Radiographic Evaluation of Valvular Heart Disease
With Computed Tomography and Magnetic Resonance Correlation

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Abstract: Valvular heart disease is a group of complex entities with varying etiologies and clinical presentations. There are a number of imaging tools available to supplement clinical evaluation of suspected valvular heart disease, with echocardiography being the most common and clinically established, and more recent emergence of computed tomography and magnetic resonance imaging as additional supportive techniques. Yet even with these newer and more sophisticated modalities, chest radiography remains one of the earliest and most common diagnostic examinations performed during the triage of patients with suspected cardiac dysfunction. Recognizing the anatomic and pathologic features of cardiac radiography including the heart’s adaptation to varying hemodynamic changes can provide clues to the radiologist regarding the underlying etiology. In this article, we will elucidate several principles relating to chamber modifications in valvular heart disease, with echocardiography being the most common diagnostic examination performed during the triage of patients with suspected cardiac dysfunction. Recognizing the anatomic and pathologic features of cardiac radiography including the heart’s adaptation to varying hemodynamic changes can provide clues to the radiologist regarding the underlying etiology. In this article, we will elucidate several principles relating to chamber modifications in response to pressure and volume overload as well as radiographic appearances associated with pulmonary fluid status and cardiac dysfunction. We will also present a pattern approach to optimize analysis of the chest radiograph for valvular heart disease, which will help guide the radiologist down a differential diagnostic pathway and create a more meaningful clinical report.

Key Words: valvular heart disease, chest radiograph, ventricle, atrium, aorta

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LEARNING OBJECTIVES

After completing this CME activity, physicians should be better able to:
1. Outline each cardiac chamber’s physiologic response to changes in pressure and volume.
2. Explain patterns of varying cardiac chamber modifications as they relate to valvular heart disease.
3. Use an algorithm to analyze the radiographic appearance of cardiac chamber abnormalities and identify the particular valvular lesion.

Chest radiography provides valuable anatomic and physiological information about various cardiac valvular diseases with negligible patient discomfort, minimal radiation, and low cost compared with other available diagnostic imaging tools. Radiography is also widely available and relatively user independent. Total heart size, specific chamber enlargement, great vessel dilation, pulmonary fluid status, and cardiac and vascular calcifications are some of the important details that may be gleaned from chest radiography. Whereas individual findings are often nonspecific, when combined with other ancillary radiographic and clinical abnormalities, specific valvular diseases may be suggested. For example, main pulmonary artery enlargement may signify a pulmonary artery aneurysm but more often indicates pulmonary hypertension resulting from a variety of pulmonary or vascular diseases or even congenital heart disease with associated left to right shunt. However, when viewed together with left atrial enlargement as well as pulmonary edema and right ventricular enlargement, mitral stenosis is suggested.1

To provide valuable clinical information, a clear understanding of anatomic and pathologic features of cardiac radiography is essential, including recognition of selective chamber and great vessel dilation and their respective appearances. Varying degrees of chamber and vessel enlargement may correlate with the severity and chronicity of certain valvular abnormalities. Whereas moderate mitral regurgitation may only produce mild left heart enlargement, chronic severe mitral regurgitation can cause extensive left atrial and ventricular dilatation. Therefore, acuity or chronicity of particular diseases can often be inferred from chest radiographs and may aid the clinician in patient triage.

In this review, we will focus on the radiographic appearances of particular valvular heart diseases and suggest a useful pattern approach and algorithm to analyze the range of associated cardiac chamber abnormalities (Fig. 1).

PRINCIPLES OF CARDIAC CHAMBER PHYSIOLOGY RELATING TO VALVULAR HEART DISEASE

Certain cardiac valvular lesions cause volume overload and others pressure overload; however, each particular heart chamber has its own compensatory mechanism to deal with the related abnormality (Table 1). Diseases that lead to pressure overload cause concentric ventricular hypertrophy, whereas those characterized by volume overload result in dilation of the ventricular chamber or eccentric hypertrophy. Although these principles are valid with respect to the ventricles, the atria react somewhat differently. Atrial chambers respond to pressure overload with compensatory atrial remodeling and dilation.2

In addition, an understanding of the characteristics and direction of flow across the diseased valve—which can be identified on magnetic resonance imaging (MRI)—yields valuable information regarding specific valvular abnormalities. Valvular stenosis causes restricted transvalvular flow resulting in a poststenotic jet directed at the distal chamber or vessel. Therefore, for example, a stenotic lesion located at

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the aortic valve may lead to poststenotic aortic dilation and a hypertrophied left ventricle proximal to the lesion, the latter being typically imperceptible radiographically. Conversely, an insufficiency lesion will cause reverse flow across the valve as well as increased forward flow from volume overload. This typically results in chamber enlargement both proximal and distal to the lesion.

At the atrioventricular valve level, mitral and tricuspid stenoses are pressure overload lesions, yet they cause proximal atrial enlargement, due to the compensatory response and remodeling tendencies of the atrial chambers. However, insufficiency lesions causing volume overload such as mitral regurgitation often lead to proximal and distal chamber dilation regardless of their location. Aortic regurgitation with reversed flow into the left ventricle commonly produces left ventricular dilation and, depending on the underlying etiology, may be accompanied by ascending aortic dilation.

In this article, we develop and advance a pattern approach originally adapted from Webb and Higgins, to optimize analysis of the chest radiograph for valvular heart disease and allow the radiologist to assist the clinician in arriving at the most appropriate diagnosis. We also correlate these radiographic findings with more recently developed tomographic modalities (computed tomography [CT] angiography (CTA) and MRI), as well as anatomic schematics.

**IMAGING OF VALVULAR HEART DISEASE**

CTA provides a more comprehensive evaluation of valvular heart disease than does chest radiography alone and is often used for treatment and surgical planning. The benefits of CTA include delineation of valvular anatomy, excellent visualization of valvular morphology and function, demonstration of varying diseases, and postoperative complications relating to valve replacements. However, its use is not without detriment. Relatively high doses of ionizing radiation are often administered due to the essential utilization of retrospective cardiac gating, a technique necessary for proper demonstration of valvular function.

Cardiac MR (CMR) has been increasingly used in recent years as an alternative imaging tool and is quickly becoming the gold standard for many aspects of valvular imaging. This is a direct result of better visualization of valve anatomy and function as well as measurement of associated ventricular volume and motion. CMR provides qualitative and quantitative assessment of stenotic and regurgitant blood flow across the valve orifice and accurate imaging alignment without obstruction created by an acoustic window, a limitation that can be encountered with echocardiography. However, many centers still have restricted MR availability, and the time required to complete a full CMR study limits its potential use and benefit. In addition, certain contraindications are prevalent in this patient population and include many implanted pacemakers, which may limit its widespread use.

Echocardiography has long been considered the modality of choice for the evaluation of cardiac valvular disease. Two-dimensional echocardiography demonstrates valvular morphology and function and can depict associated leaflet calcification. Doppler echocardiography is often used to evaluate the severity of a stenotic or regurgitant jet by measuring velocity and its gradients or calculating valvular areas. However, a more detailed description of its advantages and limitations is beyond the scope of this radiographic imaging review.

**TABLE 1. Summary of Radiographic Findings and Cardiac Chamber Adaptations With Different Valvular Heart Diseases**

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← = No radiographic or physiological change.
↑ = Chamber or vessel enlargement.
←hypertrophy = Physiological change but no radiographic change.
AR indicates aortic regurgitation; AS, aortic stenosis; LA indicates left atrium; LPA, left pulmonary artery; LV, left ventricle; MPA, main pulmonary artery; MR, mitral regurgitation; MS, mitral stenosis; PS, pulmonic stenosis; RA, right atrium; RV, right ventricle.
NORMAL HEART ON CHEST RADIOGRAPH

Before evaluating physiological manifestations of valvular diseases and their effects on cardiac chamber and vascular size, a thorough review of normal radiography of the heart is warranted (Fig. 2).

When the frontal view is examined in a clockwise manner beginning with the lower right heart border, a slightly rounded convexity forms the right atrium. Superior to this is an indentation or break in the contour of the right heart border at the insertion of the superior vena cava (SVC) into the right atrium where the vena cava courses downward, parallel to the trachea in a fairly straight line. A few centimeters above is the azygos arch, which may be seen as a convex bulge superior to right heart border just above the origin of the right main bronchus. A slightly rounded opacity along the right mediastinum representing the ascending aorta usually does not extend beyond the vascular pedicle of the right hilum or SVC border in a healthy young patient with the optimal posteroanterior (PA) imaging technique. The aortic arch then passes to the left of the trachea in most patients, creating a smooth, round opacity in the left superior mediastinum, displacing the trachea slightly to the right. Beneath the aortic arch, the main pulmonary artery produces a second rounded mass-like opacity creating an intervening lucent region known as the aortopulmonary window. The descending aorta appears as a continuous line visualized through the cardiac silhouette in continuity with the aortic arch, usually parallel to the spine. The left atrial appendage, the only portion of the left atrium contributing to the left heart border on the frontal radiograph, projects between the main pulmonary artery and superior portion of the left ventricular contour. Normally this segment of the left heart border is concave, but increased pressure and volume may cause convexity of the left atrial appendage. Finally, the inferior left heart border is formed by the anterolateral wall of the left ventricle with its apex directed downward and to the left. Under normal circumstances, the right ventricular shadow cannot be seen on the frontal radiograph.

The lateral radiograph is helpful in distinguishing a few cardiac chambers. The right ventricular silhouette lies directly behind the inferior half of the sternum. A normal slightly convex opacity between the right ventricle and aortic arch represents the ascending aorta. The left atrium forms the posterior superior border of the heart on the lateral view with a normal slightly convex bulge above the straight shadow of the inferior vena cava (IVC). Finally, the posterior inferior portion of the cardiac silhouette on the lateral view is formed by the free wall of the left ventricle.

CHAMBER DILATION

Right and left atrial enlargement as detected on radiography can be seen with valvular diseases affecting the tricuspid and mitral valves, respectively. When combined with signs of ventricular enlargement or absence thereof, the type of valvular heart disease may be inferred.

Atrial Dilation

Left Atrial Enlargement

Determination of left atrial enlargement can be made using a few different signs on chest radiography (Figs. 3B, C). On the PA radiograph, early dilation will usually manifest as straightening and enlargement of the left atrial appendage with subsequent convexity of this segment of the left heart border. Further progression of left atrial enlargement leads to a double density in the mid portion of the cardiac silhouette with its right lateral border visualized medial to the right atrial portion of the right heart border and elevation of the left main bronchus with splaying of the carina. Finally, on the lateral view, enlargement of the left atrium can result in posterior heart border displacement.
toward the anterior margin of the lower thoracic spine and posterior displacement of the left mainstem bronchus.\textsuperscript{10}

Mitral Stenosis

In the presence of left atrial enlargement, consideration should be given toward a lesion involving the mitral valve. Following the principles described above, it must then be determined whether there is chamber enlargement distal to the mitral valve lesion as well. In the absence of left ventricular enlargement, mitral stenosis should be considered.

Mitral stenosis (Fig. 3A) is usually caused by prior streptococcal infection and rheumatic fever leading to rheumatic heart disease. The mitral valve is the most common valve involved in the rheumatic process, and the degree of stenosis often determines the severity of left atrial enlargement and associated radiographic findings.\textsuperscript{1} In addition to left atrial dilation, other radiographic signs that may help to establish the diagnosis of mitral stenosis include pulmonary venous hypertension, interstitial edema, and even alveolar edema (Fig. 3B). With longstanding capillary hypertension, pulmonary capillary resistance increases, creating obstruction and increased pulmonary artery pressures. This high-pressure situation increases right ventricular afterload and causes right ventricular hypertrophy.\textsuperscript{11} The consequence of severe pulmonary hypertension is often right heart failure with secondary tricuspid insufficiency leading to volume overload and eventual right ventricular enlargement.\textsuperscript{1} Occasionally, right ventricular enlargement is visible on the PA or lateral radiographs (Figs. 3B, C).

On CT (Figs. 3D, E) and MRI (Fig. 3F), a stenotic mitral valve appears funnel shaped with thickened and often calcified leaflets.\textsuperscript{12} Left atrial enlargement, pulmonary edema, pulmonary artery dilation, and right ventricular hypertrophy as well as left atrial thrombus formation can be seen.

Left Ventricular Enlargement

Left ventricular enlargement often presents on PA radiograph as an exaggerated curvature of the left heart border with a depressed cardiac apex. However, left ventricular enlargement amplifies the left heart contour but usually does not displace other cardiac chambers. The lateral view demonstrates displacement of the posterior inferior border of the heart behind the IVC just above the diaphragm,
and when projecting posteriorly >1.8 cm behind the IVC it is suggestive of left ventricular enlargement. Mitral Regurgitation

When left ventricle dilation presents with ipsilateral atrial dilation, a left-sided valvular lesion should be considered. Regurgitation of blood through the mitral valve usually causes backward and then compensatory forward flow with ensuing enlargement of both left-sided chambers.

Acute mitral regurgitation is usually caused by ischemic heart disease with a ruptured papillary muscle or chordae tendinae tear or alternatively in the setting of endocarditis. A sudden volume overload imposed on the left atrium and left ventricle causes increased preload. The left atrium and ventricle are ill equipped (not yet remodeled) to accommodate the sudden increase in blood volume resulting in pulmonary venous congestion. Preferential right upper lobe pulmonary edema may occur in the setting of acute mitral regurgitation and is believed to be due to a regurgitant jet directed toward the right upper lobe pulmonary vein leading to focal venous hypertension and edema (Figs. 4A, B).

Chronic mitral regurgitation (Fig. 4C) can be caused by myxomatous degeneration of the mitral valve with associated leaflet prolapse, as well as rheumatic fever. Eccentric left ventricular hypertrophy or dilation is caused by volume overload, and both the left ventricle and left atrium are enlarged due to increased forward and reverse flow (Figs. 4D, E). In fact, patients with mitral insufficiency usually demonstrate larger left atria than those with purely stenotic lesions. However, only mild pulmonary venous congestion is found due to atrial dilation and remodeling with resultant decompression of increased left-sided pressures (Fig. 4D).

CTA exhibits the mitral valve apparatus including the mitral leaflets, chordae tendinae, and papillary muscles with thickening and calcification, which can be present in both mitral regurgitation and stenosis. CTA (Fig. 4F) and cine MRI (Fig. 4G) can show mitral valve prolapse into the left atrium.

Right Atrial Enlargement

Assessment of right atrial enlargement can be challenging on a frontal radiograph; however, if markedly enlarged, the lower right heart border may extend to the

FIGURE 4. A and B, Acute mitral regurgitation in a 62-year-old man presenting with chest pain and discovered to have had a myocardial infarction. Frontal radiograph (A) and axial CT image (B) demonstrate preferential right upper lobe pulmonary edema due to a regurgitant jet directed toward the right upper lobe pulmonary vein leading to focal venous hypertension and edema (encircled). C, Schematic diagram of mitral regurgitation depicts an incompetent mitral valve causing regurgitation of blood into left atrium and longstanding volume overload leading to left atrial dilation. Ultimately, left ventricular dilation develops due to high blood volumes across the mitral valve. D and E, Mitral regurgitation in a 62-year-old woman with chronic dyspnea on exertion. Frontal (D) and lateral (E) radiographs show left atrial (black arrow) and left ventricular dilation (white arrow) with no frank pulmonary edema (circle), findings suggestive of chronic mitral regurgitation. F, Mitral regurgitation in a 44-year-old man. Four-chamber CTA images from a retrospectively gated CTA examination of the heart demonstrates severely prolapsed and thickened mitral valve leaflet (arrow) causing insufficiency with left atrial and ventricular chamber enlargement. G, Mitral regurgitation in a 58-year-old woman with shortness of breath. Three-chamber cine MRI of the heart demonstrates a regurgitant jet (arrow) directed into the left atrium with left atrial and left ventricle dilation from volume overload.
right (Fig. 5A) and demonstrate disproportionate enlargement on the PA view in comparison with the lateral view.9

Tricuspid Stenosis

In the presence of isolated right atrial enlargement a lesion involving the tricuspid valve is most likely. The etiology is usually tricuspid stenosis, although congenital tricuspid atresia can have a similar appearance. However, isolated tricuspid stenosis is rare and often accompanies mitral and aortic valve disease related to rheumatic heart disease.18

Right Ventricular Enlargement

Radiographic evaluation of the heart in the setting of right ventricular dilation demonstrates clockwise rotation of the heart in the axial plane, with displacement of the left heart border laterally and superiorly, a finding most evident on a frontal radiograph. Filling of the retrosternal clear space as well as posterior displacement of the left ventricle toward the spine on the lateral view is usually evident as well8 (Figs. 3B, C).

Tricuspid Regurgitation

When right atrial and right ventricular dilation are both present, it usually indicates tricuspid valve regurgitation. Most commonly this is caused by right ventricular dilation from pulmonary hypertension with ensuing tricuspid valve annular dilation and incomplete coaptation of the valve leaflets.19 Tricuspid regurgitation (Fig. 5B) may occur due to a valve damaged by rheumatic heart disease, infection or endocarditis, increased right heart pressures, left heart failure, and as a congenital anomaly.9,20 As a result of these etiologies, right-sided volume overload causes enlargement of the compliant right atrium and then dilation of the right ventricle (Fig. 5C).

Ebstein malformation is a specific and extreme congenital form of tricuspid insufficiency. The tricuspid valve...
Leaflets are displaced apically into the right ventricle with dysplasia of 1 or more of the leaflets. The septal leaflet is generally displaced to a greater extent than the anterior or posterior leaflets. This results in an incompetent tricuspid valve with varying degrees of regurgitation. In severe cases, the heart is markedly enlarged due to striking right atrial and ventricular dilation. In fact, the inflow portion of the right ventricle between the annulus and abnormal valve leaflet may act as a functionally atrialized right ventricle.\footnote{21}

CTA findings in tricuspid regurgitation (Fig. 5C) show poor apposition of the tricuspid valve leaflets during end systole with associated right atrial and ventricular dilation causing displacement of the right ventricle to the left and leftward bowing of the interventricular septum. CMR will usually demonstrate a regurgitant systolic jet directed back toward the right atrium (Fig. 5D). Right-sided volume overload may cause distention of the SVC and IVC with reflux of contrast into the hepatic veins due to venous congestion.\footnote{17}

**GREAT VESSEL DILATION**

**Ascending Aortic Dilation**

Ascending aortic enlargement may manifest with increased curvature and convexity along the right heart border. The ascending aorta may be elongated, with increased curvature and convexity along the right heart border. This may be due to long-term high-pressure gradients across the aortic valve orifice, leading to narrowing of the aortic valve orifice and poststenotic dilation. Long-term high-pressure gradients across the aortic valve also cause left ventricular hypertrophy.

**Diagram:**

[Diagram showing great vessel dilation]

**Figure 6.** A and B, Aortic stenosis in a 68-year-old man for follow-up of known stenotic aortic valve. Frontal (A) and lateral (B) radiographs demonstrates convex, rightward bulging of the ascending aortic contour (white arrow), filling of the retrosternal clear space with bulging of the ascending aorta (black arrow), and aortic valve calcification (black arrowhead). These findings are suggestive of aortic stenosis. C, Schematic diagram of aortic stenosis demonstrates thickened aortic valve leaflets leading to narrowing of the aortic valve orifice, a poststenotic jet directed at the lateral wall of the ascending aorta with repeated pulsation on the ascending aortic wall, and poststenotic dilation. Long-term high-pressure gradients across the aortic valve also cause left ventricular hypertrophy. D, Aortic stenosis at MRI. Coronal oblique left ventricular outflow tract cine MRI of the heart demonstrates thickened aortic valve leaflets with poststenotic jet (arrow) and dilation of the ascending aorta. E and F, Aortic stenosis in a 62-year-old man with congenital bicuspid aortic valve. Axial CTA images demonstrate thickened calcified bicuspid aortic valve (black arrow) and enlarged, tortuous ascending aorta (white arrow) in keeping with poststenotic dilation from aortic stenosis.
border and mediastinum on the PA view and anterior bulging of the ascending aorta with filling of the retrosternal clear space just above the right ventricular border on the lateral view (Figs. 6A, B).

**Aortic Stenosis**

In the absence of left ventricular enlargement, the finding of ascending aortic dilation often signifies poststenotic dilation of the ascending aorta. However, CT of the thoracic aorta, particularly with electrocardiography synchronization, will allow more confident evaluation of thoracic aortic aneurysms.

Aortic stenosis (Fig. 6C) is most commonly caused by calcification of a congenitally bicuspid aortic valve in younger patients and degenerative (senile) calcification of the valve in older individuals. Postinflammatory calcification and fibrosis from rheumatic heart disease is a less common etiology. Thickening and calcification of the aortic valve leaflets may lead to poststenotic dilation of the ascending aorta with a poststenotic jet directed at the lateral ascending aortic wall, both of which are well demonstrated on CMR (Fig. 6D). This manifests on the frontal radiograph as increased curvature and right lateral displacement of the ascending aorta and filling of the retrosternal clear space with rounded bulging opacity on the lateral view (Figs. 6A, B). Over time, the left ventricle adapts to higher intracavitary pressures by developing a thickened, hypertrophic muscular wall to compensate and maintain adequate cardiac output. The morphologic changes of left ventricular hypertrophy are usually not evident on chest radiography, although some investigators have reported an increased rounded configuration of the lower portion of the left heart border. Additional radiographic evidence to support the diagnosis of aortic stenosis can often be found with calcification in the expected location of the aortic valve over the center of the cardiac border and mediastinum on the PA view and anterior bulging of the ascending aorta with filling of the retrosternal clear space just above the right ventricular border on the lateral view (Figs. 6A, B).

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**FIGURE 7.** A, Schematic diagram of aortic regurgitation demonstrates an incompetent aortic valve with regurgitation of blood into left ventricle and left ventricular volume overload and dilation. Increased left ventricle volumes across the aortic valve cause repeated pulsation of high blood volumes against the aortic wall leading to ascending aortic dilation. B and C, Aortic regurgitation in a 70-year-old man presenting for preoperative evaluation. Frontal (B) and lateral (C) radiographs demonstrate tortuous bulging of the ascending aorta with filling of the retrosternal clear space (black arrows) and enlargement of the left ventricular silhouette (white arrows), findings that may be seen in aortic regurgitation. D, Aortic regurgitation in the same 70-year-old man for preoperative evaluation. Oblique coronal CTA image demonstrates thickened calcified aortic valve (black arrow), dilated left ventricle (white arrow), and enlarged, tortuous ascending aorta (arrowhead). E, Aortic regurgitation at MRI. Three-chamber left ventricular outflow tract cine MRI of the heart demonstrates diastolic regurgitant jet (arrow) directed back into the left ventricle.
silhouette and along the left portion of the thoracic spine on the PA view or projecting over the center of the heart on the lateral view (Fig. 6B).

CTA findings (Figs. 6E, F) of aortic stenosis include thickened, calcified aortic valve cusps with reduction of the aortic valve area as assessed in peak systole. Left ventricular hypertrophy and ascending aortic dilation can also be visualized on CT.²⁶

Aortic Regurgitation

Ascending aortic enlargement combined with a dilated left ventricle usually indicates an aortic valvular lesion causing increased forward and reverse flow with volume overload indicative of aortic regurgitation.

Aortic regurgitation (Fig. 7A) may be due to intrinsic valvular disease secondary to degeneration, rheumatic heart disease, incomplete closure of a congenitally bicuspid aortic valve, and infective endocarditis. Primary aortic root disease can also lead to aortic insufficiency and may be due to aortic root dilation, systemic hypertension, aortic dissection, or trauma. Most of these diseases cause chronic aortic regurgitation with a volume overloaded left ventricle resulting in LV dilation and in some instances ascending aorta enlargement due to longstanding high volumes within the ascending aorta.²⁷ On the PA view, left ventricular dilation may be manifested as leftward and lateral displacement of the left heart border and increased convexity and lateral displacement of the enlarged ascending aortic shadow. Aortic regurgitation on the lateral view is characterized by filling of the retrocardiac space from the left ventricular shadow protruding posteriorly beyond the IVC and filling of the retrosternal clear space by enlargement of the ascending aorta (Figs. 7B, C).

On CTA imaging, findings include incomplete coaptation of the aortic valve cusps during mid to end diastole. Left ventricular enlargement, dilation of the aortic root and ascending aorta, and findings related to the underlying cause (e.g., aortic aneurysm or dissection) may be seen (Fig. 7D). Intrinsic aortic valvular disease usually causes aortic cusp shortening and thickening.²⁷ Cine CMR depicts a regurgitant jet directed back into the left ventricle due to dephasing of protons (Fig. 7E).

Pulmonary Artery Dilation

Main pulmonary artery enlargement appears as a bulging, convex, rounded opacity protruding leftward between the shadows of the aortic arch and left atrial appendage (Fig. 3B). This finding on a PA radiograph is
often indicative of pulmonary artery hypertension. There are various nonvalvular etiologies of pulmonary hypertension, which are beyond the scope of this review, but one relatively common cause is secondary pulmonary hypertension due to left heart disease, such as mitral stenosis. However, this entity usually presents with other supporting radiographic evidence, as described earlier, and aids the radiologist in the diagnosis of mitral valve disease.

**Pulmonic Stenosis**

Preferential main and left pulmonary artery enlargement, with a normal-sized right pulmonary artery is observed less commonly than isolated main pulmonary artery dilation. In the absence of other pulmonary or vascular abnormalities or a known pulmonary artery aneurysm, this usually indicates pulmonary valve stenosis.

Pulmonic stenosis (Fig. 8A) is usually congenital and may present as an isolated disorder or in conjunction with other congenital heart diseases such as tetralogy of Fallot. Rheumatic fever and carcinoid syndrome are the most likely causes of acquired pulmonic stenosis. Longstanding pulmonic stenosis causes an increased pressure gradient across the pulmonary valve with resultant elevated right ventricular pressures and ultimately right ventricular hypertrophy. The main and left pulmonary arteries create a relatively straight, tangential line with the pulmonic valve allowing a poststenotic turbulent flow jet to direct itself toward the left main pulmonary artery and is best demonstrated on cine CMR (Fig. 8B). Although the right pulmonary artery is oriented near right angle to the main pulmonary artery and is thus spared the effects of the jet, this phenomenon usually leads to main and left pulmonary artery dilation (Fig. 8C).

Pulmonary valve stenosis on CTA (Figs. 8D, E) mirrors the radiographic findings of poststenotic dilation of the main and left pulmonary arteries with associated right ventricular hypertrophy and elevated right-sided pressure causing bowing of the interventricular septum to the left and may also indicate the location of a supravalvular or subvalvular stenosis. Cine images may show thickening and decreased mobility of valve leaflets.

**CONCLUSIONS**

Chest radiography provides important anatomic and physiological information about valvular heart disease and is a widely available, quick, relatively inexpensive, and valuable diagnostic imaging tool that is often used early on when triaging patients with suspected cardiac disorders. Understanding the physiological responses of cardiac chambers and pulmonary vasculature in conjunction with respective valve pathologies will permit the radiologist to provide a more meaningful report and assist the clinician in arriving at the most appropriate diagnosis.

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**REFERENCES**

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SA-CME EXAMINATION

After completing this SA-CME activity, physicians should be better able to:
1. Outline each cardiac chamber’s physiologic response to changes in pressure and volume
2. Explain patterns of varying cardiac chamber modifications as they relate to valvular heart disease
3. Use an algorithm to analyze the radiographic appearance of cardiac chamber abnormalities and identify the particular valvular lesion

*1. Which of the following cardiac chamber modifications typically results from an insufficiency lesion causing volume overload?
   A. Proximal chamber hypertrophy; Distal chamber hypertrophy
   B. Proximal chamber hypertrophy; Distal chamber dilation
   C. Proximal chamber dilation; Distal chamber hypertrophy
   D. Proximal chamber dilation; Distal chamber dilation

   Please see the following references for further study:

*2. How does the response of the cardiac atrium differ from that of the ventricle when pumping blood against a pressure overload lesion from valvular stenosis?
   A. Atrial contraction; Ventricular hypertrophy
   B. Atrial dilation; Ventricular hypertrophy
   C. Atrial contraction; Ventricular dilation
   D. Atrial dilation; Ventricular dilation

   Please see the following references for further study:

*3. When following the algorithmic approach proposed in this manuscript, which pair of radiographic findings is recommended to begin with when evaluating for valvular heart disease?
   A. Atrial dilation and great vessel dilation
   B. Pulmonary edema and ventricular dilation
   C. Valvular calcification and lung fibrosis
   D. Ventricular dilation and valvular calcification

Please see the following references for further study:
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4. Preferential right upper lobe pulmonary edema may be caused by which of the following?
   A. Mitral stenosis
   B. Acute mitral regurgitation
   C. Chronic mitral regurgitation
   D. Aortic stenosis

Please see the following references for further study:

5. Which of the following best explains the radiographic findings in pulmonic stenosis?
   A. Main PA dilation with relatively normal right and left PA
   B. Right PA dilation with relatively normal main and left PA
   C. Preferential main and left PA dilation with relatively normal right PA
   D. Main, right and left PA dilation with pruning of peripheral pulmonary vasculature

Please see the following references for further study: