Diagnosis Acute pulmonary edema usually presents with the rapid onset of dyspnea at rest, tachypnea, tachycardia, and severe hypoxemia. Crackles and wheezing due to alveolar flooding and airway compression from peribronchial cuffing may be audible. Release of endogenous catecholamines often causes hypertension.

It is often difficult to distinguish between cardiogenic and noncardiogenic causes of acute pulmonary edema. *Echocardiography* may identify systolic and diastolic ventricular dysfunction and valvular lesions. Electrocardiographic ST elevation and evolving Q waves are usually diagnostic of acute MI and should prompt immediate institution of MI protocols and coronary artery reperfusion therapy (Chap. 295). Brain natriuretic peptide levels, when substantially elevated, support heart failure as the etiology of acute dyspnea with pulmonary edema (Chap. 279).

The use of a *Swan-Ganz catheter* permits measurement of PCWP and helps differentiate high-pressure (cardiogenic) from normal-pressure (noncardiogenic) causes of pulmonary edema. Pulmonary artery catheterization is indicated when the etiology of the pulmonary edema is uncertain, when edema is refractory to therapy, or when it is accompanied by hypotension. Data derived from use of a catheter often alter the treatment plan, but no impact on mortality rates has been demonstrated.

TREATMENT PULMONARY EDEMA

The treatment of pulmonary edema depends on the specific etiology. As an acute, life-threatening condition, a number of measures must be applied immediately to support the circulation, gas exchange, and lung mechanics. Simultaneously, conditions that frequently complicate pulmonary edema, such as infection, acidemia, anemia, and acute kidney dysfunction, must be corrected.

SUPPORT OF OXYGENATION AND VENTILATION

Patients with acute cardiogenic pulmonary edema generally have an identifiable cause of acute LV failure—such as arrhythmia, ischemia/infarction, or myocardial decompensation (Chap. 279)—that may be rapidly treated, with improvement in gas exchange. In contrast, noncardiogenic edema usually resolves much less quickly, and most patients require mechanical ventilation.

Oxygen Therapy Support of oxygenation is essential to ensure adequate O_2 delivery to peripheral tissues, including the heart.

Positive-Pressure Ventilation Pulmonary edema increases the work of breathing and the O_2 requirements of this work, imposing a significant physiologic stress on the heart. When oxygenation or ventilation is not adequate in spite of supplemental O_2, positive-pressure ventilation by face or nasal mask or by endotracheal intubation should be initiated. Noninvasive ventilation (Chap. 323) can rest the respiratory muscles, improve oxygenation and cardiac function, and reduce the need for intubation. In refractory cases, mechanical ventilation can relieve the work of breathing more completely than can noninvasive ventilation. Mechanical ventilation with positive end-expiratory pressure can have multiple beneficial effects on pulmonary edema: (1) decreases both preload and afterload, thereby improving cardiac function; (2) redistributes lung water from the intraalveolar to the extraalveolar space, where the fluid interferes less with gas exchange; and (3) increases lung volume to avoid atelectasis.

REDUCTION OF PRELOAD

In most forms of pulmonary edema, the quantity of extravascular lung water is determined by both the PCWP and the intravascular volume status.

Diuretics The "loop diuretics" furosemide, bumetanide, and torsemide are effective in most forms of pulmonary edema, even in the presence of hypoalbuminemia, hyponatremia, or hypochloremia. Furosemide is also a venodilator that rapidly reduces preload before any diuresis, and is the diuretic of choice. The initial dose of furosemide should be ≤0.5 mg/kg, but a higher dose (1 mg/kg) is required in patients with renal insufficiency, chronic diuretic use, or hypervolemia or after failure of a lower dose.

Nitrates Nitroglycerin and isosorbide dinitrate act predominantly as venodilators but have coronary vasodilating properties as well. They are rapid in onset and effective when administered by a variety of routes. Sublingual nitroglycerin (0.4 mg × 3 every 5 min) is first-line therapy for acute cardiogenic pulmonary edema. If pulmonary edema persists in the absence of hypotension, sublingual may be followed by IV nitroglycerin, commencing at 5–10 μg/min. IV nitroprusside (0.1–5 μg/kg per min) is a potent venous and arterial vasodilator. It is useful for patients with pulmonary edema and hypertension but is not recommended in states of reduced coronary artery perfusion. It requires close monitoring and titration using an arterial catheter for continuous BP measurement.

Morphine Given in 2- to 4-mg IV boluses, morphine is a transient venodilator that reduces preload while relieving dyspnea and anxiety. These effects can diminish stress, catecholamine levels, tachycardia, and ventricular afterload in patients with pulmonary edema and systemic hypertension.

Angiotensin-Converting Enzyme (ACE) Inhibitors ACE inhibitors reduce both afterload and preload and are recommended for hypertensive patients. A low dose of a short-acting agent may be initiated and followed by increasing oral doses. In acute MI with heart failure, ACE inhibitors reduce short- and long-term mortality rates.

Other Preload-Reducing Agents IV recombinant brain natriuretic peptide (nesiritide) is a potent vasodilator with diuretic properties and is effective in the treatment of cardiogenic pulmonary edema. It should be reserved for refractory patients and is not recommended in the setting of ischemia or MI.

Physical Methods In nonhypotensive patients, venous return can be reduced by use of the sitting position with the legs dangling along the side of the bed.

Inotropic and Inodilator Drugs The sympathomimetic amines dopamine and dobutamine (see above) are potent inotropic agents. The bipyridine phosphodiesterase-3 inhibitors (inodilators), such as milrinone (50 μg/kg followed by 0.25–0.75 μg/kg per min), stimulate myocardial contractility while promoting peripheral and pulmonary vasodilation. Such agents are indicated in patients with cardiogenic pulmonary edema and severe LV dysfunction.

Digitalis Glycosides Once a mainstay of treatment because of their positive inotropic action (Chap. 279), digitalis glycosides are rarely used at present. However, they may be useful for control of ventricular rate in patients with rapid atrial fibrillation or flutter and LV dysfunction, because they do not have the negative inotropic effects of other drugs that inhibit atrioventricular nodal conduction.

Intraaortic Balloon Counterpulsation IABP or other LV-assist devices (Chap. 281) may help relieve cardiogenic pulmonary edema and are indicated when refractory pulmonary edema results from the etiologies discussed in the CS section, especially in preparation for surgical repair.

Treatment of Tachyarrhythmias and Atrial-Ventricular Resynchronization (See also Chap. 277) Sinus tachycardia or atrial fibrillation can result from elevated left atrial pressure and sympathetic stimulation. Tachycardia itself can limit LV filling time and raise left atrial pressure further. Although relief of pulmonary congestion will slow the sinus rate or ventricular response in atrial fibrillation, a primary tachyarrhythmia may require cardioversion. In patients with reduced LV function and without atrial contraction or with lack of synchronized atrioventricular contraction, placement of an atrioventricular sequential pacemaker should be considered (Chap. 274).

Stimulation of Alveolar Fluid Clearance A variety of drugs can stimulate alveolar epithelial ion transport and upregulate the clearance of alveolar solute and water, but this strategy has not been proven beneficial in clinical trials thus far.