A 69-year-old woman was admitted to the hospital owing to unstable angina. Medical history disclosed only systemic hypertension. Cardiac catheterization revealed severe left-main coronary artery stenosis with normal left ventricular function. After uneventful coronary artery bypass grafting, the patient was transferred to the cardiovascular ICU. Eight hours later, the patient suddenly developed massive hemoptysis and pulseless electrical activity. Cardiopulmonary resuscitation including open-chest massage was successful. Bleeding stopped spontaneously. Bronchoscopic examination with a flexible bronchoscope via the endotracheal tube revealed blood clots in the right upper lobe bronchus without evidence of active bleeding.

**Physical Examination**

Vital signs: afebrile; pulse, 120 beats per minute; BP, 75/45 mm Hg. Pulmonary artery pressures were 28/14 mm Hg. No pulmonary artery occlusion pressure had been obtained. General: pale, diaphoretic, intubated. Head, ears, eyes, nose, throat: normal. Chest: rales on the right side. Cardiac: regular tachycardia. Abdomen: normal. Extremities: trace edema.

**Laboratory Findings**

WBC count, 13.2/µL with 80% neutrophils; hemoglobin, 6.8 g/dL; platelet count, 160/µL. Prothrombin time and partial thromboplastin time were normal. Arterial blood gas levels on FiO2 of 0.4: tidal volume, 800 mL; respirations, 28/min; positive end-expiratory pressure, 5 cm H2O; pH, 7.30; PaCO2, 42.4 mm Hg; PaO2, 112 mm Hg. A chest roentgenogram was performed (Fig 1).

_Why did this patient have massive hemoptysis?_  
_How would you manage this patient?_
Diagnosis: Massive hemoptysis secondary to rupture of the pulmonary artery by a Swan-Ganz catheter (with pseudoaneurysm formation).

Pulmonary artery rupture is a catastrophic complication of Swan-Ganz catheter use with a reported incidence of 0.2%. The mortality rate from this complication is approximately 50% and is highest for patients receiving anticoagulants who are undergoing cardiac surgery. Initial patient management focuses on volume resuscitation and airway protection as most patients succumb to asphyxia. Definitive therapy of the ruptured artery depends on the severity of bleeding and whether the patient is located in the operating room on cardiopulmonary bypass or in the ICU.

Very small tears in the pulmonary artery can repair and reendothelialize on their own. Larger perforations bleed into the lung parenchyma, bronchus, or even the pleural space if the visceral pleura ruptures. A pseudoaneurysm forms if blood is contained within the vascular space by a hematoma or surrounding lung parenchyma. If left untreated, 30 to 40% of pseudoaneurysms rebleed with a mortality rate approaching 70%. Rebleeding up to 7 months after pseudoaneurysm formation has been reported.

Several mechanisms of arterial injury are thought to occur. Inflation of the balloon itself can disrupt the artery; eccentric balloon inflation can propel the tip of the catheter through the vessel wall, or the catheter tip itself can rupture the artery if advanced too far distally before balloon inflation. The right pulmonary artery is injured more than 90% of the time, corresponding to the usual anatomic placement of the catheter.

Age greater than 60 years and pulmonary hypertension are risk factors for pulmonary artery trauma due to degenerative changes that occur in the vessel wall leading to increased fragility. With pulmonary hypertension, the increased pressure gradient across the inflated balloon may also propel the catheter further distally. The condition is reported more commonly in female than in male patients. Over half of the reported cases occur in patients undergoing cardiac surgery. Manipulation of the nondistended heart while on cardiopulmonary bypass forces the catheter distally, and hypothermia leads to increased catheter stiffness. The subsequent perforation may go unrecognized since the lungs are excluded from the circulation, only to become readily apparent when pulmonary blood flow is reestablished off bypass. Undoubtedly, anticoagulation predisposes to more severe manifestations of bleeding.

Most patients present with massive hemoptysis, but trivial bleeding may be a harbinger of rupture and should not be ignored. In the absence of hemoptysis, rupture is suggested on the chest roentgenogram when a nodule, mass, or infiltrate is seen adjacent to the catheter tip. In this setting, pulmonary angiography may be required to differentiate a pseudoaneurysm from an infarction. Pulmonary artery rupture should also be considered when a hemothorax occurs on the same side as the catheter tip or in the presence of unexplained hemodynamic deterioration.

After initial hemorrhage, 45% of cardiac surgery patients leaving the operating room without surgical repair or lung resection will eventually experience massive rebleeding, and in the majority of patients this will occur within the next 48 h. If minor hemoptysis occurs before the start of surgery, postponement is advisable followed by emergency pulmonary arteriography and therapeutic coil or balloon embolotherapy if necessary (embolotherapy is therapeutic transcatheter embolization of steel coils, absorbable gel foam sponges, or detachable balloons in order to occlude a blood vessel).

Prior to the initiation of bypass, the Swan-Ganz catheter is usually withdrawn several centimeters from the wedged position into the proximal pulmonary artery (as in this case). Should bleeding occur at this time, the catheter should be deflated and withdrawn several centimeters farther but kept in the pulmonary artery to assist with volume resuscitation. For persistent, life-threatening hemorrhage, reinflation of the catheter balloon may effectively occlude the blood supply to the ruptured artery. Positive end-expiratory pressure can be added to the ventilator as tolerated hemodynamically.

If massive hemoptysis occurs while cardiopulmonary bypass is being weaned, it should be re instituted to control bleeding by reducing pulmonary artery blood flow. Bronchoscopy with a flexible bronchoscope can localize and quantitate the bleeding. With a rigid bronchoscope, a Fogarty catheter can be inflated into the most distal airway possible to protect the rest of the lung; this tamponades endobronchial bleeding and allows time for definitive therapy. Ongoing bleeding distal to the catheter however, may still occur, with rupture of the visceral pleura and bleeding into the pleural space. The lungs are inspected through the sternotomy incision, and the site of catheter location is confirmed by palpation of the pulmonary arteries. Although proximal arterial rupture is unusual, primary repair of these injuries without resection is optimal. Bleeding is controlled with vascular clamps or a tourniquet of umbilical tape if necessary and with bypass. If extreme parenchymal hemorrhage causes visible distention of the lung, or visceral pleural rupture is seen, pulmonary resection is usually required. If the patient is not a candidate for pulmonary resection or can be stabilized off bypass with conservative measures and the reversal of anticoagulation, emergency pulmonary arteriography with embolotherapy is a consideration.

If bleeding occurs in the ICU, the catheter is
immediately retracted several centimeters proximally and the balloon can be reinflated if there is continued bleeding. The involved lung is placed in the dependent position. Volume resuscitation is followed by a chest roentgenogram and bronchoscopy. If present, anticoagulation is reversed and positive end-expiratory pressure is added to the ventilator, as tolerated hemodynamically. As before, a Fogarty catheter or double-lumen endotracheal tube is placed to protect the uninvolved lung. The patient should be heavily sedated or paralyzed if necessary to prevent dislodging these tubes.

If the patient is immediately poststernotomy, the chest can be reopened and selective pulmonary artery occlusion can be performed until resection is done. If the patient can be stabilized, immediate pulmonary arteriography and embolotherapy should be performed to prevent the risk of rebleeding. In experienced hands, this procedure has minimal morbidity and mortality. It has been used extensively in the treatment of pulmonary arteriovenous malformations with good long-term success rates.

In this patient, pulmonary arteriography showed an 11×8-mm pseudoaneurysm in a secondary branch of the pulmonary artery of the upper lobe of the right lung (Fig 2). Embolization was subsequently performed with three 5-mm Gianturco stainless steel coils (Fig 3). The patient did well and was discharged 6 days later.

CLINICAL PEARLS

1. Pulmonary artery rupture from Swan-Ganz catheter use has an incidence of 0.2% but a mortality rate of 50%. Pseudoaneurysms form when the bleeding is temporarily controlled by surrounding lung parenchyma or hematoma, but the incidence of rebleeding (which often is fatal) is 30 to 40%.

2. The presentation may include massive hemoptysis, a hemothorax, sudden hemodynamic instability, or radiographic changes alone. Trivial hemoptysis should not be ignored and may warrant further evaluation. The right pulmonary artery is injured more than 90% of the time.

3. Management of pulmonary arterial rupture includes volume resuscitation, the application of positive end-expiratory pressure on the ventilator, and protection of the airway with Fogarty catheters or double-lumen endotracheal tubes. The Swan-Ganz catheter is retracted proximally; for continued life-threatening bleeding, the balloon can be reinflated to reduce blood flow to the ruptured artery. In the operating room, bypass can be used to help control bleeding until arte-
rial repair or lung resection can be done. In the ICU, consideration should be given to emergency arteriography and embolotherapy.

SUGGESTED READINGS
Dieden JD, Friloux LA, Renner JW. Pulmonary artery false aneurysms secondary to Swan Ganz catheters. AJR 1987; 149:901-06
Swan HJC. The pulmonary artery catheter. Dis Mon 1991; 37:473-543