



pressure (difference between systolic and diastolic pressure), leads to a bounding carotid pulse often referred to as a Corrigan pulse or a water-hammer pulse. The amplitude of the pulse is diminished in low-output states such as heart failure, hypovolemia, and mitral stenosis. Tachycardia, with shorter diastolic filling times, also lowers the pulse amplitude. Aortic stenosis, when significant, leads to a delayed systolic peak and diminished carotid pulse, referred to as *pulsus parvus et tardus*. A bisferiens pulse is most perceptible on palpation of the carotid artery. It is characterized by two systolic peaks and can be found in patients with pure aortic regurgitation. The first peak is the percussion wave, which results from the rapid ejection of a large volume of blood early in systole. The second peak is the tidal wave, which is a reflected wave from the periphery. A bisferiens pulse may also be found in those with hypertrophic cardiomyopathy, in which the initial rapid upstroke of the pulse is interrupted by LVOT obstruction. The reflected wave produces the second impulse. Pulsus alternans is beat-to-beat variation in the pulse and can be found in patients with severe left ventricular systolic dysfunction.

Pulsus paradoxus is an exaggeration of the normal inspiratory fall in systolic pressure. With inspiration, negative intrathoracic pressure is transmitted to the aorta, and systolic pressure typically drops by as much as 10 mm Hg. In pulsus paradoxus, this drop is greater than 10 mm Hg and can be palpable when marked (>20 mm Hg). It is characteristic in cardiac tamponade but can also be seen in constrictive pericarditis, pulmonary embolism, hypovolemic shock, pregnancy, and severe chronic obstructive lung disease.

Because peripheral vascular disease often accompanies CAD, a detailed examination of the peripheral pulses is an absolute necessity in patients with known ischemic heart disease. In addition to the carotid, brachial, radial, femoral, popliteal, dorsalis pedis, and posterior tibial pulses, the abdominal aorta should be palpated. When the abdominal aorta is palpable below the umbilicus, the presence of an abdominal aortic aneurysm is suggested. Impaired blood flow to the lower extremities can cause claudication, a cramping pain located in the buttocks, thigh, calf, or foot, depending on the location of disease. With significant stenosis in the peripheral vasculature, the distal pulses may be significantly reduced or absent. Blood flow in a stenotic artery may be turbulent, creating an audible bruit. With normal aging, the peripheral arteries become less compliant and this change may obscure abnormal findings.

### Examination of the Precordium

A complete cardiovascular examination should always include careful inspection and palpation of the chest, because this may reveal valuable clues regarding the presence of cardiac disease. Abnormalities of the chest wall including skin findings should be observed. The presence of pectus excavatum is associated with Marfan's syndrome and mitral valve prolapse. Pectus carinatum can also be found in patients with Marfan's syndrome. Kyphoscoliosis can lead to right-sided heart failure and secondary pulmonary hypertension. One should also assess for visible pulsations, in particular in the regions of the aorta (second right intercostal space and suprasternal notch), pulmonary artery (third left intercostal space), right ventricle (left parasternal region), and left

ventricle (fourth to fifth intercostal space at the left midclavicular line). Prominent pulsations in these areas suggest enlargement of these vessels or chambers. Retraction of the left parasternal area can be observed in patients with severe left ventricular hypertrophy, whereas systolic retraction at the apex or in the left axilla (Broadbent sign) is more characteristic of constrictive pericarditis.

Palpation of the precordium is best performed when the patient, with chest exposed, is positioned supine or in a left lateral position with the examiner located on the right side of the patient. The examiner should then place the right hand over the lower left chest wall with fingertips over the region of the cardiac apex and the palm over the region of the right ventricle. The right ventricle itself is typically best palpated in the subxiphoid region with the tip of the index finger. In those patients who have chronic obstructive lung disease, are obese, or are very muscular, the normal cardiac pulsations may not be palpable. In addition, chest wall deformities may make pulsations difficult or impossible to palpate. The normal apical cardiac impulse is a brief and discrete (1 cm in diameter) pulsation located in the fourth to fifth intercostal space along the left midclavicular line. In a patient with a normal heart, this represents the point of maximal impulse (PMI). If the heart cannot be palpated with the patient supine, a left lateral position should be tried. If the left ventricle is enlarged for any reason, the PMI will typically be displaced laterally. With volume overload states such as aortic insufficiency, the left ventricle dilates, resulting in a brisk apical impulse that is increased in amplitude. With pressure overload, as in long-standing hypertension and aortic stenosis, ventricular enlargement is a result of hypertrophy, and the apical impulse is sustained. Often, it is accompanied by a palpable  $S_4$  gallop. Patients with hypertrophic cardiomyopathy can have double or triple apical impulses. Those with apical aneurysm may have an apical impulse that is larger and dyskinetic.

The right ventricle is usually not palpable. However, in those with right ventricular dilation or hypertrophy, which can be related to severe lung disease, pulmonary hypertension, or congenital heart disease, an impulse may be palpated in the left parasternal region. In some cases of severe emphysema, when the distance between the chest wall and right ventricle is increased, the right ventricle is better palpated in the subxiphoid region. With severe pulmonary hypertension, the pulmonary artery may produce a palpable impulse in the second to third intercostal space to the left of the sternum. This may be accompanied by a palpable right ventricle or a palpable pulmonic component of the second heart sound ( $S_2$ ). An aneurysm of the ascending aorta or arch may result in a palpable pulsation in the suprasternal notch. Thrills are vibratory sensations best palpated with the fingertips; they are manifestations of harsh murmurs caused by such problems as aortic stenosis, hypertrophic cardiomyopathy, and septal defects.

### Auscultation

#### Techniques

Auscultation of the heart is accomplished by the use of a stethoscope with dual chest pieces. The diaphragm is ideal for high-frequency sounds, whereas the bell is better for