I. Definition: Clinical syndrome resulting in leakage of fluid from the pulmonary capillaries and veins into the interstitium and alveoli of the lungs (Dada & Sznaider, 2003)

II. Physiology/Pathophysiology (Cotter, Kaluski, & Vered, 2005)
   A. Normal (Cotter et al., 2005)
      1. According to Starling’s Law, the flow of fluid from the pulmonary capillaries to the lungs equals the removal of fluid by pulmonary lymphatics.
      2. To prevent pulmonary edema, an active process of sodium (Na+) transport by an osmotic process removes fluid from the alveoli as a protective mechanism.
   B. Pathophysiology
      1. Pulmonary edema occurs when fluid accumulates in the alveolar spaces.
      2. Cardiogenic pulmonary edema may occur because of an increase in the hydrostatic pressure gradient associated with an altered hemodynamic status, such as in CHF. An elevated PCWP occurs because of left ventricular dysfunction (Cotter et al., 2005).
      3. Noncardiogenic pulmonary edema is caused by leakage of fluid from pulmonary capillaries with a decrease in plasma oncotic pressure and elevation of capillary pressure, producing interstitial and intra-alveolar edema.
         a) This type of pulmonary edema may be caused by several clinical conditions that result in fluid and protein accumulation in the alveoli.
         b) May be caused by many clinical conditions that cause injury to the lungs, such as acute respiratory distress syndrome and inflammatory damage to the alveolar capillary membrane (Cotter et al., 2005)
      4. Neurogenic pulmonary edema may occur because of head trauma, intracranial or subarachnoid hemorrhage, and some neurologic disorders (Cotter et al., 2005).
      5. Decreased lung and small airway compliance may result in altered ventilation, hypoxia, and respiratory failure.
      6. Hypoxia reduces the ability to actively transport Na+, leading to alveolar edema (Dada & Sznaider, 2003).

III. Clinical features (Cotter et al., 2005)
   A. Etiology: See Table 32-1.
   B. Types of pulmonary edema (see Table 32-1)
   C. History
      1. History of cancer and cancer treatment
      2. Current medications: Prescribed and over-the-counter
      3. History of presenting symptom(s): Precipitating factors, onset, location, and duration
      4. Changes in ADLs
   D. Signs and symptoms
      1. Dyspnea, orthopnea
      2. Anxiety or feeling of impending doom
      3. Frothy-pink or salmon-colored sputum
      4. Cough
      5. Cyanosis, pallor
      6. Diaphoresis
      7. Unable to lie flat
      8. Poor prognostic symptoms (Cotter et al., 2005)
         a) Hypoxia
         b) High or low blood pressure
         c) High heart rate
         d) High respiratory rate
         e) Increased PCWP
   E. Physical exam
      1. Vital signs
         a) Tachypnea
         b) Tachycardia
         c) Hypotension
      2. Integument exam: Skin pallor and livedo reticularis (skin discoloration with mottled appearance)
      3. Pulmonary exam

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4. Cardiac exam
   a) Pulsus alternans, alternating weak and strong pulse, may be a sign of left ventricular failure in CHF
   b) Heart sounds with presence of S3, S4, and harsh murmur
   c) JVD
   d) Peripheral edema of extremities

IV. Diagnostic tests (see Table 32-1)
   A. Laboratory
      1. ABGs
         a) Hypoxia (oxygen saturation < 90% and PaO2 < 60 mm Hg)
         b) Hypercapnia (CO2 > 45–55 mm Hg)
         c) Acidosis (pH < 7.35 nEq/liter). Early findings of pulmonary edema may be respiratory alkalosis because of hyperventilation.
      2. Serum albumin: May be low (normal = 3.6–5 g/dl)
      3. Blood urea nitrogen and creatinine to evaluate kidney function to ensure that renal perfusion is occurring
      4. Liver function tests to evaluate hepatic function (elevation in alanine aminotransferase, aspartate aminotransferase and bilirubin are seen with right ventricular failure and hepatic congestion)
      5. Plasma brain natriuretic peptide levels may be increased in cardiovascular pulmonary edema (Cotter et al., 2005).

B. Radiography (see Table 32-1): Chest x-ray
   1. Noncardiogenic: Bilateral consolidative pattern, interstitial edema, diffuse infiltrates
   2. Cardiogenic: Diffuse bilateral infiltrates, cardiomegaly

C. Other: Hemodynamic monitoring
   1. Pulmonary arterial pressure measurements with elevated PCWP (normal = 6–12 mm Hg)
   2. Systemic vascular resistance may be elevated (normal = 800–1,200 dynes/sec/m²)
   3. Electrocardiogram (EKG): Abnormal in cardiogenic induced

V. Differential diagnosis: Table 32-1 lists common causes of pulmonary edema.
   A. CHF (see Chapter 40)
   B. Obstruction of pulmonary lymphatics by tumor compression

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Table 32-1. Description of Types of Pulmonary Edema

<table>
<thead>
<tr>
<th>TYPE OF PULMONARY EDEMA</th>
<th>ETIOLOGY</th>
<th>CLINICAL FEATURES</th>
<th>HEMODYNAMIC PARAMETERS</th>
<th>DIAGNOSTIC STUDIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiogenic</td>
<td>Episode of acute heart failure</td>
<td>Harsh heart murmurs</td>
<td>Increased PCWP</td>
<td>Chest x-ray—enlarged heart EKG abnormal</td>
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<tr>
<td></td>
<td>Myocardial infarction</td>
<td>History of heart failure</td>
<td>Increased BNP plasma levels</td>
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<tr>
<td></td>
<td>Minor ischemia</td>
<td>History of valvular or ischemic heart disease</td>
<td>Increased LV pressures</td>
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<td></td>
<td>Hypertensive event</td>
<td>Severe respiratory distress</td>
<td>Reduced LV contractility</td>
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<tr>
<td></td>
<td>Cardiomyopathy</td>
<td>Oxygen saturation &lt; 90% on room air</td>
<td>Increased SVR</td>
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<td></td>
<td>Severe dysrhythmias</td>
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<td>Increase in troponin and creatinine</td>
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<td>Renal artery stenosis</td>
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<td></td>
<td>Cold immersion</td>
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<tr>
<td>Noncardiogenic</td>
<td>ARDS</td>
<td>Hypoxia</td>
<td>Increased PCWP</td>
<td>Chest x-ray—bilateral consolidative pattern, interstitial edema, diffuse infiltrates</td>
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<tr>
<td></td>
<td>Infection</td>
<td>Severe respiratory distress</td>
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<td>Shock</td>
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<td>Toxic damage</td>
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<td>Postoperative</td>
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<td></td>
<td>Pregnancy related</td>
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<td>Transfusion associated</td>
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<td>Excess fluid accumulation</td>
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<td>Inhaled drugs, substances, and toxins</td>
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<td></td>
<td>High altitudes</td>
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<td>Exertional</td>
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<tr>
<td>Neurogenic</td>
<td>Head injury</td>
<td>Highly variable</td>
<td>Increased SVR</td>
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<td></td>
<td>Intracranial hemorrhage</td>
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<td>Decreased LV contractility</td>
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<td>Subarachnoid hemorrhage</td>
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<td>Increased alveolar capillary leakage</td>
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<td></td>
<td>Seizures</td>
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<td>Tumors</td>
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<td>Hydrocephalus</td>
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<td>Neurosurgical procedures</td>
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</tbody>
</table>

ARDS—acute respiratory distress syndrome; BNP—brain natriuretic peptide; EKG—electrocardiogram; LV—left ventricle; PCWP—pulmonary capillary wedge pressure; SVR—systemic vascular resistance

Note. Based on information from Cotter et al., 2005.
C. CLS (see Chapter 27)
D. Acute respiratory distress syndrome
E. Early phase of septic shock (see Chapters 121 and 140)

VI. Treatment: Goal is to decrease pulmonary venous and capillary pressure, improve cardiac output, and correct underlying pathology. Patient is hospitalized for management (Cotter et al., 2005).
A. Drug therapy
1. Use of loop diuretics (e.g., furosemide, bumetanide, torsemide) causes vasodilation and decreases pulmonary congestion. Doses of 0.5–1 mg/kg may be used.
2. Administer metolazone (thiazide diuretic) 5–20 mg po once a day for treatment of CHF.
3. Vasodilators cause vasodilation, therefore decreasing pulmonary vascular pressure.
   a) Nitroprusside is started at an IV infusion of 0.5 mcg/kg/minute and titrated to achieve the desired effect; average dose is 0.5–0.8 mcg/kg/minute.
   b) Nitroglycerin is started at an IV infusion of 10–20 mcg/minute, and the dose is increased by 5–10 mcg/minute every 5–10 minutes until the desired effect occurs.
4. Morphine sulfate may be given to cause venous dilation at doses of 1–3 mg IV push. The dose is repeated every two to three hours as needed up to a total of 10–15 mg.
5. Aminophylline may be given at 5 mg/kg IV infusion for symptoms of wheezing.
7. Dysrhythmia control
B. Oxygen therapy
1. Oxygen therapy often is used, and dose is titrated to patient response. Intubation and mechanical ventilation may be necessary.
2. Continuous positive airway pressure (PAP) and bilevel-PAP have been found to be superior to oxygen therapy in decreasing the need for mechanical ventilation (Park et al., 2004).
C. Swan Ganz catheter may be placed to evaluate the cause of pulmonary edema.
D. Position patient in semi-Fowler position.
E. Obtain daily weight to monitor fluid status.
F. Obtain frequent intake and output measurements.

VII. Follow-up
A. Daily physical assessment and evaluation of response to treatment is necessary.
B. Diagnostic studies, such as chest x-ray and ABGs, may be done to evaluate patient condition.

VIII. Referrals
A. Pulmonary consult: To evaluate lung status and assist with medical management as needed
B. Respiratory therapy: May be needed for oxygen therapy, ventilatory management, percussion, or respiratory treatments

References