BRIEF COMMUNICATIONS

THROMBOSIS OF THE PULMONARY ARTERY STUMP AFTER DISTAL LIGATION

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Patients who have undergone a Fontan operation are at risk for the development of thrombi in a variety of locations, including the caval system, the systemic venous atrium, the distal pulmonary arteries, and the systemic ventricle.¹⁻³ Recently, in several patients born with univentricular heart and antegrade pulmonary flow, we observed thrombi within the pulmonary artery stump after distal ligation of the main pulmonary artery. Thrombosis has not previously been documented in this location. This finding has implications regarding the optimal medical and surgical management for these patients.

CASE 1. A male infant was born at term with transposition of the great arteries, double aortic arch, and absent interventricular septum, precluding biventricular repair. He initially underwent ligation of the ductus arteriosus, division of the left aortic arch, and banding of the pulmonary artery. At the age of 6 months, he underwent a bidirectional Glenn anastomosis with distal ligation of the main pulmonary artery to preclude antegrade flow. He subsequently did well. At the age of 26 months, he underwent elective cardiac catheterization in preparation for a total cavopulmonary connection. He was in sinus rhythm, with the hemoglobin value and platelet count being within normal limits.

As is our current practice for patients undergoing staged procedures toward the Fontan operation, we performed transesophageal echocardiography immediately before catheterization. This demonstrated a 1 cm sessile thrombus within the stump of the ligated pulmonary artery, immediately distal to the pulmonic valve. The pulmonic valve opened partially, and color flow Doppler echocardiography showed flow into the pulmonary artery, with regurgitation also seen. Ventricular function was excellent, with no other thrombi found within the heart or vascular structures. Angiography demonstrated that contrast material entered the pulmonary artery, outlining the thrombus. Clearance of contrast material from this site was delayed.

CASE 2. A male infant was born at term with double-inlet left ventricle, L-malposition of the great arteries, and mild pulmonic stenosis. At the age of 2 months, he underwent banding of the pulmonary artery, followed at

the age of 9 months by a bidirectional Glenn anastomosis with ligation of the distal main pulmonary artery. When he was 15 months old, he underwent cardiac catheterization before undergoing the total cavopulmonary connection. He was in sinus rhythm, with a mildly elevated hemoglobin level (15.3 gm/dl) and a platelet count within the normal range.

Transesophageal echocardiography demonstrated a very large thrombus within the main pulmonary artery stump, occupying its entire volume (Fig. 1). Color flow Doppler echocardiography demonstrated antegrade flow into the pulmonary artery with regurgitation. The ventricular function was good, with no other thrombi noted. Angiography showed contrast material entering the pulmonary artery and outlining the thrombus, with extremely delayed clearance of contrast material from the pulmonary artery stump.

CASE 3. A male infant was born at term with tricuspid atresia, ventricular septal defect, and normally related great arteries. A classic right Blalock-Taussig shunt was performed at the age of 2 weeks. Postoperatively, thrombosis of the sagittal sinus developed. Hemoglobin, platelet count, protein C and S, antithrombin III, and plasminogen levels were all within normal limits. He recovered from these events and did well. At the age of 10 months, he underwent a bidirectional Glenn anastomosis, takedown of the Blalock-Taussig shunt, and ligation of the distal main pulmonary artery. When he was 18 months old, cardiac catheterization was performed in preparation for the total cavopulmonary connection. The patient was in normal sinus rhythm, with elevated hemoglobin values (16.5 gm/dl) and a platelet count within the normal range.

Transesophageal echocardiography demonstrated a very large thrombus within the main pulmonary artery, just distal to the pulmonic valve (Fig. 2). The thrombus filled virtually the entire artery, interfering with pulmonic valve motion. Valvular regurgitation was noted. Ventricular function was good, with no other thrombi noted. Angiography demonstrated faint opacification of the pulmonary artery stump with delayed clearance of contrast material.

Discussion. These three patients had certain anatomic similarities, that is, a univentricular heart with antegrade flow into the pulmonary artery. As part of the surgical staging toward a Fontan procedure, they underwent a bidirectional Glenn anastomosis, with ligation of the distal main pulmonary artery to exclude antegrade pulmonic flow. This ligation creates a blind stump, which appears to be a potential nidus for thrombus formation, presumably because of the pres-

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Fig. 1. Transesophageal echocardiogram showing cross section of the main pulmonary artery (MPA), just above the level of the valve, with thrombus filling the artery.

ence of stagnant flow. Furthermore, if pulmonic regurgitation is present (as in these three patients) such a thrombus may gain access to the systemic ventricle with the potential for systemic embolic complications. Although our patients appear to have escaped such complications, these problems are certainly known to occur in patients having the Fontan operation.¹⁻⁵

The occurrence of these thrombi in this location highlights the importance of aggressive evaluation of patients such as these and further suggests that prevention of thrombus should be a consideration when antegrade pulmonary blood flow is being curtailed. Although the optimal surgical technique for exclusion of the pulmonary artery from the systemic ventricle is not clearly defined, consideration should be given to patch closure or primary closure at the level of the pulmonic valve, rather than (or in addition to) ligation of the distal pulmonary artery.

REFERENCES

1. Dajee H, Deutsch LS, Benson LM, Perloff JK, Laks H. Thrombolytic therapy for superior vena caval thrombosis following superior vena cava-pulmonary anastomosis. *Ann Thorac Surg* 1984;38:637-9.
2. Putnam JB, Lemmer JH, Rocchini AP, Bove EL. Embo-

Fig. 2. Transesophageal echocardiogram showing the heart in short axis at the level of the aorta. A large thrombus is seen just above the level of the pulmonic valve, occluding the artery. RVOT, Right ventricular outflow tract; CLOT, thrombus; AO, aorta; MPA, main pulmonary artery; LV, left ventricle.

- lectomy for acute pulmonary artery occlusion following Fontan procedure. *Ann Thorac Surg* 1988;45:335-6.
3. Okita Y, Miki S, Kusuhara K, et al. Massive systemic venous thrombosis after Fontan operation: report of a case. *Thorac Cardiovasc Surg* 1988;36:234-6.
 4. Mahony L, Nikaidoh H, Fixler DE. Thrombolytic treat-

- ment with streptokinase for late intraatrial thrombosis after modified Fontan procedure. *Am J Cardiol* 1988;62:343-4.
5. Dobell ARC, Trusler GA, Smallhorn JF, Williams WG. Atrial thrombi after the Fontan operation. *Ann Thorac Surg* 1986;42:664-7.

FATAL PULMONARY HYPERTENSION AFTER HEART TRANSPLANTATION: SEQUELAE OF POSTACTINIC PULMONARY VASCULAR CHANGES

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A 41-year-old woman was admitted for heart transplantation because of doxorubicin-induced cardiomyopathy. In 1981, she had undergone combined treatment with chemotherapy and radiotherapy for Hodgkin's disease stage IIB and 9 years later for recurrent stage IIIB disease. The treatment included a total doxorubicin dose of 340 mg and a total irradiation dose to the paraaortic space of 3620 rads. She was in total remission for 4 years when her cardiomyopathy was in an end stage and she showed catecholamine-dependent biventricular heart failure. Cardiac catheterization revealed a severe dilative cardiomyopathy, probably caused by the toxic effects of doxorubicin. Pulmonary artery pressure was 55/32/38 mm Hg, and pulmonary vascular resistance was 331 dyn · sec · cm⁻⁵. Cardiac index was 1.73 L/m².

In July 1994, orthotopic heart transplantation was performed. No residual tumor tissue was found. Before the aortic crossclamp was opened, 1000 mg of methylprednisolone was administered as a standard immunosuppressive therapy. Total ischemic time was 77 minutes. A right-sided parietal pleurectomy was performed to drain chronic benign effusion. Because of expected diffuse bleeding after pleurectomy, 2 million units of aprotinin were added to the extracorporeal circulation (ECC). Weaning from cardiopulmonary bypass was accomplished without inotropic support. Seventeen minutes after decanulation and after initiation of heparin reversal with an infusion of protamine, a sudden rise of mean pulmonary artery pressure occurred, from 15 to 60 mm Hg. Mean arterial pressure dropped from 68 to 20 mm Hg. Oxygenation remained adequate. The patient was immediately fully reheparinized, recannulated, and reperfused. All the following attempts to wean the patient from ECC failed because of a progressive rise of pulmonary artery pressure to suprasystemic levels, with maximal mean values of 90 mm Hg and concomitant failure of the right side of the

heart. Inotropic substances (epinephrine, dopamine, and norepinephrine) were ineffective and nitroglycerin, prostaglandin E₁, and inhaled nitric oxide had no effect on pulmonary vascular resistance. Acute pulmonary artery embolization could be excluded. Even the implanted right ventricular assist device could not overcome the pulmonary vascular resistance. At a flow rate of 2 to 3 L/min, pulmonary artery pressure was in excess of 90 mm Hg, with a systemic arterial pressure of 25 to 30 mm Hg. Inspiratory airway pressure rose to 40 cm H₂O, and the patient died of massive hemorrhagic pulmonary edema with failing oxygenation. At autopsy, the transplanted heart showed no relevant pathologic changes. Significant alterations were found in the lungs, mostly in the venous and capillary circulation, with intravascular coagulation. The small pulmonary veins were narrowed by a loose, sparsely cellular intimal tissue suggestive of intimal swelling during operation (Fig. 1). The capillaries were filled with fibrin plugs. The lungs showed fibrosis in the pericardiac region, mostly as a result of former radiation, and a hemorrhagic edema was present. Before operation, plasma protein levels were in the normal range and immunoelectrophoresis showed only a slight hypoinmunoglobulinemia.

Adverse reaction to protamine. The patient had no predisposing factors toward adverse reactions to protamine (previous exposure to the drug, insulin dependence, fish allergy),¹ and the clinical picture of isolated and overwhelming pulmonary hypertension was not compatible with an immunoglobulin E-mediated anaphylaxis, which decreases systemic vascular resistance and increases capillary permeability and airway resistance. After administration of 1 gm of methylprednisone, any anaphylactic reaction should also be diminished. The direct systemic vasodilatory effect of protamine was obviated by very slow rates of drug administration (5 mg/min). Protamine may also react with circulating immunoglobulin G or immunoglobulin M antibodies, which results in pulmonary vasoconstriction by elevation of anaphylatoxins and thromboxane A₂. Pulmonary hypertension was excessive, however, and could not be influenced by any vasodilatory drug as would be expected in thromboxane A₂-related hypertension.² Protamine-induced pulmonary hypertension involves the arterial vascular bed mainly by increasing the tone of arterioles, whereas in our patient the pathologic substrate was a predominant obstruction of the venous circulation, which best explains the impressive hemor-

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