was admitted with chest pain 1 week earlier with an unresolving lower respiratory tract infection and who subsequently died of cardiac arrest. (A, B) Axial and coronal computed tomography thorax images, demonstrating a moderate-sized high-attenuating pericardial effusion (white arrows) with bilateral pleural effusions, which was subsequently confirmed on postmortem to be a hemorrhagic pericardial effusion. (C) Postmortem evaluation revealed an infarction of the left ventricle in the region supplied by the left anterior descending coronary artery with associated rupture of the left ventricular free wall (black arrowhead), which led to cardiac tamponade. This figure is available in colour online at http://carjonline.org/.

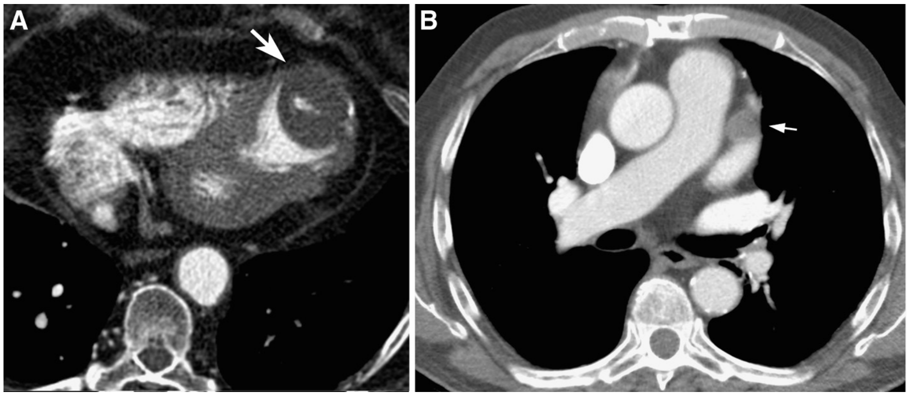

Figure 6. Intracardiac thrombus. (A) Axial contrast-enhanced computed tomography (CT) image, showing thrombus in the apex of the left ventricle with associated thinning and focal calcification of the apical myocardium from previous transmural infarction (arrow). (B) Axial contrast-enhanced CT, showing thrombus in the left atrial appendage (arrow) in a patient with known atrial fibrillation.

could indicate an acute left ventricular perforation secondary to myocardial infarction in the absence of other etiologies such as a Stanford type A aortic dissection or coagulopathy.

Other chronic disease processes that can affect the pericardium and result in constrictive pericarditis include infections, for example, tuberculosis; radiotherapy; cardiac surgery; connective-tissue diseases; and uremia due to renal failure [11,12]. Pericardial calcification can be readily identified on CT, and it is a better modality for depicting calcific pericardial disease compared with echocardiography due to the loss of echoes from calcification. Pericardial calcification itself may indicate the presence of constriction, but constrictive pericarditis remains primarily a clinical and echocardiographic diagnosis.

Cardiac Masses

Cardiac masses are uncommon and may consist of benign etiologies such as a thrombus, myxoma, or simple cysts, or as primary and secondary malignant neoplasms. Thrombus in the cardiac chambers represents an important source of embolism and can be detected by CT imaging, often incidentally. Intracardiac filling defects are likely to be thrombi when there is no enhancement with intravenous contrast and where supporting features for thrombus development are present, such as areas of prior infarction (Figures 1 and 6), impaired left ventricular function, or left ventricular aneurysm formation. Thrombus is most often found in the left ventricle in the setting of impaired left ventricular function, but, in patients with atrial fibrillation, thrombus may also be seen, on contrast-enhanced CT, in the left atrial appendage.

Myxomas, the most common benign intracardiac tumour, which can be incidentally detected on CT, is recognized by its characteristic location in the left atrium (70%, with 25% seen in the right atrium) and its pedunculated configuration with a stalk adherent to the interatrial septum. Even on noncardiac-gated static images of the heart, tumour prolapse through the mitral valve can be seen and can result in outflow obstruction [13]. Another benign condition that may be mistaken for a neoplasm is lipomatous hypertrophy of the interatrial septum, which has an incidence of 2.2% on thoracic CT [14]. This condition represents fatty infiltration of the interatrial septum and can have a prominent ‘‘mass-like’’ appearance on CT (Figures 2 and 7). The lack of enhancement with contrast and low-attenuation values of <0 HU can be helpful in characterizing this process. The most common primary malignant tumour of the heart in adults, cardiac sarcoma, is typically found in the right atrium and may show findings such as vascularity and calcification within the mass as well as features of invasion into adjacent structures, for example, the tricuspid apparatus.

Cardiac metastasis should be sought in patients with disseminated malignancy (Figures 8–10). These malignant lesions may seed to the heart by hematogenous spread, venous extension, or direct invasion. The most common site of metastatic disease is, first, the pericardium, followed by epicardial fat, myocardial metastasis, and finally intracardiac metastasis. Direct invasion to the heart should be excluded in advanced lung cancer, direct transvenous spread into the

Figure 7. A 73-year-old man undergoing investigation of a pulmonary nodule. Axial contrast-enhanced computed tomography image, showing lipomatous hypertrophy of the interatrial septum and right atrial walls (arrowhead), with attenuation values of <0 HU.

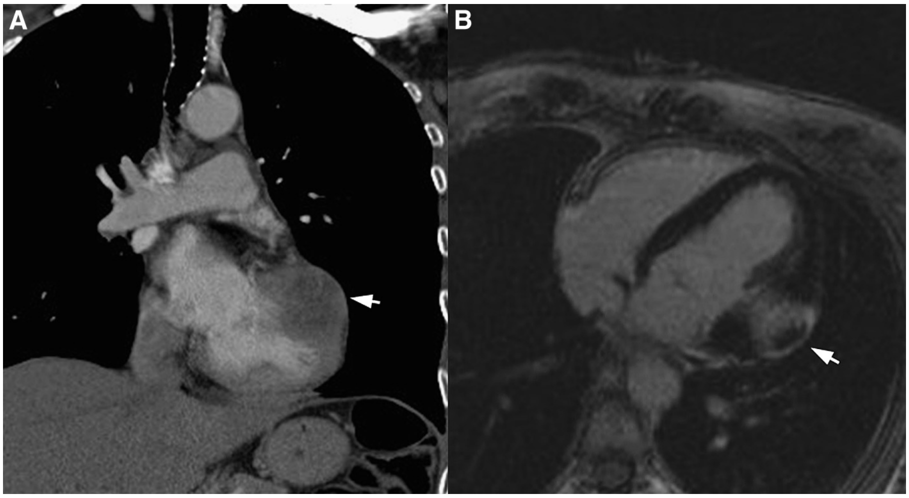

Figure 8. Cardiac metastasis. Axial contrast-enhanced computed tomography (A) and postcontrast volume interpolated breath-hold examination (VIBE) axial magnetic resonance image (B) of the chest in a patient with known primary adenocarcinoma of the lung and worsening shortness of breath, showing metastasis to the left ventricular free wall (arrows).

heart via the inferior vena cava in patients with hepatocellular carcinoma or renal cell carcinoma, or hematogenous spread of sarcomas to the intracardiac chambers.

Valvular Lesions

Calcification of the heart valves, such as the aortic and mitral valves, can provide important clinical information regarding underlying valvular heart disease (Figure 11). Mitral valve calcification is often seen in association with degenerative valvular stenosis and has a reported CT incidence of 8.8% [15]. The superior spatial resolution of CT makes it useful for delineating the extent of mitral annular calcification, because heavy calcification can degrade image quality on other modalities, including echocardiography and magnetic resonance imaging. The degree of mitral valve calcification also has been shown to correlate to the severity of mitral valve disease on echocardiography [15]. Furthermore, the incidental finding of aortic and mitral valve calcification on CT has been shown to hold prognostic value as an independent predictor of cardiovascular events [16]. Although electrocardiographic-gated CT studies are best used to assess aortic valve morphology, it may be possible to identify bicuspid aortic valves on nongated studies in which a linear configuration of the valve leaflets is seen instead of the more typical tricuspid Y shape. In patients with sepsis and risk factors for infective endocarditis, valvular vegetations can be seen on thoracic CT (Figure 12).

Clinical outcomes from valvular heart disease have improved substantially, largely through the surgical replacement of diseased valves with prosthetic valves. Hence, larger patient populations will be found to have prosthetic valves on chest imaging. Prosthetic valves can be clearly visualized on CT, and recognition of common prosthetic valve types (metallic tilting disc, bileaflet, ball and cage or tissue prosthetic valves) is important because dysfunction of the prosthesis can have serious clinical implications. More recently, transcatheter aortic valve implants have been used successfully, and the anatomical detail of the stent-valve assembly can also be easily appreciated (Figure 13).

Implantable Electronic Cardiac Devices and Central Venous Catheters

Pacemakers, implantable cardiac defibrillators (ICD), and loop recorders are among the different types of implantable

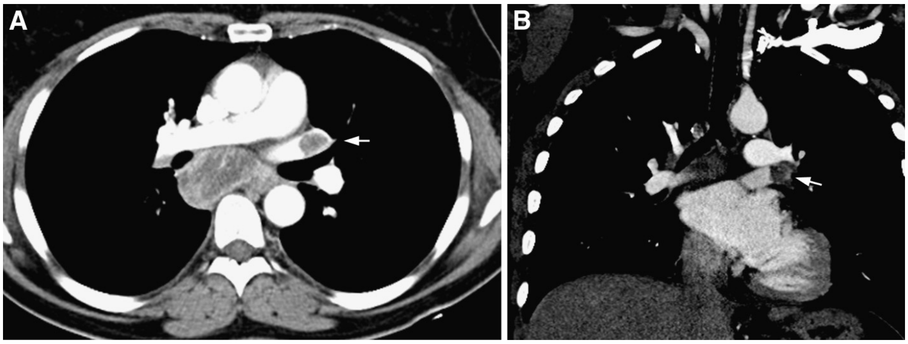

Figure 9. Intracardiac tumour thrombus. Axial (A) and coronal (B) computed tomography reconstructions in a 65-year-old woman with metastatic ovarian cancer, showing subcarinal lymphadenopathy and tumour thrombus in the left superior pulmonary vein (arrows).

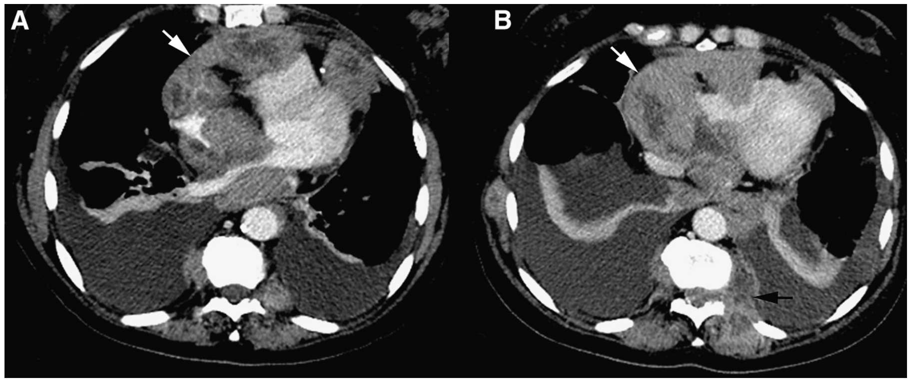

Figure 10. (A,B) Axial images from a contrast-enhanced computed tomography in a 65-year-old woman with recurrent acute myelogenous leukanemia. There is a multilobular soft-tissue mass encasing the atria and the right ventricle, and at the left ventricular apex (white arrows), with severe compression of the left atrium and pulmonary veins. There also is mass-like thickening of the interatrial septum with enhancement and central necrosis. The normal myocardium of the heart in these regions is not seen nor is the pericardial fat plane; hence, invasion of the myocardium into the cardiac chambers is suspected. (B) In the paravertebral regions bilaterally, there are enhancing soft-tissue masses. The left paravertebral mass extends into the spinal cord and through the chest wall into the left erector spinae muscle (black arrow).

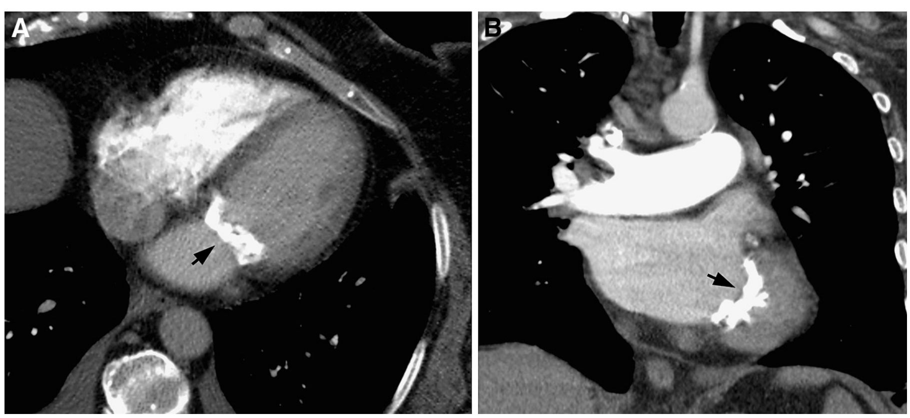

Figure 11. A 52-year-old woman admitted with sudden onset dyspnea and pleuritic chest pain. Computed tomography (CT) pulmonary angiography was performed to exclude pulmonary emboli. Axial (A) and coronal (B) CT images, showing heavy calcification of the mitral valve leaflets and annulus (arrows), which suggests underlying mitral stenosis. Heavy or heterotopic mitral annular calcification can be mistaken for a mass on echocardiography or magnetic resonance imaging, and CT can be the best modality to depict heavy valvular calcification.

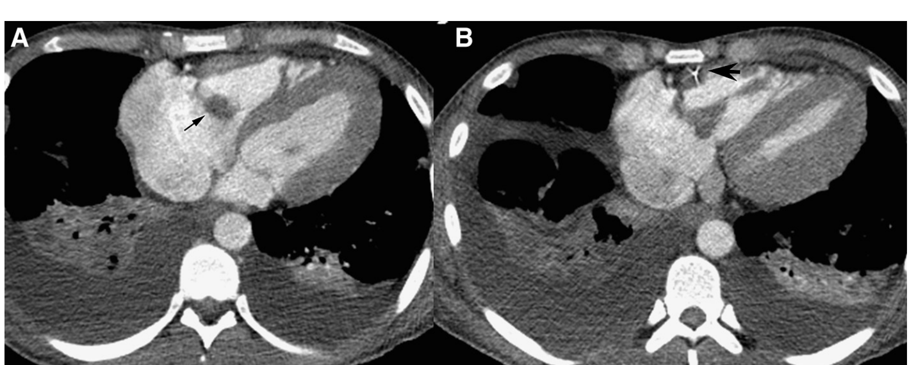

Figure 12. Valvular vegetations. Contrast-enhanced axial computed tomography images, (A) showing a lobular soft-tissue mass adherent to the tricuspid valve (thin black arrow) in a patient with a history of intravenous drug use. (B) The metallic artifact (thick black arrow) in the tricuspid valve apparatus was subsequently confirmed to be a retained needle.

Figure 13. Coronal multiplanar computed tomography reconstruction, showing the presence of a transcatheter aortic valve implant seated in the left ventricular outflow tract (black arrow). A single cardiac pacing lead is also seen to cross the tricuspid valve to terminate in the apex of the right ventricle (white arrow).

cardiac devices available. Both pacemakers and ICDs consist of a generator box, which is usually implanted in the upper left pectoral region, and accompanying pacing leads (Figures 3, 4, and 13). Pacemaker generator boxes are smaller than ICDs and may have a single lead, which terminates in the right ventricular apex, or have 2 leads (‘‘dual chamber’’), which terminate in the right atrium and the right ventricle apex, respectively. More specialized cardiac resynchronization therapy devices in patients with heart failure usually have 3 pacing leads, with the additional ventricular lead being placed via the coronary sinus to pace the epicardial surface of the lateral left ventricular wall. ICDs have larger physical dimensions, and ICD leads feature shock coils at the distal end, which appear thicker than the standard pacing lead. Subcutaneously implanted loop recorders are more variable in position but typically do not have any external leads and are smaller in physical dimensions.

It is important to evaluate both the generator box and leads on CT for complications in the soft-tissue pocket, such as hematoma formation and infective collections, and the leads for evidence of displacement, fracture, or perforation [17]. The incidence of pacemaker infection is reported to be between 0.5% and 1.5%, and may require surgical explantation of the complete pacemaker system if present [18]. Lead perforation can be challenging to identify on CT because beam-hardening artifacts can cause the lead tip to appear as if it projects beyond the epicardium, and correlation with lead functionality and impedance testing is required if clinically suspected. Secondary signs of perforation, such as a hemorrhagic effusion, hemothorax, or pneumothorax, can be helpful in the right clinical context (Figure 14).

Many radiology departments facilitate the insertion of central venous catheters (CVC), such as peripherally inserted central catheters and hemodialysis catheters, and complications related to CVC placement are readily detected. CVC tip malpositioning, which occurs in approximately 3.3% of insertions, may result in vascular or pericardial perforation, central venous stenosis, and venous thrombosis [19]. Right atrial placement of hemodialysis catheter tips has also been reported to result in intracavitary atrial thrombosis [20]. Therefore, CVCs should be routinely evaluated for these potential complications on thoracic CT by checking their course, tip location, and surrounding vascular or cardiac structures.

Conclusion

With the increasing use of CT imaging in the evaluation of cardiopulmonary disease, incidental cardiac disease will be more frequently encountered. Radiologists should have a checklist for evaluating the heart, which includes identification of normal variants as well as pericardial, valvular, and myocardial pathology, which may include metastatic disease. Complications of coronary artery bypass graft surgery, implantable cardiac device placement, and CVCs should also be assessed when appropriate. An increased awareness and knowledge of the spectrum of radiologic findings of cardiac disease will allow the radiologist to provide a comprehensive

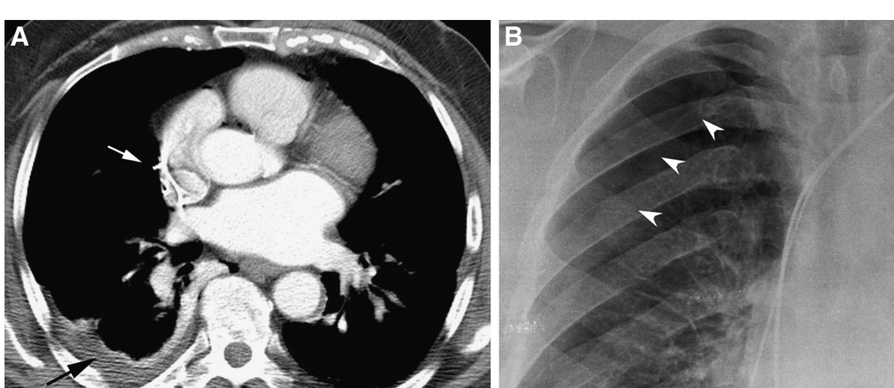

Figure 14. Pacemaker lead perforation. The tip of the atrial lead helix is seen to perforate the wall of the right atrium on axial (A) computed tomography imaging (white arrow) associated with a right-sided hemothorax (black arrow) and pneumothorax (B, white arrowheads).

report, which may find relevant incidental findings or precise etiologies for the clinical presentation of their patients.

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