Detecting cardiac abnormalities on routine chest CT

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The use of computed tomography (CT) has increased significantly since its advent about 40 years ago with an estimated 62 million scans performed in the United States every year.[1] It is likely that a large portion of this increase is due to the ability of CT angiography to detect pulmonary embolism and aortic dissection. Standard chest CT has also revolutionized imaging of the lungs with its ability to differentiate between many pulmonary disorders.

All too often, however, radiologists forget to analyze the heart while interpreting these studies. With improved multislice scanners and shortened imaging times, many cardiac abnormalities can be detected even on an ungated study.[2–4] In many institutions CT for aortic disease is gated and, if slice reconstruction is thin enough, important findings may become obvious.[2]

CT findings in the heart may contribute additional information to findings in the lungs, or may point to an entirely separate disease process. In either case, they are likely to aid the referring physician in appropriately treating the patient. It therefore behooves the conscientious radiologist to evaluate the heart and be able to recognize the more common abnormalities encountered on a routine chest CT.

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Cardiac calcification

Coronary artery calcium

CT is extremely sensitive for detection of coronary artery calcium. As atherosclerosis is the sole cause of calcium in the coronary arteries, coronary calcium is specific for the presence of atherosclerosis[2,5] (Figure 1).

Although one cannot infer the presence of significant obstruction from the presence of calcium alone, it is still an important observation and may be the first evidence of coronary atherosclerosis. Soft plaque in the coronary arteries will almost never be discernible on ungated studies, but may be visible on gated aortic studies and it could provide an explanation for chest pain in a patient thought to have a dissection.[5]

Coronary aneurysms can frequently be identified on gated and ungated studies, especially when calcified (Figure 2). They typically result from atherosclerosis and rarely from Kawasaki's disease.[6] Atherosclerotic aneurysms are a site for thrombosis or can be a source of emboli to distal vessels.[6] In Kawasaki's disease the aneurysms are typically proximal and can cause ischemia.

Valvular calcium

Calcium can also be seen in the regions of the mitral and aortic valves.[2,3] Mitral annular calcium is common in elderly individuals, is a degenerative phenomenon and is an incidental finding as there are no symptoms or hemodynamic abnormalities usually associated with it[7] (Figure 3). It is important not to confuse this with a calcified mitral valve, which occurs in mitral stenosis due to rheumatic heart disease (Figure 4) and which is quite rare in developed countries.[7] Mitral annular and mitral valve calcium are readily distinguishable as the former occurs in the atrioventricular groove around the mitral valve and the latter in the valve at the midplane of the left ventricle. A rare cause of calcium in the region of the mitral valve is casseous necrosis of the mitral annulus (Figure 5).

Calcium in the aortic valve suggests aortic stenosis (Figure 6) and the more heavily calcified the valve, the more likely a significant obstruction is present.[8] Calcium occasionally occurs in the pulmonary valve after balloon valvuloplasty for pulmonary valve stenosis.[2]

Myocardial and pericardial calcium

Calcium in the myocardium of the left ventricle or in a papillary muscle is indicative of a previous myocardial infarct (Figure 7), but does not necessarily indicate an aneurysm or clot.[2] Calcium in the wall of the heart is usually curvilinear although it can occasionally have an amorphous appearance.

The location of the calcified myocardium can be used to localize the culprit

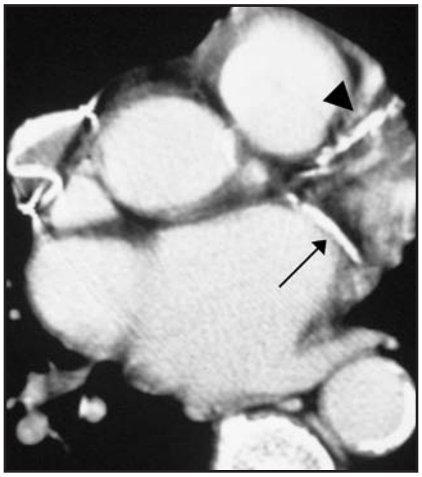

FIGURE 1. *Coronary artery calcium. The left anterior descending (arrowhead) and left circumflex arteries (black arrow) are diffusely calcified indicating severe atherosclerosis.*

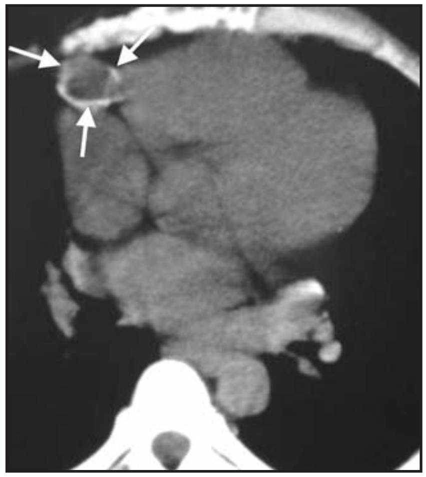

FIGURE 2. *Calcified aneurysm of the mid right coronary artery (arrows).*

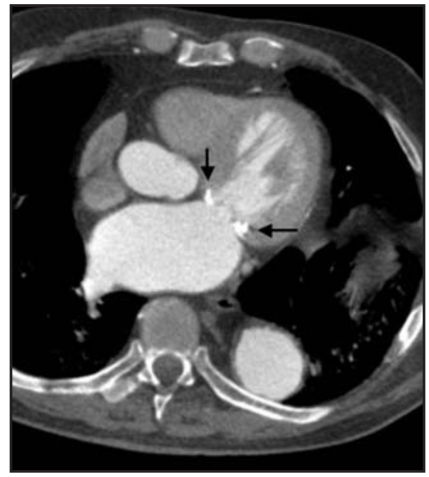

FIGURE 3. *Mitral annular calcium (arrows) is present on either side of the valve.*

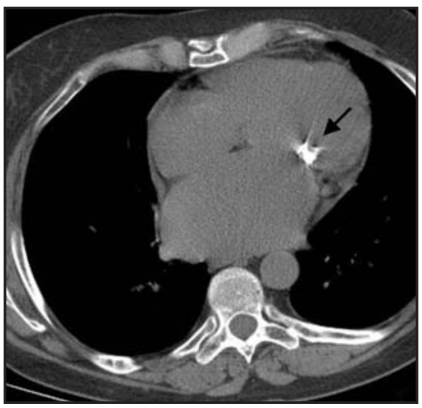

FIGURE 4. *Mitral valve calcium in a patient with rheumatic mitral stenosis. The calcium (arrow) is at the midplane of the valve.*

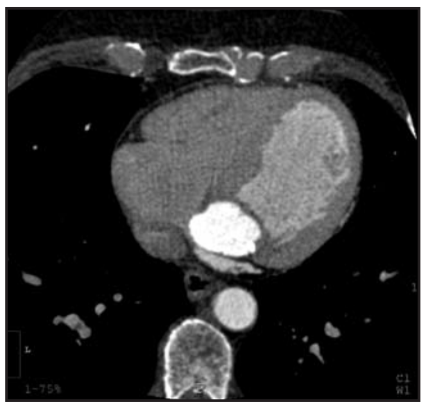

FIGURE 5. *Casseous necrosis of the mitral valve annulus. There is a large collection of calcium at the bottom of the mitral valve.*

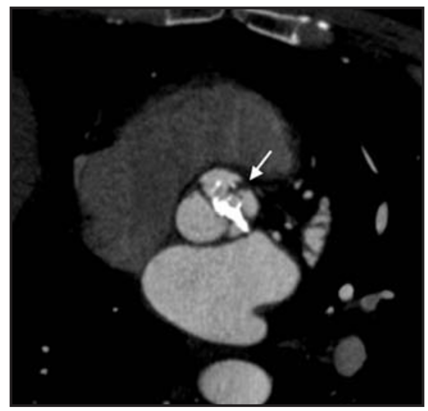

FIGURE 6. *Calcified bicuspid aortic valve in a patient with calcific aortic stenosis. An incomplete raphe is present between the left and right valve leaflets (arrow).*

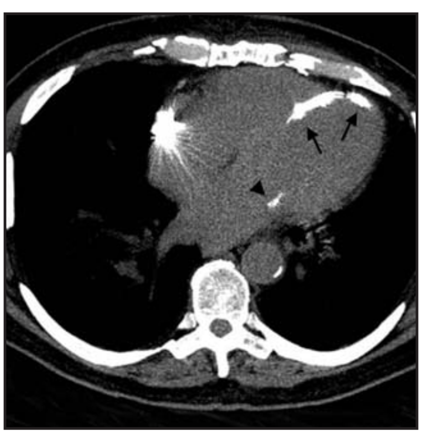

FIGURE 7. *Anterior infarction from left anterior descending occlusion. Calcium is present in a large apical and apical septal infarct (arrows) and in a papillary muscle tip (arrowhead).*

FIGURE 8. *Inferior infarction from right coronary artery occlusion. Calcium is present in the posterobasal portion of the left ventricle (arrow) and papillary muscle (arrowhead).*

FIGURE 9. *Calcific pericarditis. The pericardium is diffusely thickened (arrowheads) and calcified over the right heart (white arrows) and left atrium (black arrow).*

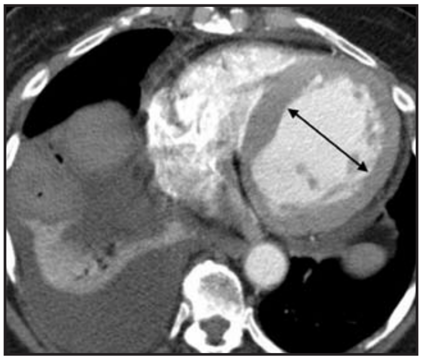

FIGURE 10. Left ventricular (LV) enlargement in a patient with chronic aortic regurgitation. The transverse diameter of the LV cavity was 6.5 cm (line with arrowheads). Left ventricular wall thickness was normal.

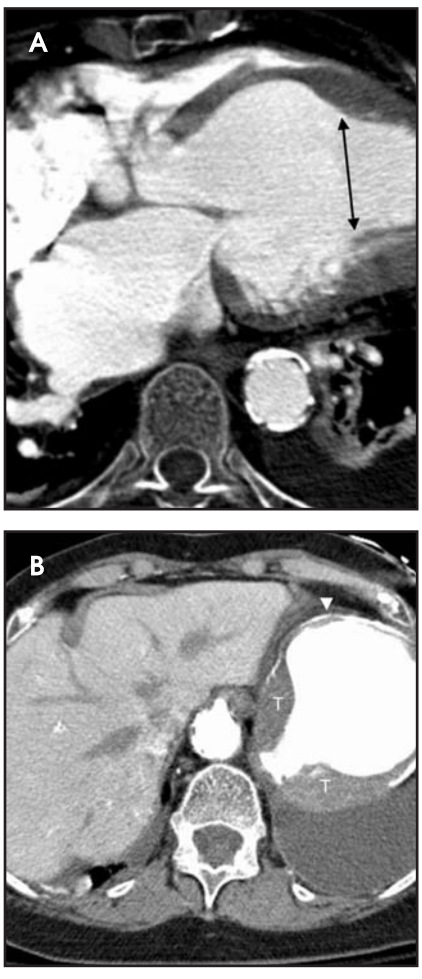

FIGURE 13. Left ventricular true aneurysm. A and B. Axial CT scans at the level of the mid left ventricle and upper abdomen demonstrate a huge aneurysm with a wide mouth (line with arrowheads). The apex of the ventricle is thinned and calcified (white arrowheads). Thrombus lines the lower portion of the aneurysm (T).

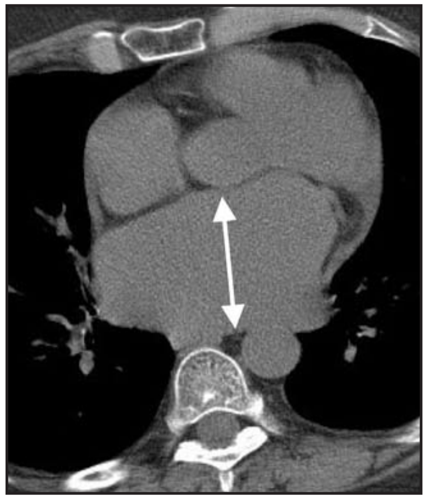

FIGURE 11. Left atrial enlargement in a patient with mitral valve stenosis. The anteroposterior diameter of the left atrium was over 6 cm (line with arrowheads).

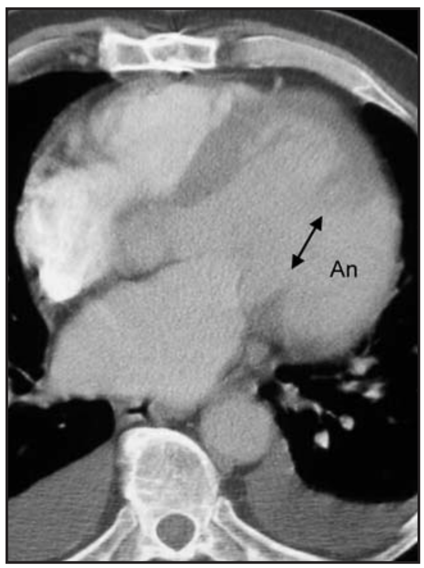

FIGURE 14. Left ventricular pseudoaneurysm. The large lateral wall aneurysm (An) has a relatively narrow neck (line with arrowheads).

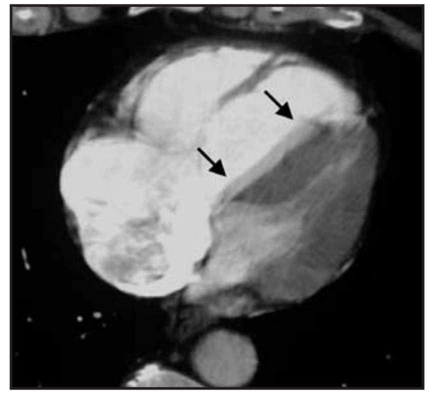

FIGURE 12. Right heart failure secondary to pulmonary arterial hypertension. At the midplane of the heart, the right ventricle is substantially larger than the left ventricle. Flattening of the ventricular septum (arrows) indicates high right ventricular pressure.

lesion in a coronary artery.[2] For example, posterior wall calcification is compatible with a right coronary artery territory infarct (Figure 8) whereas calcium at the apex or in the ventricular septum usually results from an anterior descending territory infarct (Figure 7). It is important to distinguish myocardial calcium from pericardial calcium as it is seen in patients with constrictive pericarditis.[2,9] Calcium in the pericardium usually extends onto the right heart (Figure 9) whereas the right ventricular rarely, if ever, calcifies post infarction.[9] Calcium in the atrioventricular groove is said to be nearly pathognomonic of pericardial constriction.

Chamber analysis

CT can be useful for analyzing cardiac chambers to determine their size, shape and thickness.[2,3] If the CT is gated, scans will usually be obtained during diastole. With the proper views, one will be able to accurately measure end-diastolic chamber dimensions and wall thickness. On nongated studies the images may not reveal the true ventricular morphology because the phase of the cardiac cycle is unknown and the imaging plane will not likely be optimal.

Because the heart may be partially contracted, a cardiac chamber will be at least as large as it appears, but it could be larger. The ventricular wall, on the other hand, will be at least as thin as it appears, but it could be thinner. Because of this, it is possible to underestimate ventricular size and overestimate ventricular wall thickness.

The normal left ventricle has a quasi-ellipsoidal shape. Using echocardiographic measurements as a standard, in adults its normal short axis dimension and wall thickness at end diastole should be approximately 5.6 cm and 11 mm respectively (Figure 10). By the same standards a normal left atrium

FIGURE 15. *Fatty replaced apical left ventricular infarct. Attenuation of the hypodense area at the apex (arrow) was consistent with fat rather than soft tissue attenuation as one would expect with thrombus.*

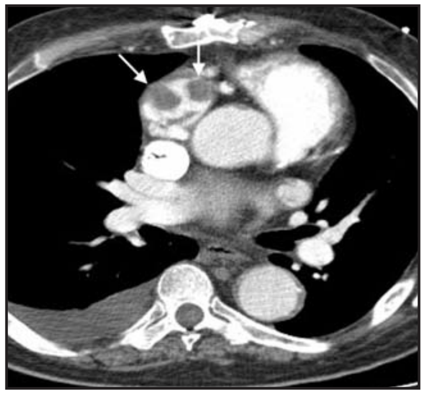

FIGURE 16. *Thrombus in the right atrial appendage (arrows) in a patient with peripheral venous thrombosis and multiple pulmonary emboli.*

Figure 17. *Thrombus in the left atrial appendage (arrow) in a patient with mitral stenosis.*

FIGURE 18. *Left atrial myxoma. A smooth filling defect (arrows) is present along the anterior left atrial wall. The left atrium is normal size.*

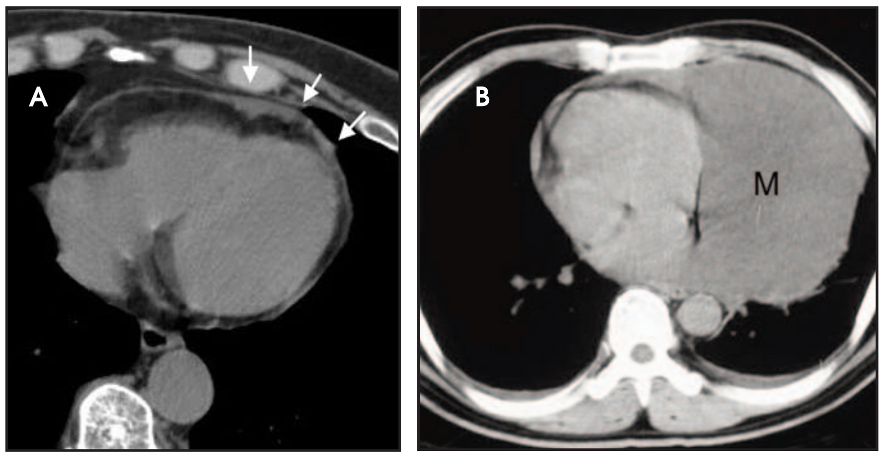

FIGURE 19. *A. Pericardial metastases in a patient with small cell lung carcinoma. The anterior pericardium is irregularly thickened (arrows). There is no pericardial fluid, however. B. Huge pericardial mass (M) in a patient with metastatic liposarcoma to the heart. The heart is displaced to the right.*

should have an anteroposterior dimension of approximately 4.5 cm[3] (Figure 11).

The right ventricle has a triangular shape with the ventricular septum bulging into it. It has a thin wall measuring less than 4 mm in thickness.[2] Right heart enlargement can be qualitatively assessed by comparing its size to the corresponding left heart. At the midplane of the left ventricle, the internal diameter of the right ventricle is usually equal to or slightly less than that of the left ventricle[2] (Figure 12).

Aneurysms vs. pseudoaneurysms

The walls of the heart are normally smooth in contour. A focal bulge in the ventricular wall frequently indicates an aneurysm.[2] As with any imaging modality, on CT a true aneurysm should have a relatively wide mouth or neck (Figure 13). True left ventricular aneurysms can be located anywhere. In contrast, a left ventricular pseudoaneurysm is almost always located posteriorly or inferiorly.[2] Because a pseudoaneurysm is the result of a contained myocardial rupture, it is characterized by a narrow mouth or neck[2] (Figure 14).

Intracardiac thrombus

On contrast-enhanced studies, cardiac thrombus can usually be readily identified as a filling defect (Figure 13B) and is sometimes visible as an area of decreased attenuation on noncontrast studies.[4] In patients with ischemic heart disease, it is more commonly located in the left ventricle than the right ventricle.[4] Thrombus in the apex is sometimes mimicked by fat in the myocardium, another sign of infarction (Figure 15).

Right ventricular and right atrial clots are usually either a tumor thrombus or a migrated clot from the lower extremities (Figure 16). A left atrial clot may be difficult to distinguish from an atrial tumor. Most atrial clots are plastered against the atrial wall in an enlarged atrium or in the atrial appendage (Figure 17). A filling defect is less likely to be a clot and more

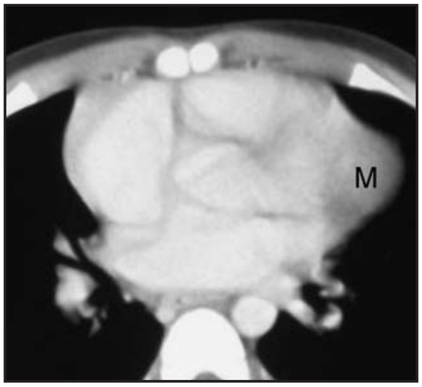

FIGURE 20. *4-year-old boy with rhabdomyoma of the left ventricle. A mass (M) protrudes from the upper portion of the left ventricle and slightly indents the chamber.*

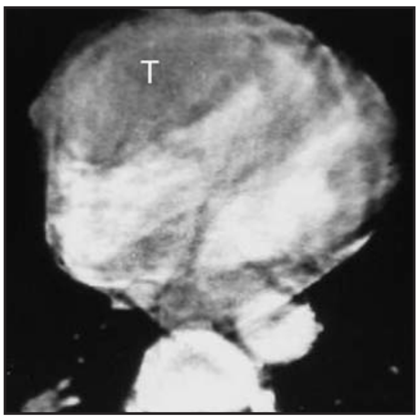

FIGURE 21. *Rhabdomyosarcoma in an adult. The right ventricular wall is diffusely infiltrated by tumor (T).*

likely to be tumor if the atrium is not enlarged (Figure 18).

Cardiac tumors

The majority of cardiac tumors are metastases, which are 20 to 40 times more common than primary cardiac tumors.[4,10] The visceral pericardium is involved in about 90% of patients who have metastases to the heart (Figure 19). Lung, breast and lymphoma are the most commonly encountered metastases in the heart due to their high prevalence and in the case of lung cancer, its close proximity.[8,11] Melanoma and lymphoma have the highest proclivity to metastasize to the heart.[4,9,11]

Of the primary benign cardiac tumors, myxoma is the most common.[4,10] These are intracavitary, are usually located in the left atrium (Figure 18) and are

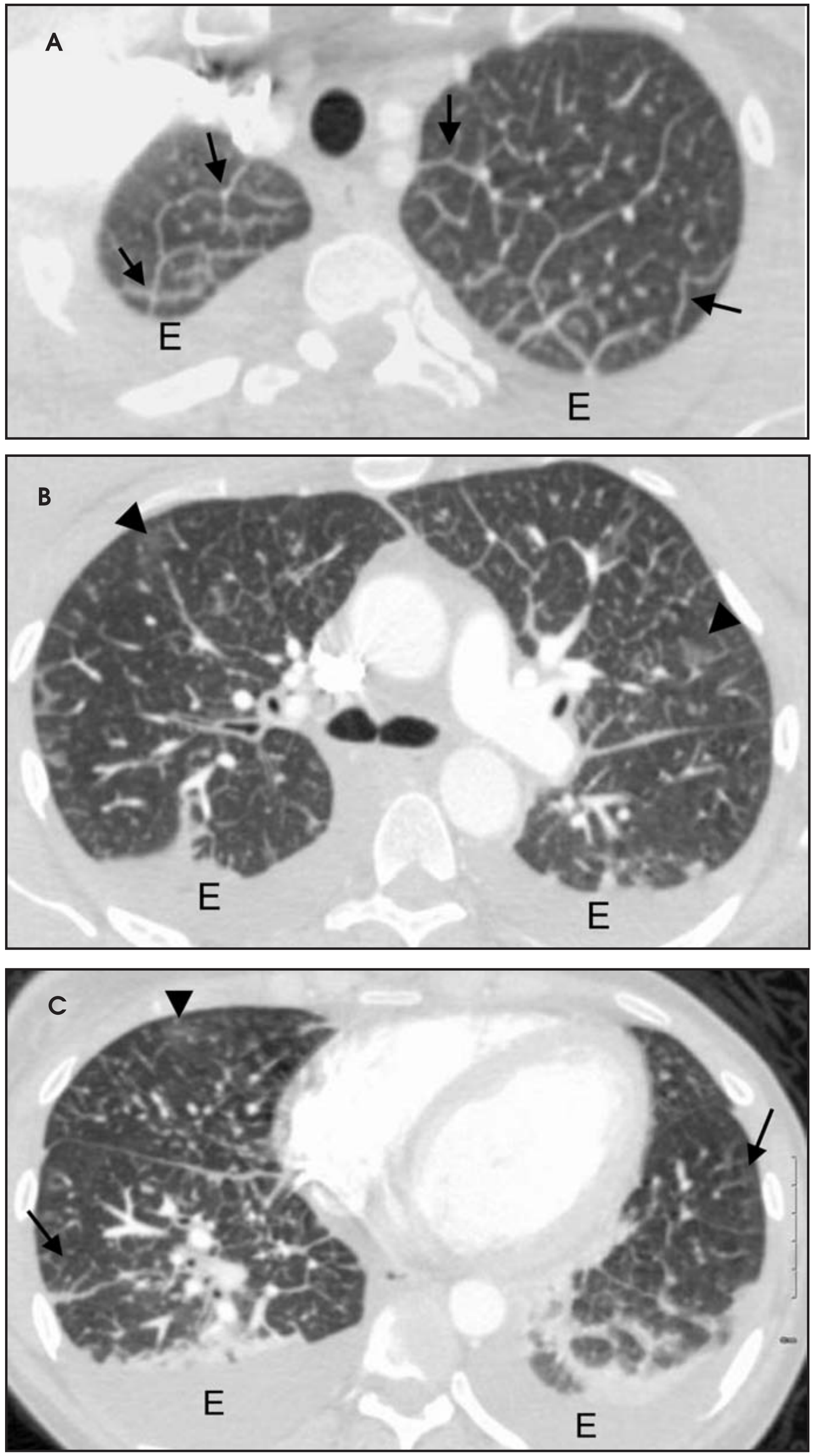

FIGURE 22. *Hydrostatic pulmonary edema in a patient with left ventricular failure. Scans through 3 levels of the thorax demonstrate classic findings of an elevated pulmonary capillary wedge pressure: thickened interlobular septa (arrows) and peribronchovascular interstitium; pleural effusions (E); and patchy areas of ground glass opacity and consolidation (arrowheads). The left ventricle looks enlarged.*

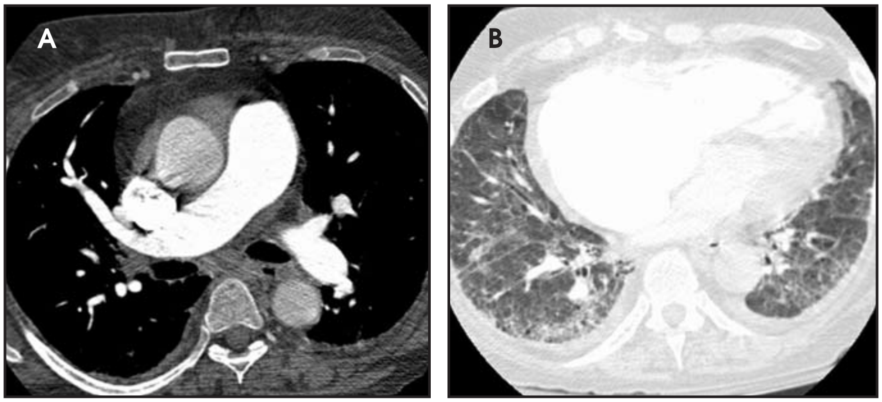

FIGURE 23. *Primary pulmonary hypertension. (A) Mediastinal window at the level of the right pulmonary artery demonstrates enlargement of the pulmonary trunk and right and left main pulmonary arteries. (B) Lung window at the bottom of the heart. The peripheral vessels are very small (pruned).*

FIGURE 26. *A left internal mammary graft to the left anterior descending is visible in the anterior mediastinal fat (small arrow). The saphenous vein graft at the same level (large arrow) must then go to either a diagonal or an obtuse marginal.*

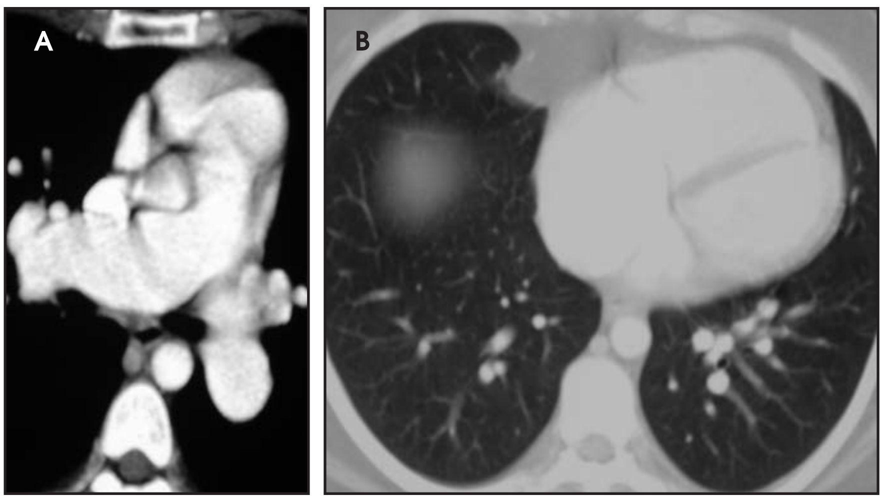

FIGURE 24. *Pulmonary overcirculation (shunt vascularity) secondary to an atrial septal defect in an adult. (A) Scan at the level of the pulmonary trunk demonstrates enlargement of the central pulmonary arteries, just as one would see with pulmonary hypertension. (B) Scan through the lung bases demonstrates enlargement of the peripheral vessels as well.*

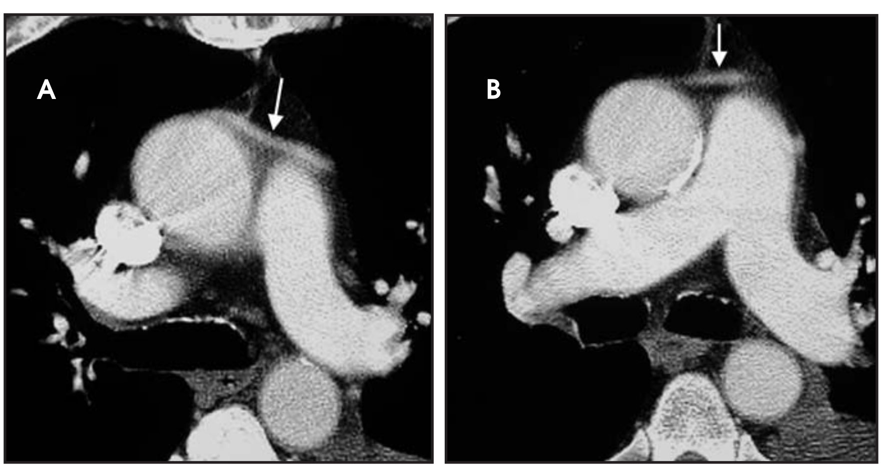

FIGURE 25. *(A) Saphenous vein bypass graft to the left anterior descending (arrow). (B) Saphenous vein bypass graft to an obtuse marginal (arrow) arises just below the left anterior descending graft.*

attached to the atrial septum.[4] They can occur in any chamber, however, and are sometimes multiple. Rhabdomyoma is a tumor of the myocardial wall (Figure 20) and is associated with tuberous sclerosis.[4] Other benign primary cardiac tumors include lipomas, fibromas and elastofibromas.[4]

The most common primary malignant tumors are angiosarcoma in adults and rhabdomyosarcoma in children.[4,10] These tumors are rare and usually cannot reliably be differentiated from metastases by CT or magnetic resonance imaging (Figure 21).

Pulmonary vascularity

Chest CT can also assess abnormalities in pulmonary vascularity. Clinically pulmonary venous hypertension is diagnosed by an elevated pulmonary capillary wedge pressure greater than 14 mmHg. CT findings include redistribution of pulmonary blood flow to the nondependant lung zones, thickening of the fissures (subpleural edema), ground glass opacities, air space consolidations and pleural effusions[2,12] (Figure 22).

Pulmonary arterial or precapillary pulmonary hypertension is caused by increased pulmonary resistance. The key finding on CT is an enlarged pulmonary trunk with normal to diminished peripheral pulmonary arteries[2,12]

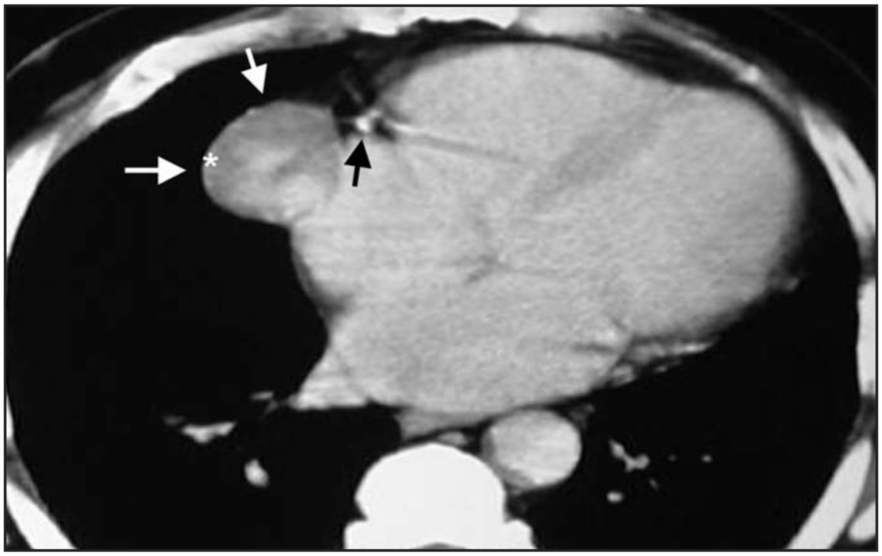

FIGURE 27. *Large atherosclerotic aneurysm of the saphenous graft to the distal right coronary artery (arrows) has areas of lower attenuation likely representing clot (*). The aneurysm is posterior to the normal location of the right coronary artery in the anterior atrioventricular groove (black arrow).*

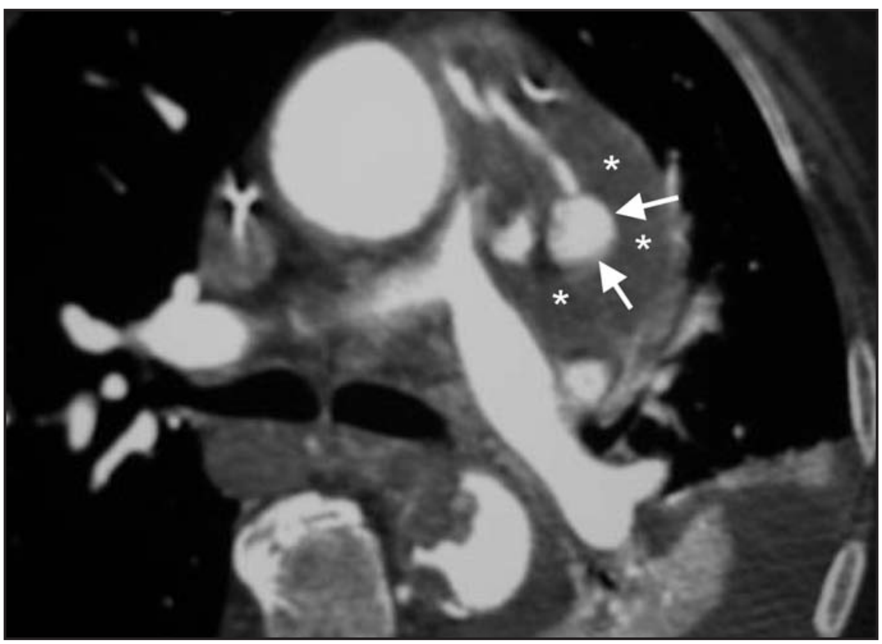

FIGURE 28. *A large mycotic aneurysm (white arrows) is present in a saphenous vein graft to diagonal. The aneurysm is surrounded by pus (*). Mycotic aneurysms were also present in two other grafts.*

(Figure 23). For patients younger than 50, a pulmonary trunk to aortic ratio >1 is a reliable indicator of precapillary hypertension in patients without overcirculation.[13] For patients older than 50, because the aorta dilates, this is less reliable and using a measurement of the pulmonary artery short axis >3.5 cm is a better indicator.[13] These criteria are fairly specific but they have only moderate sensitivity.

In contrast to pulmonary arterial hypertension, all of the pulmonary vessels are enlarged in pulmonary overcirculation.[14] The two main diseases causing pulmonary overcirculation are left-to-right shunts and chronic systemic volume overload.[14] In the former

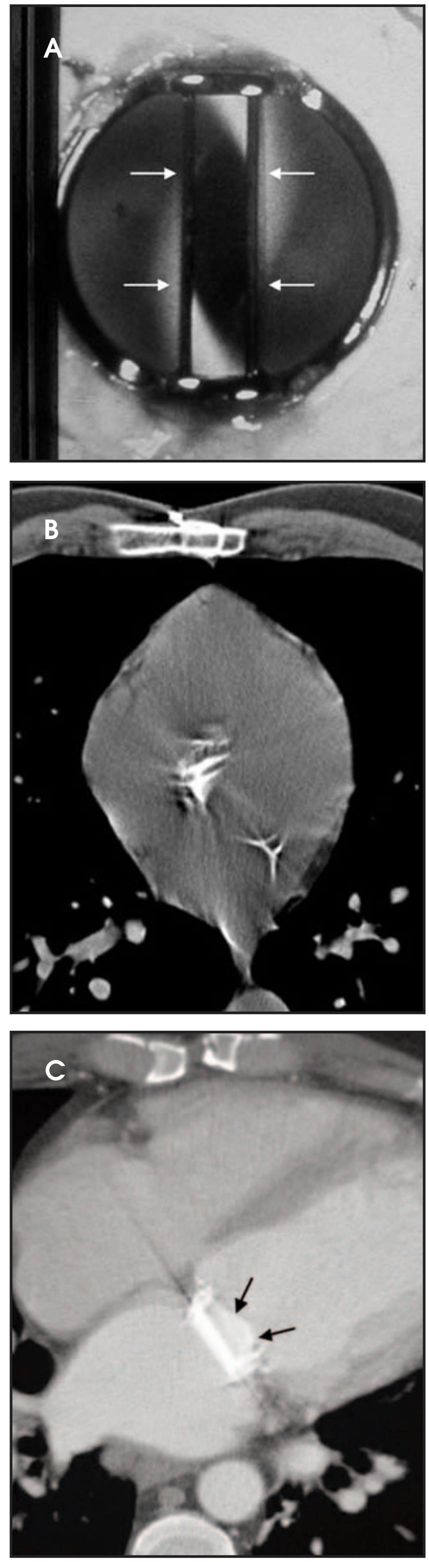

FIGURE 29. *St. Jude Medical valve. (A) Photograph of the valve on-end with the leaflets open (arrows). (B) Aortic valve with the leaflets open (arrows). (C) Mitral valve prosthesis seen with a leaflet enface (arrows).*

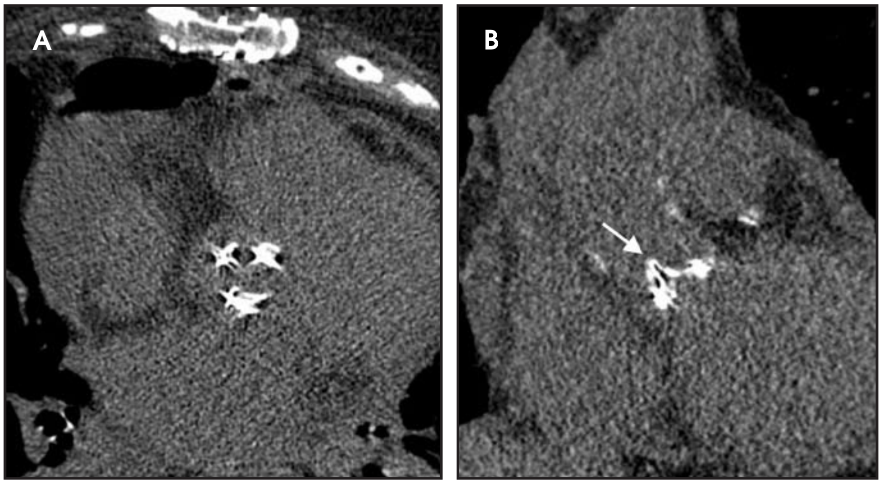

FIGURE 30. *Carpentier-Edwards bovine pericardial valve in the aortic position. A. When enface, three "crosses" are visible, corresponding to the 3 struts seen on-end. B. Coronal reconstruction shows one of the struts in profile (arrow).*

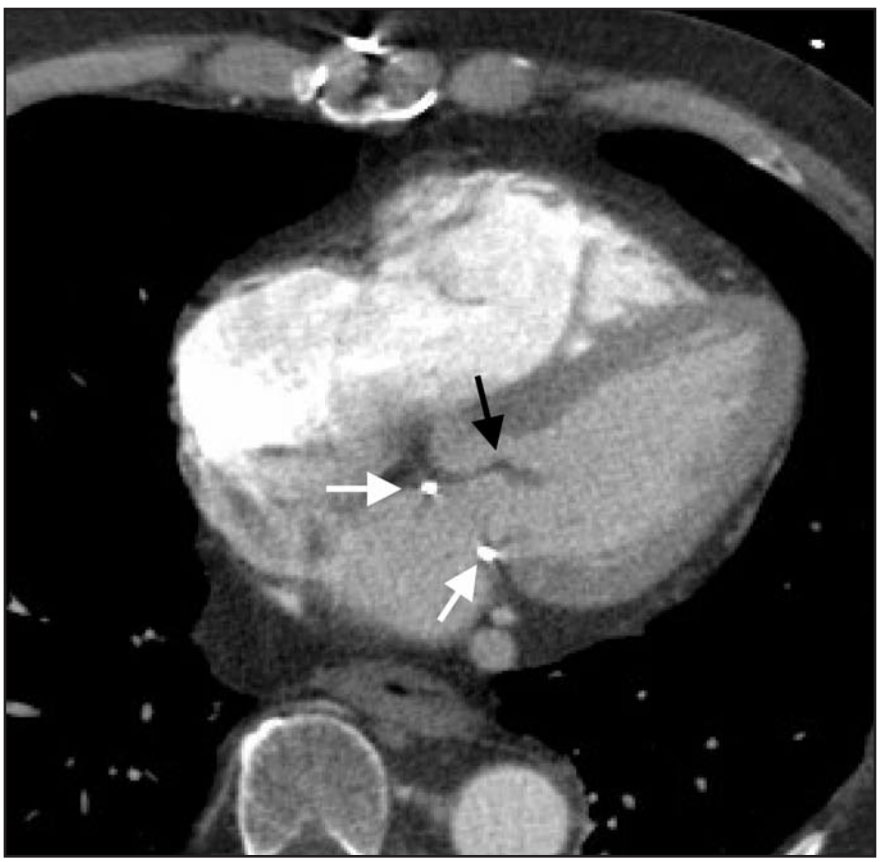

FIGURE 31. *Mitral annuloplasty ring. A metallic structure is visible on either side of the annulus (white arrows). The mitral valve anterior leaflet is thickened (black arrow).*

case, either an atrial septal defect (Figure 24) or partial anomalous pulmonary venous return is the most likely cause in an adult. Severe, chronic anemia and pregnancy can also give the appearance of pulmonary overcirculation.

The postoperative heart

Detecting signs of prior cardiac surgery on a chest CT is usually simple due to the presence of synthetic material and sternotomy wires.[15] More detailed interpretation of postoperative findings can be challenging without prior knowledge and experience. Following a few basic principles, any radiologist will be able to analyze the common postoperative findings from prior coronary artery bypass grafts or valve repair.

Coronary artery bypass grafts

The origins of common coronary artery grafts can usually be readily identified. A vein graft to the left anterior descending (LAD) usually originates from the anterior aorta several centimeters above the aortic valve[16,17] (Figure 25A). A graft to an obtuse marginal branch of the left circumflex usually arises from the anterior aorta slightly above the origin of the LAD graft (Figure 25B).

Right coronary artery grafts usually arise just above the sinus of the Valsalva and course to the right side of the heart. A left internal mammary graft to the left anterior descending is usually visible in the anterior mediastinal fat (Figure 26) and is frequently accompanied by multiple surgical clips.[16,17] Visible contrast within a graft indicates patency, but does not guarantee a lack of stenosis.[17]

Occluded grafts may be visible when surrounded by mediastinal fat, but will have soft tissue attenuation. Saphenous vein grafts can develop atherosclerotic aneurysms in the same fashion as native vessels.[17] They can be distinguished from native coronary aneurysms by location (Figure 27). Mycotic aneurysms can also form in coronary bypass grafts[17] (Figure 28).

Valve replacement

Two of the most widely used prosthetic valves are the St. Jude Medical and Carpentier-Edwards bovine pericardial valves. The St. Jude valve is a mechanical valve with 2 half-moon shaped leaflets.[18] When the valve is open, the leaflets are oriented parallel to the direction of blood flow; when the valve is closed, the leaflets are oriented horizontally to each other[18] (Figure 29). The Carpentier-Edwards bovine pericardial valve has a distinct appearance on CT. In cross section, its 3 metallic struts appear as 3 crosses that are oriented in the shape of a triangle. When viewed in profile, the struts have an elongated narrow U shape (Figure 30). Mitral anuloplasty rings come in many shapes, but similar to mitral annular calcium, are readily recognized by their characteristic location and lack of leaflets[15] (Figure 31). Tricuspid anuloplasty rings and valves are similar in appearance to their mitral counterparts, but on the other side of the heart.

Conclusion

A large number of cardiac abnormalities may be visible on standard thoracic CT. A conscientious effort in evaluating the heart and applying these principles may provide important information for the clinician caring for the patient and, as a side benefit, enhance your credibility to your local cardiologist.

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Products used

- Brilliance CT 40-channel and 64-channel scanners, Brilliance iCT, Philips Healthcare, Andover, MA.
- Isovue 370 (iopamidol), Bracco Diagnostics Inc., Princeton, NJ.

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