Diagn Interv Radiol 2023; DOI: 10.4274/dir.2022.221419

CARDIOVASCULAR IMAGING

PICTORIAL ESSAY

Cross-sectional imaging findings of cardiac outpouchings

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ABSTRACT

A cardiac outpouching (CO) is a protrusion in a heart chamber's internal anatomical lining. Most COs are clinically insignificant, but some are of vital importance, requiring immediate surgery. Cross-sectional imaging findings of COs, such as location, morphology, size, and accompanying wall motion abnormalities, play an essential role in determining the correct diagnosis and appropriate clinical management. Therefore, radiologists should be familiar with them. This article reviews the key cross-sectional imaging findings and differential diagnoses of COs.

KEYWORDS

Aneurysm, cardiac catheterization, computed topography angiography, congenital heart disease, coronary artery disease, diagnosis, diverticulum, echocardiogram, embolism, magnetic resonance imaging, outpouching, pericardial, pseudoaneurysm, three-dimensional, ventricles

A cardiac outpouching (CO) is a protrusion in a heart chamber's internal anatomical lining.[1,2] Although most COs are clinically insignificant, some may be vital, requiring immediate surgery. Moreover, identifying COs, which may be responsible for thromboembolic events, before performing invasive procedures is crucial. Therefore, the recognition and characterization of COs are of great importance.[1] Imaging findings of COs, such as location, morphology, size, and accompanying wall motion abnormalities, should be carefully evaluated along with the patient's clinical history to determine the correct diagnosis and appropriate clinical management.[2] This article reviews the key cross-sectional imaging findings and differential diagnoses of COs (Figure 1). COs that occur as a result of surgery are outside the scope of this article.

Ventricular outpouchings

Ventricular true aneurysms (VTAs)

VTAs are usually wide-necked outpouchings, surrounded by dyskinetic and scarred myocardium. The presence of a smooth transition between the healthy myocardium and outpouching walls is a crucial finding for VTAs.[1-3] The walls of VTAs often exhibit late gadolinium elevation (LGE) on magnetic resonance imaging (MRI) caused by scarred myocardium. Moreover, this scarred myocardial tissue may contain fatty metaplasia and calcification.[3] (Supplementary Figure 1). Because VTAs may contain thrombi, the presence of thrombus should be carefully examined when a VTA is detected (Figure 2, Supplementary Video 1). VTAs are often detected on the left ventricle (LV) but can also be seen on the right ventricle (RV). The etiopathogenesis of VTAs may include myocardial infarction (MI), myocarditis, Chagas disease, and trauma,[1,3,4] their medical management may consist of anticoagulation to prevent thromboembolism and afterload reduction. Surgical treatment may be considered for large VTAs, a VTA with an increased size during follow-up, angina, rupture, or heart failure.

Ventricular pseudoaneurysms (VPs)

VPs are often outpouchings in the posterior–inferior wall of the LV; they have a narrow neck and are surrounded by the pericardium as the result of a full-thickness myocardial tear

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Received 08 February 2022; revision requested 07 March 2022; accepted 28 March 2022.

Epub: 02.01.2023

Publication date: 31.01.2023

DOI: 10.4274/dir.2022.221419

You may cite this article as: Ufuk F, Hazırolan T. Cross-sectional imaging findings of cardiac outpouchings. *Diagn Interv Radiol.* 2023;29(1):68-79.

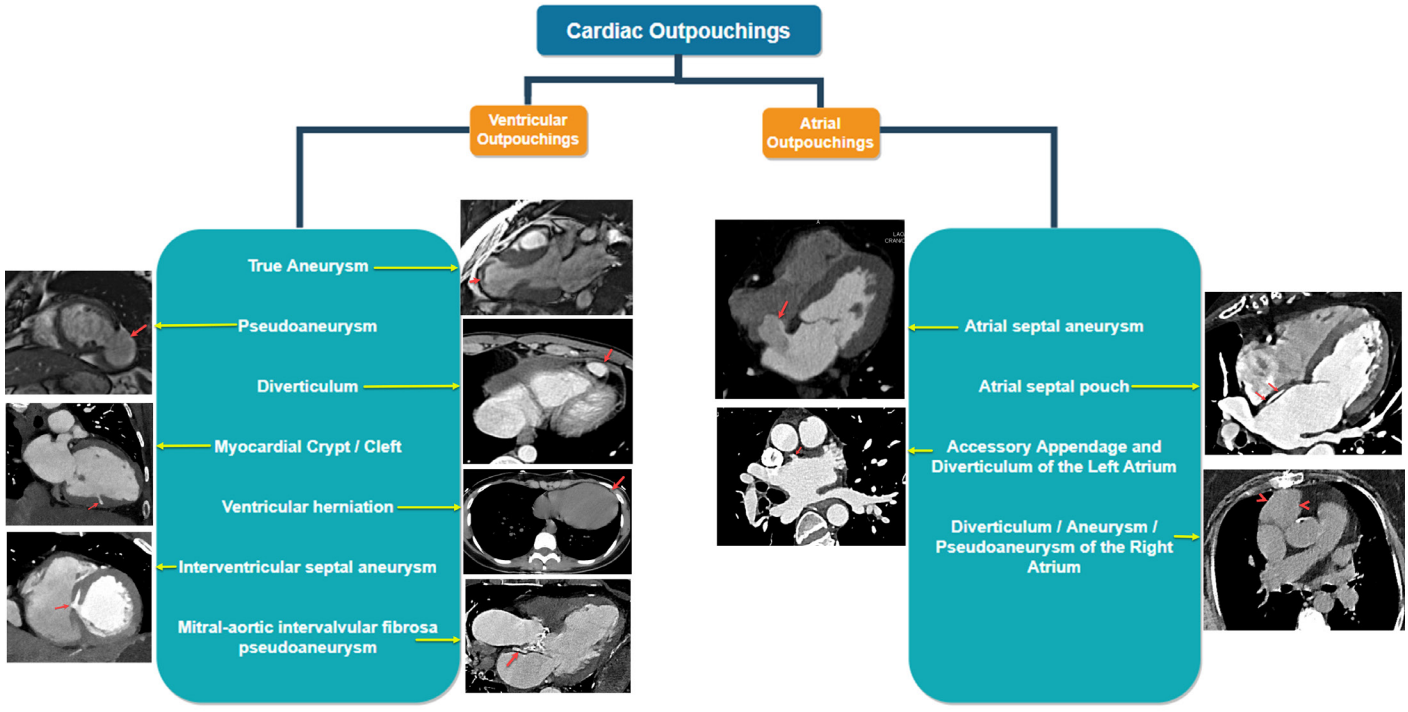

Figure 1. Atrial and ventricular outpouchings.

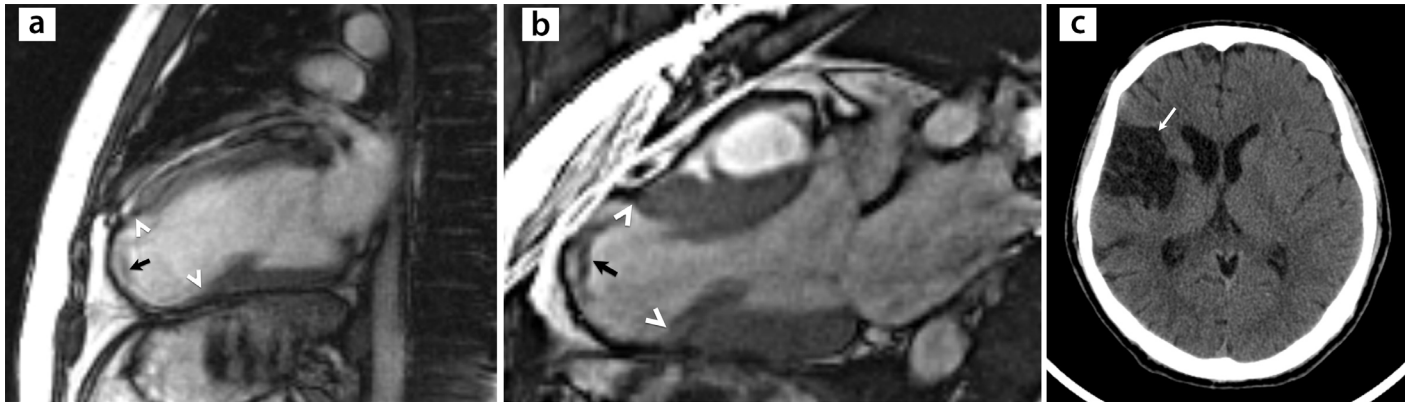

Figure 2. (a-c) A 73-year-old male patient with a history of myocardial infarction and cerebrovascular events underwent cardiac magnetic resonance (MR) imaging with a suspected left ventricular thrombus. Cardiac MR images of a left ventricle apical true aneurysm. Balanced steady-state free precession MR images with **(a)** a two-chamber view during mid-diastole and **(b)** a left ventricular outflow tract view during end systole revealing left ventricular apical dilatation with smooth transition between the healthy and thinned myocardium (arrowheads). Note the left ventricular thrombus (arrows). **(c)** Axial cranial computed tomography image depicting chronic right middle cerebral artery territory infarction (arrow). See also Supplementary Video 1.

or rupture (Figure 3, Supplementary Figure 2, Supplementary Video 2).[3] The presence of an abrupt transition between the healthy myocardium and outpouching is a crucial imaging finding for VPs, unlike VTAs.[1-3] Moreover, VPs are often accompanied by hemorrhagic pericardial effusion, and focal LGE can be seen in the pericardium surrounding the VP. The etiopathogenesis of VPs may include MI, trauma, infection, and iatrogenic injury (Figure 4).[2,3] Untreated VPs have high mortality, and surgery is the treatment of choice in patients with VP.

Main points

- A cardiac outpouching (CO) is a protrusion in a heart chamber's internal anatomical lining.
- Most CO are clinically insignificant, but some may be vital, requiring immediate surgery.
- The imaging findings of COs should be carefully evaluated along with the patient's clinical history to determine the correct diagnosis and appropriate clinical management.

Ventricular diverticulum (VD)

VD is an outpouching surrounded by healthy myocardial tissue. Therefore, VD exhibits synchronous contractility with the ventricles, and VD walls do not exhibit LGE on MRI, unlike VTAs and VPs.[1,5] Notably, VDs are often congenital, but they may rarely be acquired (Figure 5, Supplementary Figure 3). Although rare, VDs may be associated with ventricular thrombus, thromboembolism, and ventricular arrhythmias. Follow-up of patients is usually sufficient, and treatment should be based on complications (Supplementary Figure 4). Arrhythmogenic right ventricular cardiomyopathy (ARVC) can mimic VDs and is characterized by functional and wall motion abnormalities (akinesia, dyskinesia) of the RV and ventricular tachyarrhythmias. A

corrugated pattern (accordion-like) can be seen on the RV-free wall caused by multiple outpouchings. Unlike VDs, outpouchings in ARVCs are akinetic or dyskinetic, and RV dysfunction is present (Supplementary Figure 5).[6]

Myocardial crypts (MCs) or clefts

MCs, also known as myocardial clefts, are narrow outpouchings of the ventricles, usually perpendicular to the interventricular septum. They are generally detected in the basal inferoseptal region of the LV and have uncertain clinical significance (Figure 6).[1] Patients with MCs are almost entirely asymptomatic and do not require treatment. MCs decrease in size or disappear during ventricular systole and do not cause wall

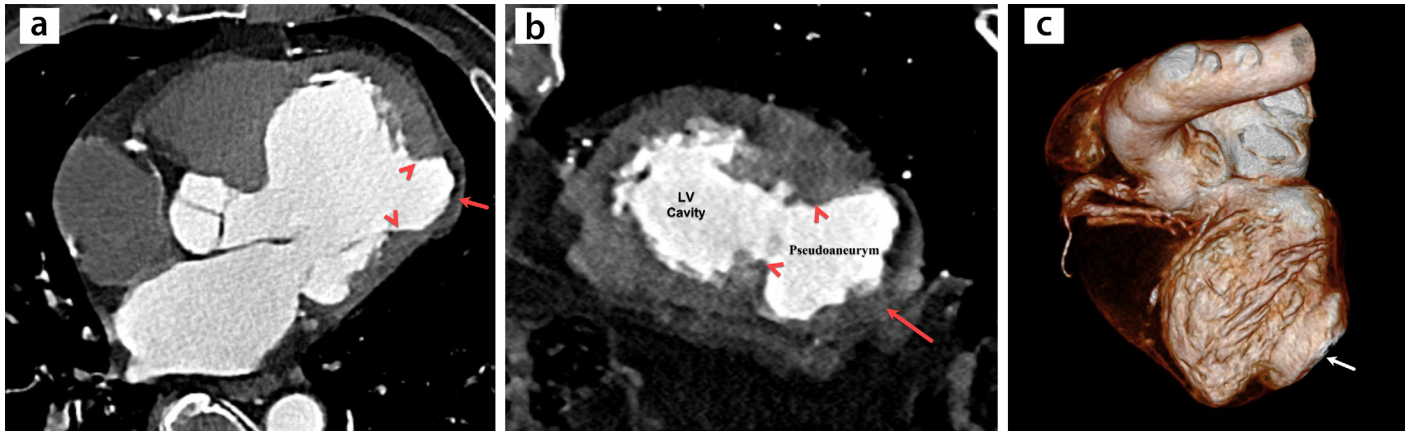

Figure 3. (a-c) A 68-year-old male patient presented to the emergency department with acute chest pain and underwent chest computed tomography (CT) angiography with a suspected acute aortic syndrome. The CT angiography images reveal a left ventricular pseudoaneurysm. Multiplanar reformatted CT angiography images with **(a)** left ventricular outflow tract view and **(b)** two-chamber view depicting outpouching in the left ventricle (arrows), with an abrupt transition between the healthy and thinned myocardium (arrowheads). The patient underwent surgery, and the pseudoaneurysm was repaired.

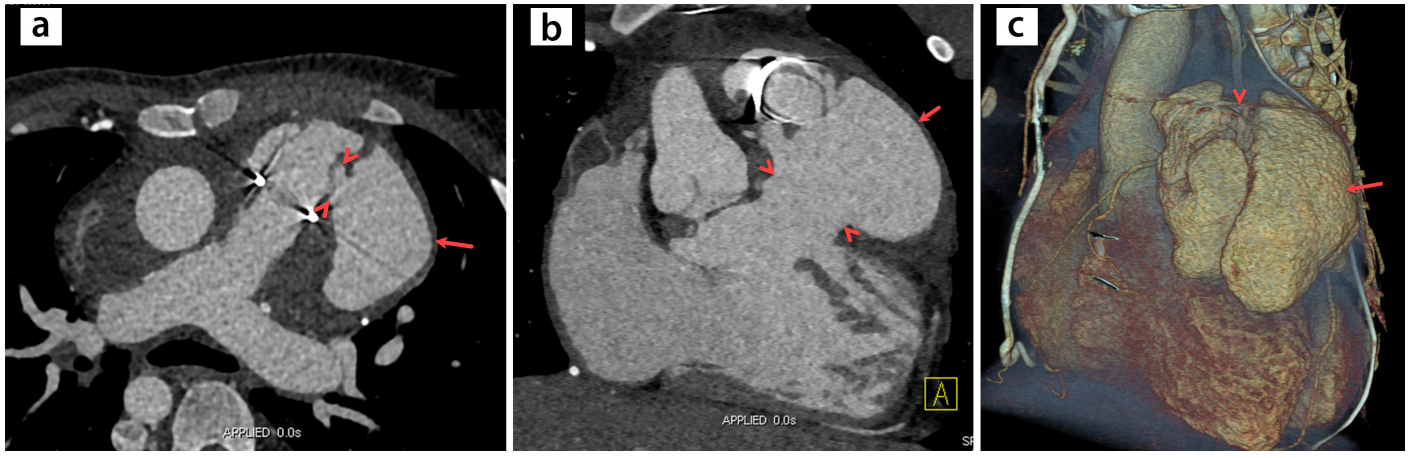

Figure 4. (a-c) A 15-year-old boy with a history of pulmonary valve replacement for tetralogy of Fallot underwent cardiac computed tomography (CT) angiography with a suspected right ventricle outflow tract pseudoaneurysm. **(a)** Axial and **(b)** coronal CT images revealing a giant multiloculated pseudoaneurysm (arrows) with a narrow neck (arrowheads). **(c)** Three-dimensional volume rendering CT image demonstrating a right ventricular pseudoaneurysm (arrow) with a narrow neck (arrowhead).

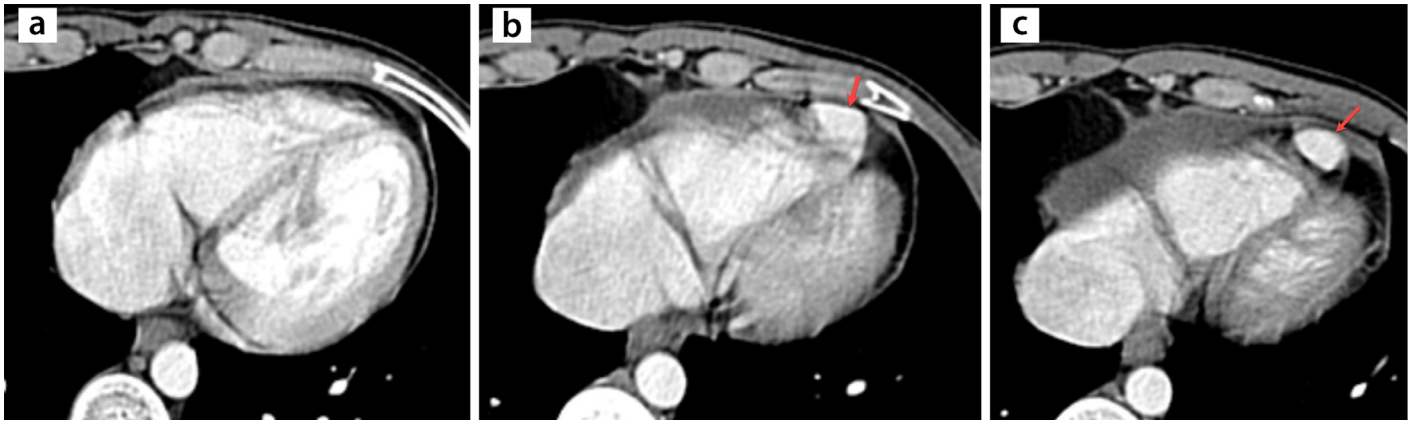

Figure 5. (a-c) A 19-year-old male patient with right lower quadrant abdominal pain underwent contrast-enhanced abdominal computed tomography (CT) with a suspected acute appendicitis. **(a-c)** Consecutive axial CT images at the lung bases revealing right ventricular apical outpouching (arrows). Because of the high risk of thromboembolism, the patient underwent surgery, and the diagnosis of the right ventricular diverticulum was histopathologically confirmed.

motion defects. They are more common in patients with hypertrophic cardiomyopathy (HCM) than in healthy populations. In addition, MCs have been suggested as a predictor of gene carrier status in HCM, and when they are multiple, the patient should be examined for HCM.[7]

Ventricular herniation

Ventricular herniation may result from the outpouching of healthy ventricles caused by a congenital, traumatic, or iatrogenic pericardial defect (Figure 7, Supplementary Figure 6).[1,2,8] Although patients with ventricular herniation are almost completely asymptomatic, incarceration, cardiac valvular insufficiency, or coronary artery compression may rarely be detected. Surgery is preferred in cases that develop complications or are symptomatic.

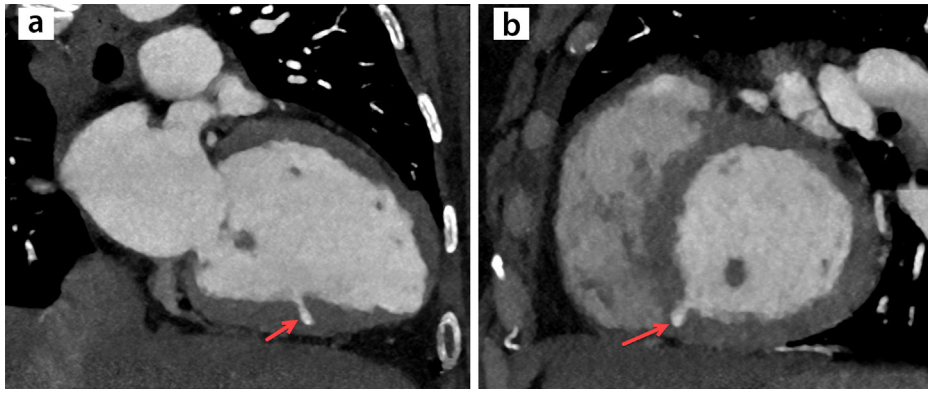

Figure 6. (a, b) A 39-year-old male patient with atypical chest pain underwent contrast-enhanced coronary computed tomography (CT) angiography. Multiplanar reformatted **(a)** two-chamber and **(b)** short-axis view CT angiography images demonstrating a narrow outpouching of the left ventricle cavity into the inferoseptal myocardium (arrows), consistent with myocardial crypt (cleft). Coronary CT angiography did not detect any coronary artery lesions, and the patient was followed up without treatment.

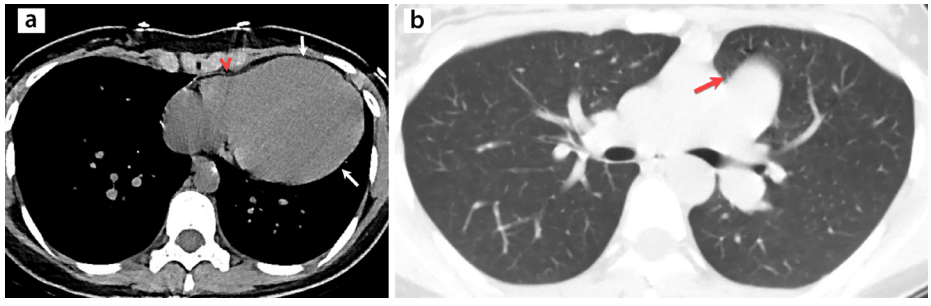

Figure 7. (a, b) A 27-year-old male patient underwent unenhanced chest computed tomography (CT) as a result of abnormal findings on chest radiography. **(a)** Axial CT image with mediastinum window settings revealing the levo-position of the heart and biventricular apical ballooning (arrows). Note an interruption of the pericardium at the level of the right atrioventricular groove (arrowhead). **(b)** Axial CT image with lung window settings depicting herniation of lung tissue between the aorta and main pulmonary artery (arrow) consistent with partial pericardial agenesis.

Interventricular septal aneurysm (IVSAs)

IVSAs are characterized by an outpouching of the interventricular septum to either side. They have two forms, membranous or muscular (Figures 8 and 9), and are often seen in the membranous region and are usually congenital. Rarely, IVSAs may occur secondary to trauma, ischemia, surgery, or infection.[9,10] Although IVSAs are often detected incidentally, they carry risks such as rupture, thrombosis, arrhythmias, right ventricular outflow obstruction, paradoxical thromboembolism, and infective endocarditis. Moreover, IVSAs may be associated with congenital cardiac anomalies, such as transposition of the great arteries and ventricular septal defects.[1,5,9,10] Although anticoagulation is recommended in asymptomatic cases of IVSAs, surgical treatment is considered in symptomatic patients and those who develop complications. In the differential diagnosis for muscular IVSA, MCs should be considered. Although muscular IVSA indents toward the right ventricle, MCs terminate in the myocardium and do not indent the RV.[1,5,9]

Mitral-aortic intervalvular fibrosa pseudoaneurysm (MAIVF)

The fibrous connection between the mitral and aortic valve is known as the MAIVF. Pseudoaneurysm formation may rarely occur in the MAIVF as a result of infective endocarditis, surgery, or trauma (Figure 10). An MAIVF pseudoaneurysm may cause thromboembolism, septic embolism, mitral valve

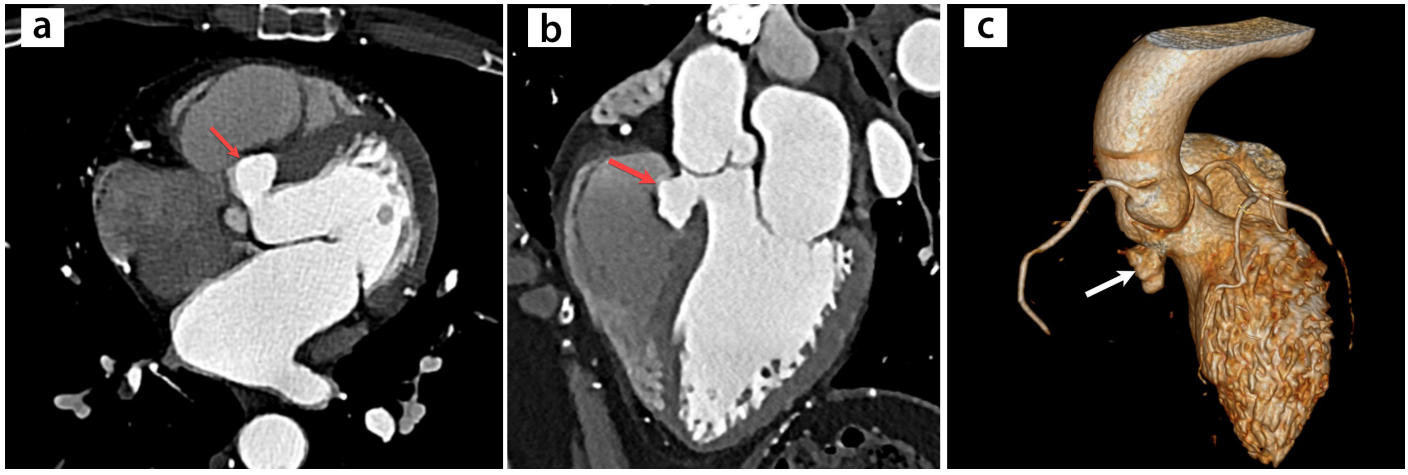

Figure 8. (a-c) A 45-year-old female patient with an abnormal finding on echocardiography underwent contrast-enhanced cardiac computed tomography (CT) angiography. **(a)** Axial, **(b)** multiplanar reformatted, and **(c)** three-dimensional volume rendering CT images demonstrating the bowing of the interventricular septum to the right (arrows), consistent with membranous interventricular septal aneurysm. The patient refused surgery and was followed up with anticoagulation.

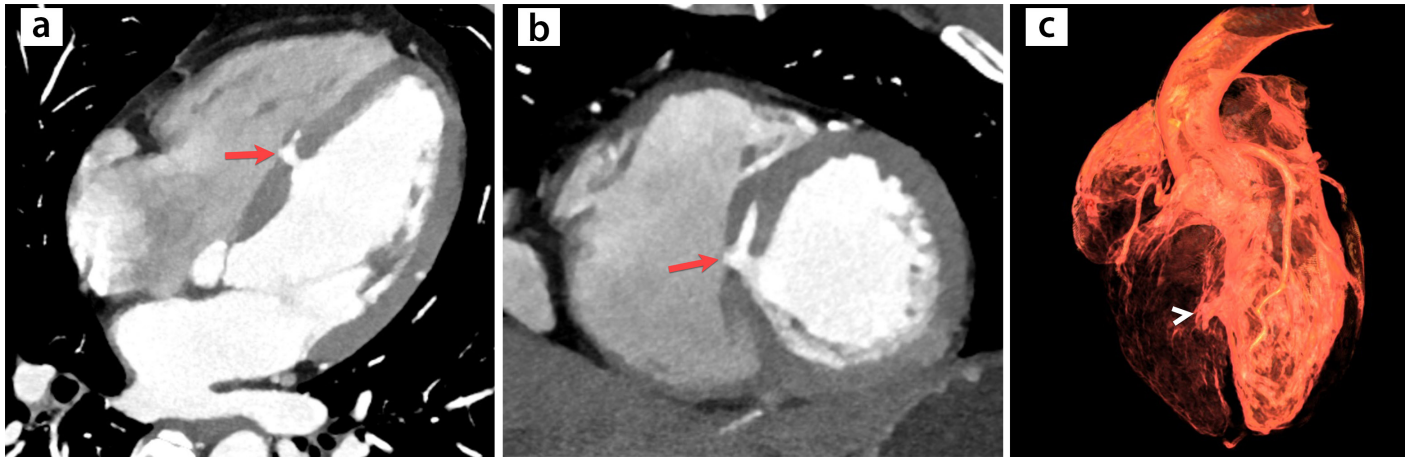

Figure 9. (a-c) A 46-year-old female patient with atypical chest pain underwent contrast-enhanced coronary computed tomography (CT) angiography. Multiplanar reformatted **(a)** four-chamber view and **(b)** shot axis view CT images revealing the bowing of the muscular interventricular septum and left ventricular outpouching (arrows). **(c)** Three-dimensional volume rendering CT images demonstrating the outpouching of the left ventricle to the right (arrowhead).

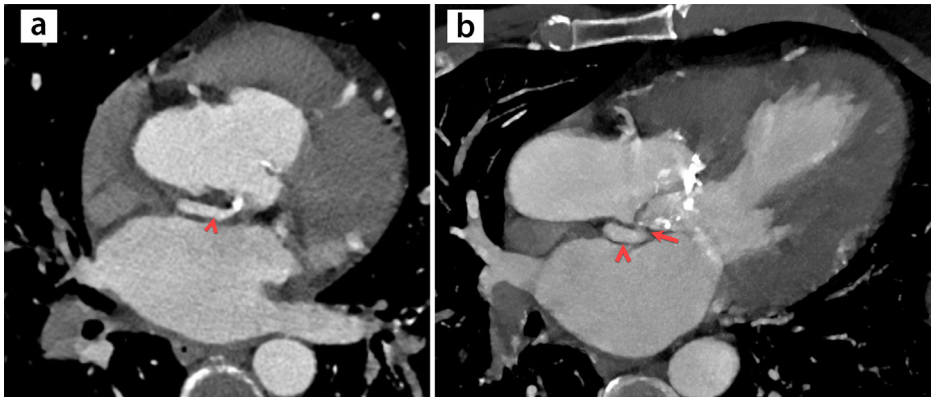

Figure 10. (a, b) A 40-year-old male patient with a history of rheumatic heart disease and endocarditis underwent contrast-enhanced coronary computed tomography (CT) angiography. **(a)** Axial and **(b)** multiplanar reformatted CT images revealing a pseudoaneurysm between the mitral and aortic valve (arrowheads), with a narrow connection to the left ventricle outflow tract (arrow). The patient underwent surgery, and the pseudoaneurysm was repaired.

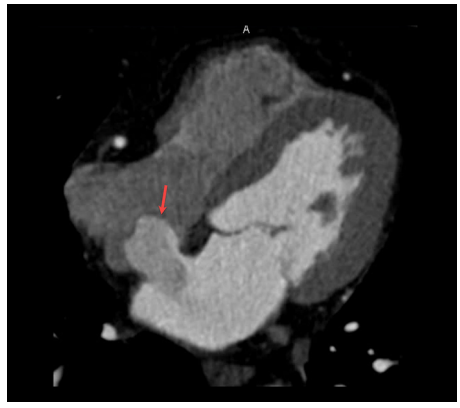

Figure 11. A 54-year-old female patient with atypical chest pain underwent contrast-enhanced coronary computed tomography (CT) angiography. Multiplanar reformatted four-chamber view CT image demonstrating the outpouching of the interatrial septum (arrow), consistent with atrial septal aneurysm. See also Supplementary Video 2.

dysfunction, and rupture. Rarely, it can cause the compression of adjacent structures, including the coronary arteries.[11] Surgery is the preferred treatment because of the high risk of serious complications.

Atrial outpouchings

Atrial septal aneurysm

Atrial or interatrial septal aneurysms (ASAs) are characterized as outpouchings (with a protrusion >11 mm to either side in adults) of the interatrial septum beyond the interatrial septal plane (Figure 11, Supplementary Video 3).[12,13] They are often congenital, and patients with ASAs are usually asymptomatic. Atrial septal aneurysms are divided into different subgroups according to their dynamic protrusion into the right and left atrium (LA) on echocardiography.[12] They can be associated with patent foramen ovale (PFO), atrial septal defect, stroke, and thromboembolism.[13] Therefore, when ASAs are detected, accompanying findings should be carefully examined. Treatment is not recommended in patients with ASAs unless complications occur.

Atrial septal pouch (ASP)

ASPs are characterized by a well-defined pouch along the interatrial septum and can occur on either the left side (40.8%), right side (5.1%), or both (3.7%). ASPs can cause thrombus formation, and arrhythmogenic focus can be detected in ASPs (Figure 12).[14] Left-sided ASPs have been associated with thromboembolism, stroke, PFO, and atrial fibrillation. Treatment is not recommended in patients with ASPs unless complications develop.[12,14]

Accessory appendage (AA) and diverticulum of the left atrium

AAs and diverticula of the LA are common outpouchings of the LA, and both are considered anatomical variants.[1,13] Although AAs are characterized by outpouchings with trabeculated contours and a small base, LA diverticula are characterized by outpouchings with smooth contours and a broad base (Figure 13). Both are usually located in the anterior upper wall of the LA and can be associated with thromboembolism, stroke, and arrhythmia.[1,2,13] The presence of these outpouchings should be examined before invasive procedures (such as radiofrequency ablation) to prevent complications, such as wall penetration and atrioesophageal fistula.[1,3]

Diverticulum, aneurysm, and pseudoaneurysm of the right atrium (RA)

Diverticula, aneurysms, and pseudoaneurysms of the RA are unusual outpouchings and may present similar clinical and radiological findings. These are characterized by outpouchings that originate from the RA appendage (Figure 14). Distinguishing between diverticula, aneurysms, and pseudoaneurysms definitively without surgery is often impossible. These RA outpouchings are usually congenital and detected incidentally, but they may present various clinical symptoms.[1,2,13] The subthebesian sinus, also known as subeustachian or Keith sinus, is an outpouching of the RA wall below the coronary sinus ostium. It is an anatomical variant that should not be misdiagnosed as a diverticulum or aneurysm (Figure 15).[15] Right atrial diverticula, aneurysms, and pseudoaneurysms may cause fatal complications, such as pulmonary thromboembolism, arrhythmias, and sudden cardiac death. Although follow-up and anticoagulation are recommended in patients with RA outpouchings who are asymptomatic, surgery is preferred in patients who are symptomatic.[13,15]

Ventricular and atrial outpouchings and differential diagnoses are summarized in Table 1.

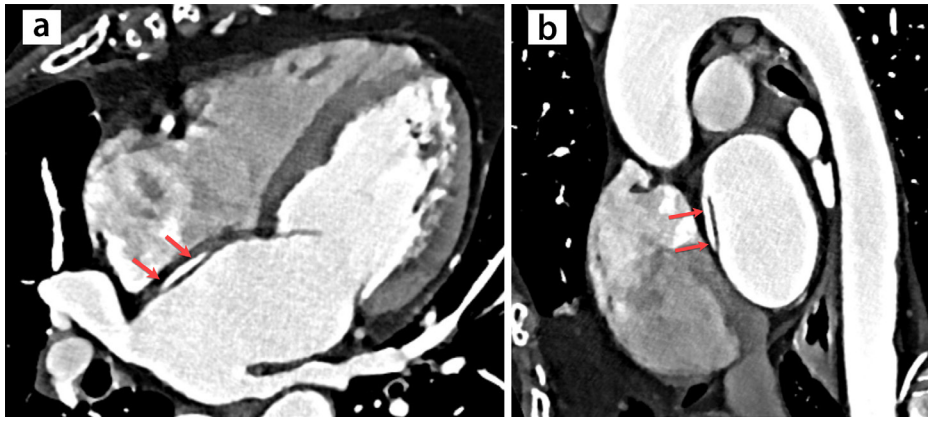

Figure 12. **(a, b)** A 44-year-old female patient with chest pain underwent contrast-enhanced coronary computed tomography (CT) angiography. **(a, b)** Multiplanar reformatted CT images depicting a well-defined outpouching along the interatrial septum (arrows), consistent with atrial septal pouch.

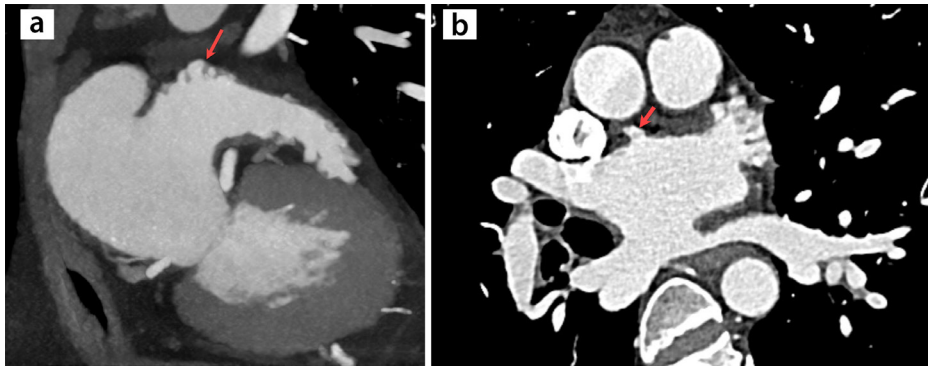

Figure 13. **(a, b)** Left atrial outpouchings in patients on coronary computed tomography (CT) angiography. **(a)** Multiplanar reformatted CT image depicting multiple outpouchings in the left atrium with trabeculated contours and narrow necks (arrow), consistent with accessory appendage. **(b)** Multiplanar reformatted CT image revealing an outpouching in the left atrium with smooth contours and a broad neck (arrow), consistent with diverticulum.

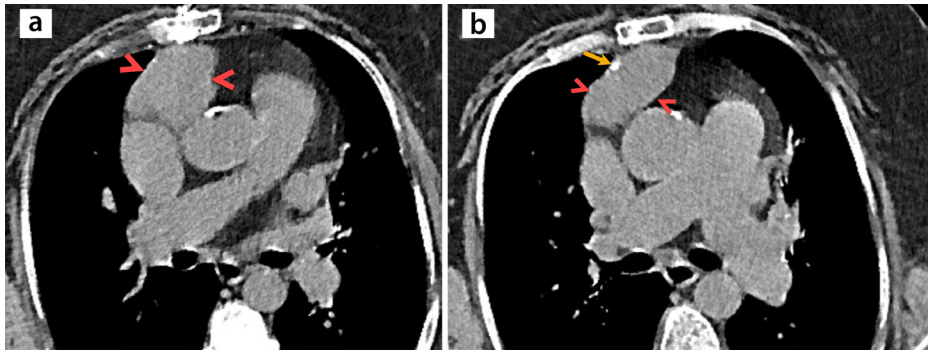

Figure 14. **(a, b)** A 78-year-old female patient with a history of coronary artery bypass grafting, recurrent pulmonary thromboembolism, and chronic kidney disease referred for unenhanced chest computed tomography (CT) because of abnormal findings on echocardiography. **(a, b)** Consecutive axial CT images demonstrating a right atrial outpouching (arrowheads), including calcification (arrow). The diagnosis of the right atrial pseudoaneurysm was pathologically confirmed, and the calcification was found to be consistent with chronic thrombus.

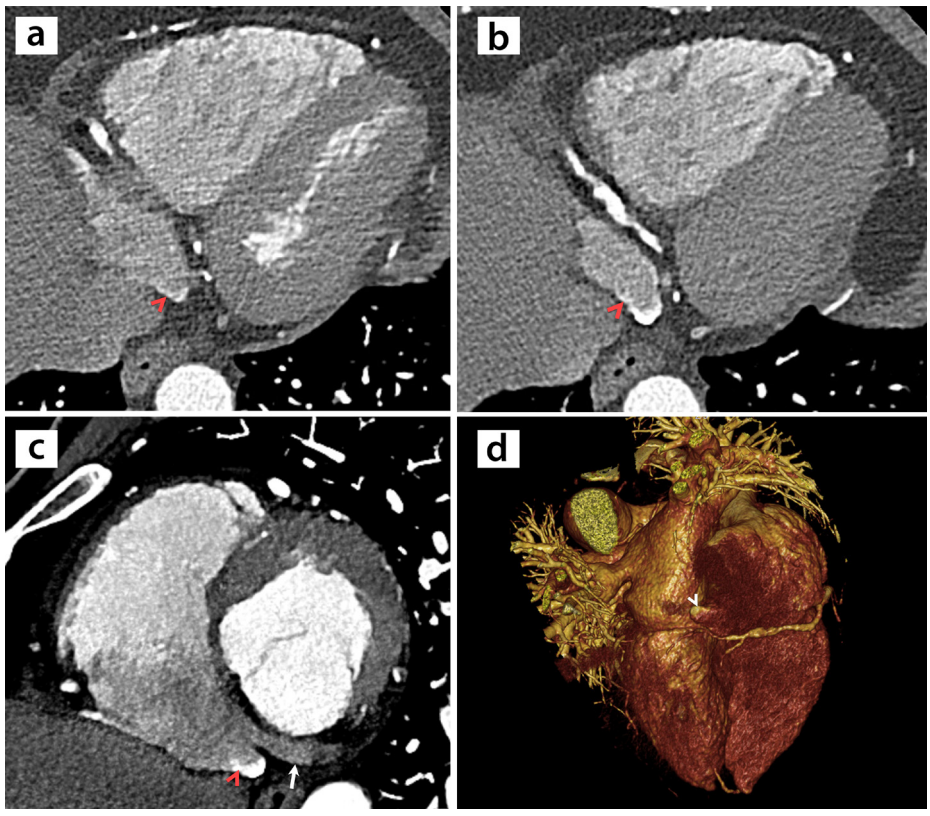

Figure 15. (a-c) A 61-year-old male patient with chest pain underwent contrast-enhanced coronary computed tomography (CT) angiography. **(a, b)** Consecutive axial and **(c)** multiplanar reformatted CT images demonstrating an outpouching of the right atrial wall (arrowheads) below the coronary sinus ostium (arrow), indicating a subthebesian (subeustachian or Keith) sinus. **(d)** Three-dimensional volume rendering CT images demonstrating the outpouching of the right atrium (arrowhead).

Table 1. Cardiac outpouchings and differential diagnoses on cross-sectional imaging

Condition	Common imaging features	Differential diagnosis
Ventricular true aneurysm	Wide-necked outpouchings located on the apical or anterior wall of the LV and surrounded by dyskinetic myocardium; smooth transition between the healthy and thinned (scarred) myocardium; fatty metaplasia and calcification can be seen in the scarred myocardium surrounding the aneurysms	***Pseudoaneurysm*** (narrow-necked outpouchings, surrounded by the pericardium, accompanied by hemorrhagic pericardial effusion and abrupt transition between the healthy and scarred myocardium) ***Takotsubo cardiomyopathy*** (transient regional wall motion abnormalities of the LV caused by a stressful trigger, absence of LGE, and no myocardial thinning on MRI) ***Apical aneurysm associated with midventricular hypertrophic cardiomyopathy*** (midventricular myocardial hypertrophy is apparent)
Ventricular pseudoaneurysm	Narrow-necked outpouchings surrounded by the pericardium, accompanied by hemorrhagic pericardial effusion and abrupt transition between the healthy and scarred myocardium and located on the basal or posterior wall of the LV	***True aneurysm*** (wide-necked outpouchings located on the apical or anterior wall of the LV and surrounded by dyskinetic myocardium; smooth transition between the healthy and scarred myocardium) ***Takotsubo cardiomyopathy*** (transient regional wall motion abnormalities of the LV caused by a stressful trigger, absence of LGE, and no myocardial thinning on MRI) ***Apical aneurysm associated with midventricular hypertrophic cardiomyopathy*** (midventricular myocardial hypertrophy is apparent)
Ventricular diverticulum	Includes all myocardial layers and shows synchronous contractility with the associated ventricular myocardium; diverticulum walls do not show LGE on MRI	***True aneurysm*** (wide-necked outpouchings surrounded by dyskinetic scarred myocardium; aneurysm walls show LGE on MRI) ***Pseudoaneurysm*** (surrounded by the pericardium; pericardium shows LGE on MRI, accompanied by hemorrhagic pericardial effusion) ***Apical aneurysm associated with midventricular hypertrophic cardiomyopathy*** (midventricular myocardial hypertrophy is apparent) ***Arrhythmogenic RV cardiomyopathy*** (functional and wall motion abnormalities of the RV and ventricular tachyarrhythmias; akinetic or dyskinetic multiple diverticulum-like outpouchings on the RV-free wall) ***Butterfly apex*** (anatomic variation; both the RV and LV form separate apices) (Supplementary Video 4, Supplementary Figure 7)

Table 1. Continued

Condition	Common imaging features	Differential diagnosis
Myocardial crypts/clefts	Narrow invaginations usually perpendicular to the LV wall, which decrease in size or disappear during ventricular systole, do not cause wall motion defects, and are usually seen in the basal inferoseptal region	***Ventricular septal defect*** (connection between both ventricles) ***Interventricular septal aneurysm*** (muscular interventricular septal aneurysm expands to the depth of the myocardium, and myocardial crypts gradually narrow toward the depth of the myocardium)
Ventricular herniation	Protrusion of the healthy RV or LV from iatrogenic or congenital pericardial defects	***True aneurysm*** (wide-necked outpouchings located on the apical or anterior wall of the LV and surrounded by dyskinetic myocardium; smooth transition between the healthy and scarred myocardium) ***Pseudoaneurysm*** (narrow-necked outpouchings surrounded by the pericardium, accompanied by hemorrhagic pericardial effusion and an abrupt transition between the healthy and scarred myocardium)
Interventricular septal aneurysm	Interventricular septum bowed to either side, which may be found in the membranous or muscular interventricular septum	***Myocardial crypts/clefts*** (narrow invaginations usually perpendicular to the LV wall, which decrease in size or disappear during ventricular systole and gradually narrow toward the depth of the myocardium)
Mitral-aortic intervalvular fibrosa pseudoaneurysm	Originates from the fibrous connection between the mitral and aortic valve and is seen as an outpouching between the ascending aorta and LA	***Sinus of valsalva aneurysm*** (abnormal dilatation of one of the aortic sinuses, causing thoracic aortic dilatation)
Atrial septal aneurysm	Abnormal bowing (with a base diameter ≥15 mm and deviation ≥10 mm to either side) of the interatrial septum beyond the interatrial septal plane	***Atrial septal pouch*** (well-defined pouch along the interatrial septum) ***Accessory left atrial appendage*** (outpouching of the LA with trabeculated contours and small base) ***Diverticulum of the*** LA (outpouching of the LA with smooth contours and broad base)
Atrial septal pouch	Well-defined pouch along the interatrial septum	***Atrial septal aneurysm*** (abnormal bowing of the interatrial septum beyond interatrial septal plane) ***Accessory atrial appendage*** (outpouching of the atria with trabeculated contours and small base) ***Diverticulum of the atrium*** (outpouching of the atria with smooth contours and broad base)
Accessory appendage of the LA	Outpouching of the LA with trabeculated contours and small base	***Atrial septal aneurysm*** (abnormal bowing of the interatrial septum beyond the interatrial septal plane) ***Atrial septal pouch*** (Well-defined pouch along the interatrial septum) ***Diverticulum of the atrium*** (outpouching of the atria with smooth contours and broad base)
Diverticulum	Outpouching of the atria with smooth contours and broad base	***Atrial septal aneurysm*** (abnormal bowing of the interatrial septum beyond the interatrial septal plane) ***Atrial septal pouch*** (well-defined pouch along the interatrial septum) ***Accessory appendage*** (Outpouching of the LA with trabeculated contours and small base)
Aneurysm and pseudoaneurysm of the RA	Outpouching that originates from the RA appendage	***Subthebesian sinus*** (also known as subeustachian sinus or Keith sinus; an outpouching of the right atrial wall below the coronary sinus ostium) ***Diverticulum of the atrium*** (Outpouching of the atria with smooth contours and surrounded by musculature)

LV, left ventricle; RV, right ventricle; LGE, late gadolinium enhancement; MRI, magnetic resonance imaging; LA, left atrium; RA, right atrium.

Conclusion

Radiologists should be familiar with COs on cross-sectional imaging, as the timely characterization of COs is essential to ensure optimal clinical management and therapeutic approaches.

Conflict of interest disclosure

The authors declared no conflicts of interest.

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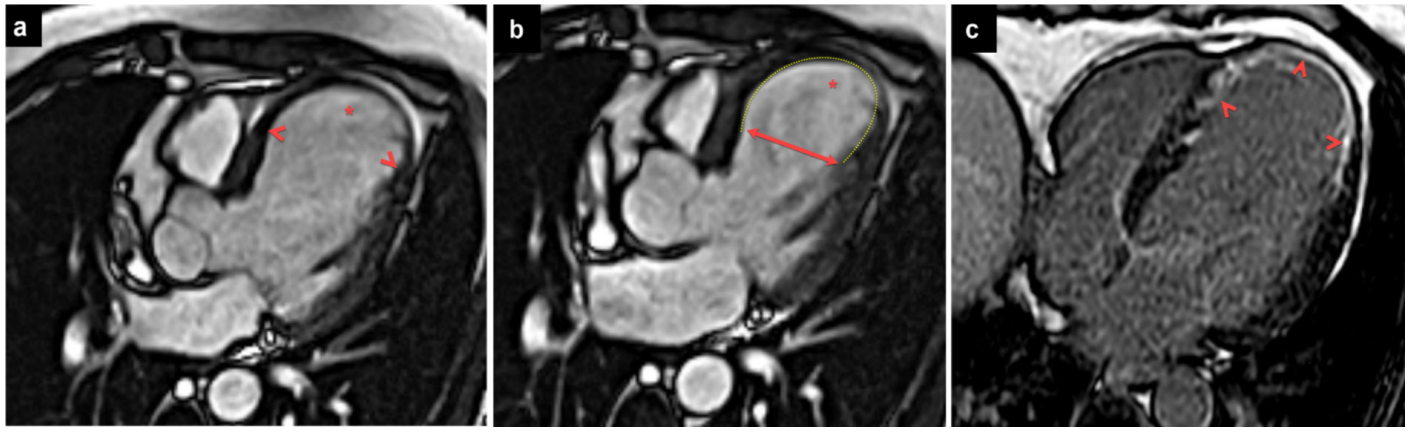
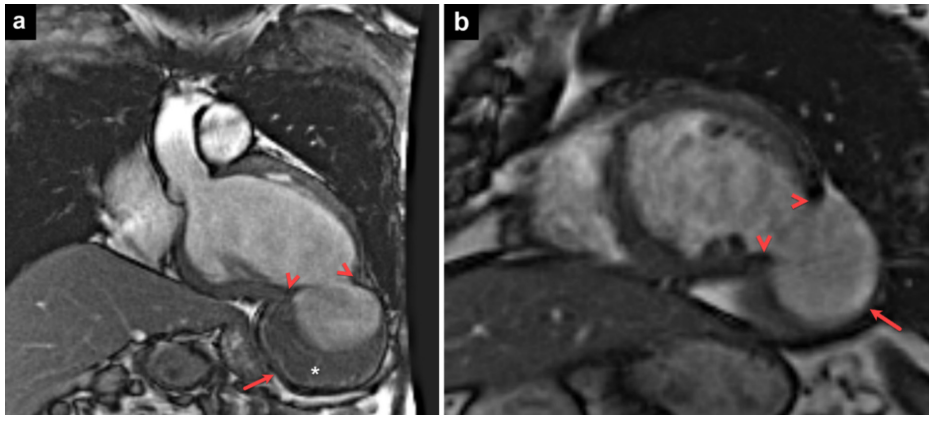
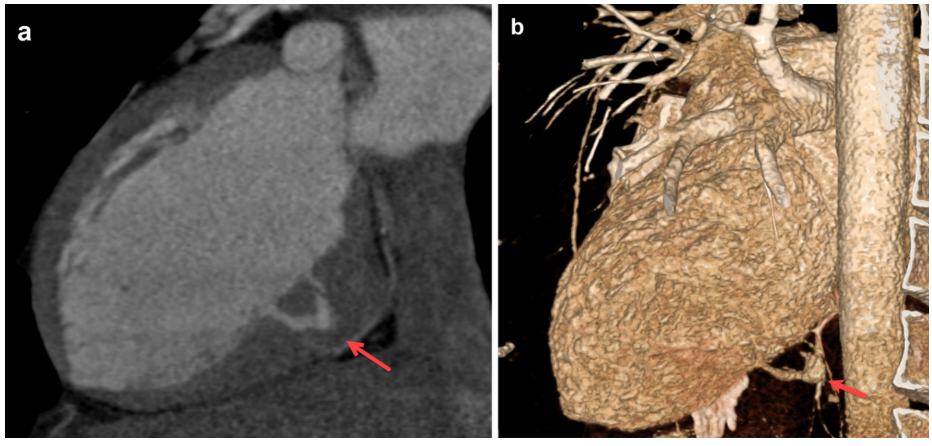


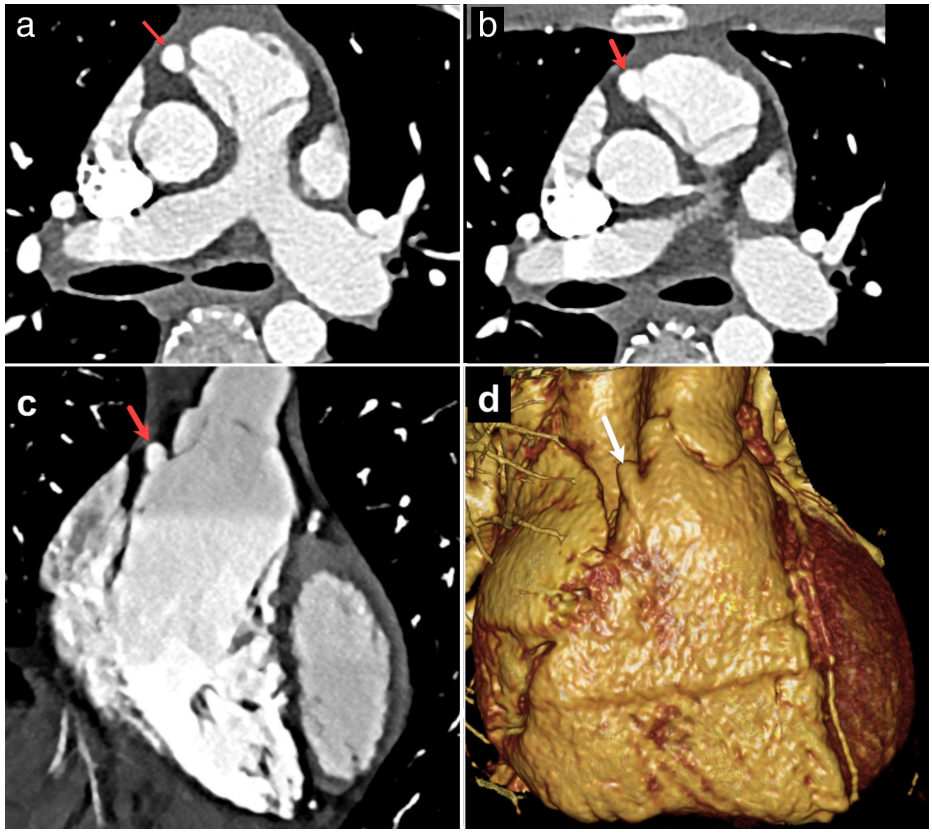
Supplementary Figure 1. (a-c) A 71-year-old male patient with a history of myocardial infarction and coronary bypass grafting. Balanced steady-state free precession magnetic resonance (MR) images with a left ventricular outflow tract view during **(a)** mid-diastole and **(b)** end systole revealing left ventricle (LV) apical dilatation (*) with a wide neck (two-way arrow). Note the smooth transition between the healthy and thinned myocardium (arrowheads). **(c)** Phase-sensitive inversion-recovery MR image depicting LV apical late gadolinium enhancement (arrowheads).



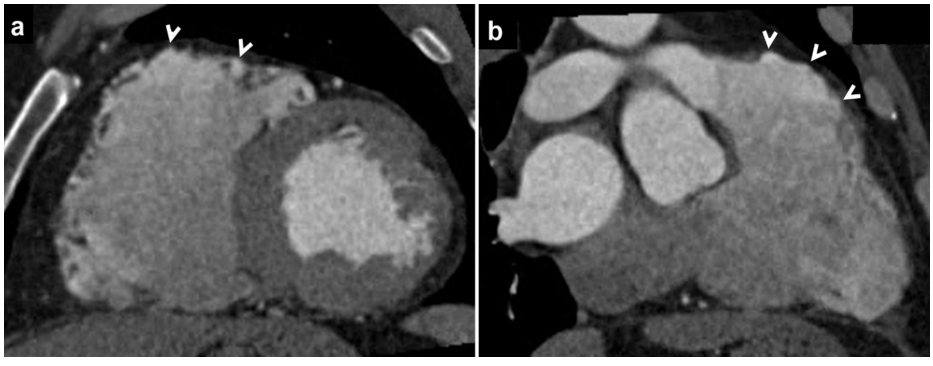
Supplementary Figure 2. (a, b) A 65-year-old male patient presented with acute chest pain and underwent cardiac magnetic resonance (MR) imaging with a suspected ventricular aneurysm. Balanced steady-state free precession MR images with **(a)** left ventricular outflow tract view and **(b)** short-axis view reveal a large outpouching in the left ventricle lateral wall (arrows) with thrombus (*). Note the abrupt transition between the healthy and thinned myocardium (arrowheads), consistent with pseudoaneurysm. The patient underwent surgery, and the pseudoaneurysm was repaired.



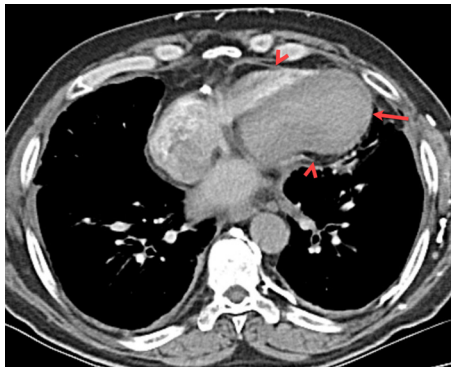
Supplementary Figure 3. (a, b) A 37-year-old male patient with atypical chest pain underwent contrast-enhanced coronary computed tomography (CT) angiography. **(a)** Multiplanar reformatted and **(b)** three-dimensional volume rendering CT images demonstrating a left ventricle outpouching (arrows), consistent with a submitral left ventricular diverticulum. Because the patient was asymptomatic, follow-up without treatment was recommended.



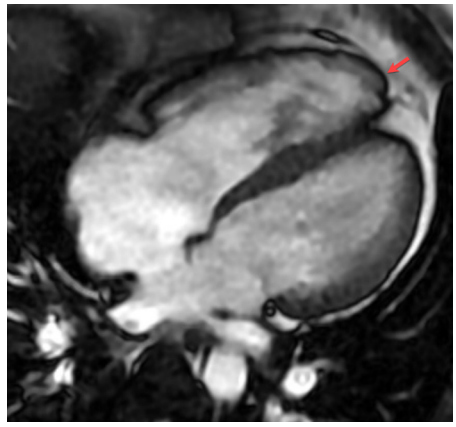
Supplementary Figure 4. (a-d) A 45-year-old female patient with ventricular tachycardia (VT) underwent contrast-enhanced cardiac computed tomography (CT) angiography. **(a, b)** Consecutive axial and **(c)** coronal reformatted CT images revealing an outpouching in the right ventricle (RV) outflow tract (RVOT, arrows). **(d)** Three-dimensional volume rendering CT image demonstrating the RV diverticulum (arrows). In the intracardiac electrophysiological study, continuous monomorphic self-terminating VT was induced at the RVOT level. Excision of the RVOT diverticulum and surgical ablation of the arrhythmogenic focus were performed, and the patient's complaints completely disappeared.



Supplementary Figure 5. (a, b) Arrhythmogenic right ventricular cardiomyopathy in a 45-year-old male patient. **(a, b)** Multiplanar reformatted cardiac computed tomography images revealing dilation of the right ventricle (RV) and corrugated (accordion-like) pattern on the RV-free wall caused by multiple outpouchings (diverticulum-like).



Supplementary Figure 6. A 66-year-old male patient with a history of partial pericardiectomy 28 years ago caused by constrictive pericarditis. Contrast-enhanced chest computed tomography image revealing ventricular herniation from an iatrogenic pericardial defect and left ventricular apical ballooning (arrow). Note an abrupt interruption of the pericardium at the midventricular level (arrowheads).



Supplementary Figure 7. Butterfly apex, an anatomic variation that is not to be confused with pathological conditions. Balanced steady-state free precession magnetic resonance image with a four-chamber view demonstrating both the right (arrow) and left ventricles forming separate apices.

Supplementary Video 1 link: https://www.youtube.com/shorts/__i8Rb8vV7E

Supplementary Video 1. Balanced steady-state free precession cine magnetic resonance imaging revealing left ventricular apical dyskinesia and dilation with a wide neck, compatible with a true ventricular aneurysm.

Supplementary Video 2 link: https://www.youtube.com/shorts/Hq-ur3V5rYk

Supplementary Video 2. Balanced steady-state free precession cine magnetic resonance imaging demonstrating a large outpouching in the basal part of the left ventricle with a narrow neck and abrupt transition between the healthy and thinned myocardium, consistent with a left ventricular pseudoaneurysm.

Supplementary Video 3 link: https://www.youtube.com/watch?v=5K9JkTEPlj4

Supplementary Video 3. Cardiac computed tomography images demonstrating the bidirectional abnormal motion and bowing of the interatrial septum during different cardiac phases, consistent with atrial septal aneurysm.

Supplementary Video 4 link: https://www.youtube.com/shorts/n6jV56LQ0mQ

Supplementary Video 4. Cine cardiac magnetic resonance imaging depicting both the right and left ventricles forming separate apices, consistent with a butterfly apex. Butterfly apex is an anatomic variation that is not to be confused with pathological conditions.