ventricular septal defect is typically associated with a loud murmur.

The frequency of a murmur can be high or low; higher-frequency murmurs are more correlated with high velocity of flow at the site of turbulence. It is also important to notice the configuration or shape of a murmur, such as crescendo, crescendo-decrescendo, decrescendo, or plateau (Fig. 3-5). The quality of a murmur (e.g., harsh, blowing, rumbling) and the pattern of radiation are also helpful in diagnosis. Physical maneuvers can sometimes help clarify the nature of a particular murmur (see Table 3-4).

Murmurs can be divided into three different categories (Table 3-8). Systolic murmurs begin with or after S_1 and end with or before S_2. Diastolic murmurs begin with or after S_2 and end with or before S_1. Continuous murmurs begin in systole and continue through diastole. Murmurs can result from abnormalities on the left or right side of the heart or in the great vessels. Right-sided murmurs become louder with inspiration because of increased venous return. This can help differentiate them from left-sided murmurs, which are unaffected by respiration.

Systolic murmurs should be further differentiated based on timing (i.e., early systolic, midsystolic, late systolic, and holosystolic murmurs). Early systolic murmurs begin with S_1, are decrescendo, and end typically before mid systole. Ventricular septal defects and acute mitral regurgitation may lead to early systolic murmurs. Midsystolic murmurs begin after S_1 and end before S_2, often in a crescendo-decrescendo shape. They are typically caused by obstruction to left ventricular outflow, accelerated flow through the aortic or pulmonic valve, or enlargement of the aortic root or pulmonary trunk. Aortic stenosis, when less than severe in degree, causes a midsystolic murmur that may be harsh and may radiate to the carotids. Pulmonic stenosis leads to a similar murmur that does not radiate to the carotid arteries but may change with inspiration. The murmur of hypertrophic cardiomyopathy may be mistaken for aortic stenosis; however, it does not radiate to the carotids and becomes exaggerated with diminished venous return. Innocent or benign murmurs may also occur as a result of aortic valve sclerosis, vibrations of a left ventricular false tendon, or vibration of normal pulmonary leaflets. They are generally less harsh and shorter in duration. High-flow states such as those found in patients with fever, during pregnancy, or with anemia may also lead to midsystolic murmurs.

Holosystolic murmurs begin with S_1 and end with S_2; the classic examples are the murmurs associated with mitral regurgitation and tricuspid regurgitation. They may also occur with ventricular septal defects and patent ductus arteriosus. Late systolic murmurs begin in mid to late systole and end with S_2. They can be characteristic of more severe aortic stenosis and are also typical of murmurs associated with mitral valve prolapse.

Diastolic murmurs are also classified by timing (i.e., early diastolic, mid diastolic, and late diastolic). Early diastolic murmurs begin with S_2 and can result from aortic or pulmonic regurgitation; they are usually decrescendo in shape. Shorter and quieter murmurs typically represent an acute process or mild regurgitation, whereas longer-lasting and louder murmurs are likely due to more severe regurgitation. Mid-diastolic murmurs begin after S_2 and are usually caused by mitral or tricuspid stenosis. They are low pitched and are often referred to as *diastolic rumbles*. Because

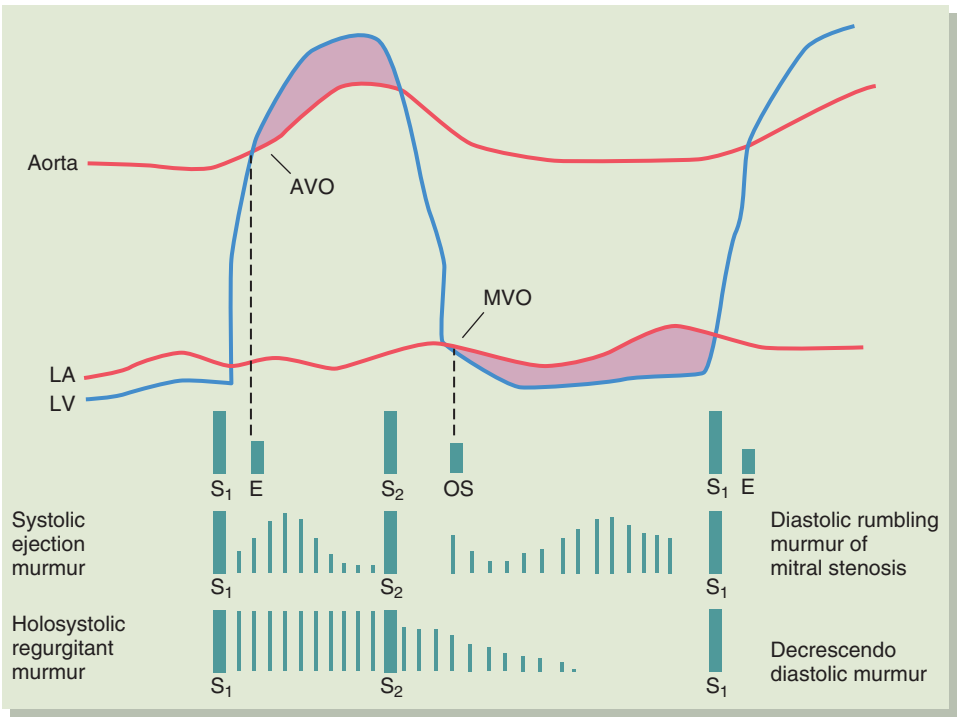

FIGURE 3-5 Abnormal sounds and murmurs associated with valvular dysfunction displayed simultaneously with left atrial (LA), left ventricular (LV), and aortic pressure tracings. The *shaded areas* represent pressure gradients across the aortic valve during systole or across mitral valve during diastole; they are characteristic of aortic stenosis and mitral stenosis, respectively. AVO, Aortic valve opening; E, ejection click of the aortic valve; MVO, mitral valve opening; OS, opening snap of the mitral valve; S_1, first heart sound; S_2, second heart sound.