creased, there were no subsequent ventricular arrhythmias, and the patient was able to be discharged in good physical condition.

We believe that this case represents the oldest reported patient with primary prolongation of the Q-T interval who was totally asymptomatic until the appearance of exacerbating factors resulted in life-threatening arrhythmias. In view of the increasing frequency of case reports of this syndrome, it is suggested that a number of asymptomatic persons with prolonged Q-T intervals may well be at risk when provoked by extrinsic factors that tend to accentuate disturbances in repolarization. Early diagnosis of this disorder is, therefore, essential to prevent the impressive mortality associated with lack of therapy.

REFERENCES

16 Esplin DW: Effects of diphenylhydantoin or synaptic transmission in cat spinal cord and stellate ganglion. J Pharmacol Exp Ther 190:301-321, 1971

Transvenous Pulmonary Embolectomy for Acute Massive Pulmonary Embolism*

William G. Scoggins, M.D.,** and Lazar J. Greenfield, M.D.†

Transvenous pulmonary embolectomy employing a vacuum-cupped directionally controlled catheter is a relatively new technique used in the management of major pulmonary embolism. We present the findings in a patient with acute massive pulmonary embolism who underwent transvenous pulmonary embolectomy, with immediate and marked improvement in hemodynamic function and survival. Insertion of a new intracaval filter at the same time provided protection against recurrent thromboembolism.

As if the diagnosis of pulmonary embolism did not present the clinician with enough difficulty,1 the subsequent management of the disorder, especially mas-

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sive pulmonary embolism, adds further confusion because of therapeutic methods which range from treatment with drugs alone to open pulmonary embolectomy with the patient on cardiopulmonary bypass.

This report concerns a patient seen shortly after the occurrence of massive pulmonary embolism and hemodynamic collapse, who failed to respond to administration of heparin and vasopressor drugs. The application of a new technique using a transvenous catheter for pulmonary embolectomy, followed by the insertion of a vena caval filter, resulted in immediate hemodynamic recovery and survival.

CASE REPORT

This 51-year-old man was admitted to a community hospital following an automobile accident which resulted in a fracture of the left tibial condyle and shaft. The patient was treated with a cast and was making an uneventful recovery until the morning of the fourth day of hospitalization, at which time he became nauseated and diaphoretic, with complaints of pain in his left calf. His blood pressure, which had been 154/100 mm Hg, fell to unobtainable levels, while his apical pulse rate increased from 50 to 130 beats per minute. The respiratory rate had increased from 18/min to 40/min, and the diagnosis of acute massive pulmonary embolism was made. Heparin was given intravenously at a dose of 15,000 units, and blood pressure was supported with administration of levarterenol (Levophed) bitartrate.

The patient was transferred to the Medical College of Virginia Hospital, where physical examination revealed that the patient was diaphoretic and confused. His blood pressure was 60/0 mm Hg, and his pulse rate was 128 beats per minute. The respiratory rate had increased from 18/min to 40/min, and the diagnosis of acute massive pulmonary embolism was made. Heparin was given intravenously at a dose of 15,000 units, and blood pressure was supported with administration of levartenol (Levophed) bitartrate.

The patient was transferred to the Medical College of Virginia Hospital, where physical examination revealed that the patient was diaphoretic and confused. His blood pressure was 60/0 mm Hg, and his pulse rate was 128 beats per minute.

*From the Department of Surgery, Medical College of Virginia, Virginia Commonwealth University, Richmond. The hemodynamic data were supported by SCOR grant HL 14251.
**Instructor in Medicine and Surgery.
†Professor and Chairman, Department of Surgery. Reprint requests: Dr. Greenfield, Box 786 MCV Station, Richmond, Virginia 23298

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minute. The respiration rate was 36/min. The findings from examination of the lungs were unremarkable, but auscultation of the heart showed tachycardia, ventricular gallop, and accentuation of the pulmonic component of the second heart sound. Analysis of arterial blood gas levels with the patient receiving nasally administered oxygen at 4 L/min showed an arterial oxygen pressure \( (PaO_2) \) of 48 mm Hg, an arterial carbon dioxide tension \( (PaCO_2) \) of 27 mm Hg, a pH of 7.33, and a bicarbonate level of 13.5 mEq/L. The hemoglobin saturation was 80 percent.

The patient was transported to the angiographic suite, where a No. 7 French flow-directed triple-lumen thermistor beaded catheter was passed into the main pulmonary artery. The hemodynamic data are presented in Table 1. A pulmonary angiogram was obtained (Fig 1).

In the absence of any signs of clinical improvement, the right common femoral vein was exposed with the patient under local anesthesia, and a steerable vacuum-cupped catheter was introduced and directed under fluoroscopic guidance into the pulmonary arteries of the lower lobe, based on the angiographic findings. By injecting 6 to 8 ml of meglumine diatrizoate (Renografin) intermittently through the suction-cupped catheter, the position of the catheter was verified, which enabled juxtaposition of the suction cup to the tail of the embolus. The application of suction by syringe then produced aspiration of the end of the embolus into the cup, and the embolus was held there by continued vacuum via syringe as the entire catheter and embolus were withdrawn from the right ventricle and out through the femoral vein. An embolus measuring 1 cm x 5 cm was removed from the left lower lobe, and a smaller embolus measuring 1.5 cm x 1 cm was extracted from the right lower lobe. Two other emboli were successfully aspirated from the pulmonary vascular bed but were dislodged from the cup in the right ventricle, with presumed fragmentation and repeated embolization. With evidence of a satisfactory reduction in pulmonary arterial pressure and improvement in systemic pressure, the embolectomy was completed three hours following the first injection of heparin. A stainless steel filter was inserted into the inferior vena cava through the same femoral venotomy, as previously reported. Hemo-
dynamic data were obtained which showed that the systemic blood pressure had risen to 110/80 mm Hg (with a mean of 90 mm Hg) and no longer required support by levarterenol therapy (Table 1). In addition to the hemodynamic improvement, the patient had become alert and oriented, and his output of urine had increased.

Arterial blood gas levels determined six hours after transvenous embolectomy and with the patient receiving nasal oxygen at a rate of 10 L/min showed a \( PaO_2 \) of 93 mm Hg, a \( PaCO_2 \) of 30 mm Hg, pH of 7.46, and bicarbonate level of 21 mEq/L. The hemoglobin saturation was 97 percent. Administration of heparin was resumed eight hours after surgery. On the 13th postoperative day, a repeat pulmonary angiogram was obtained (Fig 3). An inferior venacavagram demonstrated patency of the filtering device, with a radiolucent area suggestive of an entrapped thrombus. Twenty-three days after admission the patient was discharged. A follow-up venacavagram obtained five months later showed resolution of the radiolucent area and complete patency of the filter. The patient remains in good health one year after the procedure.

**DISCUSSION**

Although transvenous pulmonary embolectomies have been performed in other patients who usually improved, this case is unique in the rapidity of diagnosis, the hemodynamic documentation of improvement, and the technique employed. On arrival the patient was in hemodynamic collapse despite administration of heparin and levarterenol bitartrate. He was confused, diaphoretic, and oliguric; and right cardiac catheterization confirmed a low cardiac index and high pulmonary vascular resistance. Immediately after transvenous pulmonary embolectomy, supportive therapy with vasopressor drugs was terminated. The cardiac index doubled, and pulmonary vascular resistance fell. In support of the hemodynamic data, the patient became oriented and alert, with a reduction in the respiratory rate and a resumption of normal urinary output.

Whether or not the patient would have survived or had further sequelae had he not undergone transvenous embolectomy and placement of an inferior vena caval
Number 4 in a Series

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214-A
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Indications: As a bronchodilator for bronchial asthma and for reversible bronchospasm which may occur in association with bronchitis and emphysema.

Contraindications: Known hypersensitivity to sympathomimetic amines.

Warnings: Usage in Pregnancy: The safety of the use of Bricanyl sulfate in human pregnancy has not been established. The use of the drug in pregnancy, lactation, or women of childbearing potential requires that the expected therapeutic benefit of the drug be weighed against its possible hazards to the mother or child. Usage in Pediatrics: Bricanyl sulfate tablets are not presently recommended for children below the age of twelve years due to insufficient clinical data in this pediatric group.

Precautions: Bricanyl sulfate should be used with caution in patients with diabetes, hypertension, and hyperthyroidism. As with other sympathomimetic bronchodilator agents, Bricanyl sulfate should be administered cautiously to cardiac patients, especially those with associated arrhythmias. Although the concomitant use of Bricanyl sulfate with other sympathomimetic agents is not recommended, the use of an aerosol bronchodilator of the adrenergic stimulant type for the relief of an acute bronchospasm is not precluded in patients receiving chronic oral Bricanyl sulfate therapy.

Adverse Reactions: Commonly observed side effects include nervousness and tremor. Other reported reactions include headache, increased heart rate, palpitations, drowsiness, nausea, vomiting, and sweating. These reactions are generally transient in nature, usually do not require treatment, and appear to diminish in frequency with continued therapy. In general, all the side effects observed are characteristic of those commonly seen with sympathomimetic amines.

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The clinical faculty, consisting of 15 instructors, will provide personal training and instruction, utilizing the facilities of five major hospitals. Each of the hospitals offer particular emphasis on certain aspects of pulmonary medicine.

Table 1—Hemodynamic Data

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Before Embolectomy with Levarterenol</th>
<th>After Embolectomy without Levarterenol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean right atrial pressure, mm Hg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inspiration</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Expiration</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Right ventricular pressure, mm Hg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inspiration</td>
<td>55/25</td>
<td>40/31</td>
</tr>
<tr>
<td>Expiration</td>
<td>37/20</td>
<td>22/15</td>
</tr>
<tr>
<td>Pulmonary arterial pressure, mm Hg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inspiration</td>
<td>52/42</td>
<td>40/30</td>
</tr>
<tr>
<td>Expiration</td>
<td>35/25</td>
<td>28/20</td>
</tr>
<tr>
<td>Mean pulmonary arterial pressure, mm Hg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wedge pressure, mm Hg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inspiration</td>
<td>38</td>
<td>26</td>
</tr>
<tr>
<td>Expiration</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Arterial blood pressure, mm Hg (mean)</td>
<td>76/50 (58)</td>
<td>100/80 (90)</td>
</tr>
<tr>
<td>Cardiac output, L/min</td>
<td>2.25</td>
<td>4.95</td>
</tr>
<tr>
<td>Cardiac index, L/min/sq m</td>
<td>1.04</td>
<td>2.29</td>
</tr>
<tr>
<td>Pulmonary arterial resistance, mm Hg min L⁻¹</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inspiration</td>
<td>15.6</td>
<td>4.65</td>
</tr>
<tr>
<td>Expiration</td>
<td>8.0</td>
<td>3.23</td>
</tr>
<tr>
<td>Total pulmonary resistance, mm Hg min L⁻¹</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inspiration</td>
<td>20.0</td>
<td>6.67</td>
</tr>
<tr>
<td>Expiration</td>
<td>12.4</td>
<td>5.25</td>
</tr>
<tr>
<td>Total systemic resistance, mm Hg min L⁻¹</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inspiration</td>
<td>16.9</td>
<td>14.10</td>
</tr>
<tr>
<td>Expiration</td>
<td>16.9</td>
<td>14.10</td>
</tr>
</tbody>
</table>

Filter is subject to debate, perhaps one that can only be resolved by further clinical trials. Since the filling defect seen on the inferior venacavagram most likely represents remnants of an entrapped embolus, it seems more likely that management of the patient with heparin therapy alone would have led to a fatal outcome.

In the past, this patient would have been managed either by continued anticoagulation therapy or open embolectomy with the patient on cardiopulmonary bypass. Anticoagulation therapy had been instituted, and in the absence of hemodynamic improvement, the patient clearly fulfilled the criteria of Sasahara and Bartram for embolectomy. Similarly, the patient’s hemodynamic collapse, associated with an elevated mean pulmonary arterial pressure and a greater than 50 percent occlusion of his pulmonary vascular bed, placed him in class 4 by our criteria and made him a candidate for embolectomy. Unfortunately, open pulmonary embolectomy is associated with significant mortality. The lowest reported mortality is 23 percent in highly selected patients; but based on the results of a multicenter questionnaire, the overall mortality approaches 57 percent. The high mortality from open embolectomy is not surprising when one considers the fact that the patient in cardiovascular collapse must tolerate general anesthesia and cardiopulmonary bypass.

Transvenous pulmonary embolectomy by catheter offers a number of advantages. Since the surgical approach is via femoral venotomy with the patient under local anesthesia, the need for thoracotomy and its deleterious effects are obviated. Neither a team familiar with cardiopulmonary bypass nor an operating theater is required. Should a patient initially have hypotension refractory to vasopressor therapy or cardiac arrest, he can be placed on partial cardiopulmonary bypass for pulmonary arteriographic studies, and then transvenous

Figure 3. Pulmonary angiogram obtained 13 days after transvenous embolectomy shows loss of filling defect at origin of arteries to left lower lobe, with improved flow to lower lobe. Opacification of artery to right lower lobe is also improved. Slight increase in filling to upper lobes is also evident.
Pulmonary embolism can be recognized and treated by measures capable of removing the emboli itself. The fact that this is done in one location and by the same group of physicians permits maximal efficiency. In this case, the procedure was completed within three hours of the clinical diagnosis established at another hospital.

The major side effects in transvenous pulmonary embolization that cannot be attributed to the embolus are, transient cardiac arrhythmias which result from retraction of the catheter, and infection of the wound. The one instance of ventricular perforation, which occurred in an agonal patient, resulted from the use of a No. 12 French standard cardiac catheter. This has not occurred in our experience since 1974 and seems unlikely because of the current utilization of a soft steerable catheter. The device for directional control also adds the ability to increase the number of emboli removed; however, we have shown experimentally that subtotal embolization effectively restores satisfactory cardiac output.

Transvenous pulmonary embolization must be considered experimental at present but should offer the physician a surgical alternative with lower morbidity and mortality for the management of massive pulmonary embolism.

REFERENCES

Intrathoracic hemorrhage from adhesions torn by a spontaneous pneumothorax is relatively uncommon. Continued hemorrhage from such adhesions after evacuation of 1,500 ml of blood would usually require thoracotomy for control. Through a flexible fiberoptic bronchoscope, we confirmed the source of hemorrhage and cauterized the bleeding point. This case illustrates another application for pleuroscopic examination, further broadening the use of the flexible fiberoptic bronchoscope.

Spontaneous pneumothorax is a fairly common occurrence in young adults and occasionally reveals portions of the lung bound to the chest wall as a result of adhesions. Endoscopic surgery upon plural adhesions was first described by Jacobus in 1923 and was part of the treatment for tuberculosis during the era of pulmonary collapse therapy. There has been a recent surge of interest of pleuroscopic (thoracoscopic) examination with the flexible fiberoptic bronchoscope for diagnosis and staging of pleural disease.

CASE REPORT
A 33-year-old man was admitted to our hospital with a 12-hour history of left parasternal chest pain and dyspnea on exertion. He had no history of cardiopulmonary disease, and the findings from his physical examination were unremarkable, except for decreased breath sounds on the left. The patient's chest x-ray film initially showed a 90 percent pneumothorax on the left, with the left upper lobe suspended from an apical adhesion (Fig 1). A chest tube and Heimlich valve failed to reexpand his lung initially. Water-sealed suction (25 cm H2O) and physical therapy were then applied. Thirty-six hours after the onset of symptoms (24 hours after admission), the patient began to bleed from the left side of his chest, and x-ray films showed that his apical adhesion had broken and that his chest was partially filled with blood (Fig 1). The patient bled 1,500 ml into his chest bottle in three hours and was resisting more than 50 percent reexpansion with suction.

Pleuroscopy examination by means of a flexible fiberoptic bronchoscope through the chest tube site revealed an actively bleeding torn adhesion in the left apex, several blebs over the partially reexpanded left apex (one of which contained a flapping defect), and about 500 ml of clotted blood in the lower left chest cavity. A Teflon-sheathed bronchial brush was advanced through the suction port of the bronchoscope, and under vision through the bronchoscope, the bleeding adhesion was cauterized (Fig 2). A chest tube was inserted through the wound, and the lung was expanded with suction of 100 mm Hg.

An immediate thoracotomy was thus averted by pleuroscopic cautery control of intrathoracic hemorrhage. Five months later, the patient is without empyema or recurrence of his pneumothorax.

DISCUSSION
Thoracoscopic examination for the safe division of pleural adhesions was a common practice during the era of pulmonary collapse therapy for tuberculosis. Empyema was occasionally associated with this technique but was usually tuberculous empyema. Recently, several authors have advocated the application of the flexible fiberoptic bronchoscope for the safe division of pleural adhesions.