Clinical Use of Blade Atrial Septostomy

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SUMMARY A cardiac catheter enclosing an extensible blade was used to enlarge the interatrial opening in seven patients. Two patients with transposition of the great arteries who had balloon atrial septostomy as newborns subsequently presented with clinical evidence of a restrictive interatrial opening at 1 and 4 months of age. Cardiac catheterization confirmed restenosis of the interatrial opening and inadequate intracardiac mixing. After blade atrial septostomy the systemic arterial oxygen saturation increased by 20% and 30%, respectively. Five patients with mitral atresia complex, ages 2 months–9½ years, had a restrictive interatrial communication and severe pulmonary venous hypertension (mean left atrial pressures ranged from 20–38 mm Hg). Following blade atrial septostomy, the pressure gradient between the atria was almost completely abolished and prompt clinical improvement was observed in each patient. All patients tolerated the procedure without complications.

Blade atrial septostomy was a safe, effective procedure for enlarging the interatrial communication in this limited series of patients with an interatrial septum too thick to permit adequate rupture by conventional balloon atrial septostomy.

AN ADEQUATE INTERATRIAL OPENING is essential for survival in transposition of the great arteries (TGA), mitral atresia, tricuspid atresia, pulmonary atresia with an intact interventricular septum, and total anomalous pulmonary venous return. Although balloon atrial septostomy (BAS) has been utilized to enlarge the interatrial opening in infants,1–6 a thick interatrial septum in older infants and children may preclude a successful BAS.4, 7 Some patients, after an apparently successful BAS, later manifest clinical deterioration probably resulting from just initial stretching rather than tearing of the interatrial septum and subsequent stenosis of the interatrial opening. Repeat BAS is rarely effective.8 Other septostomy methods have generally been ineffective and associated with high morbidity and mortality.5, 9

In a previous communication we described a technique for enlarging an interatrial opening in an experimental animal using a catheter with an extensible surgical blade.10 This report describes the clinical application of the technique.

Materials and Methods

Two early prototypes of the catheter were made from #6 and #7 French woven Dacron catheters. The blade catheter currently used is #5 French Teflon with a 2.5 cm stainless metal tubing at the tip (fig. 1). A slit is present in the long axis of the metal tubing. A tiny surgical blade 12 mm long and 1 mm wide is attached to a lever which is pivoted within the metal tubing (fig. 2). The proximal end of the blade is linked to a guide wire. The proximal portion of the catheter is connected to a “Y” extension, with one branch for fluid infusion and pressure measurement, and the other branch for the wire used to control the blade.

From April 1976 to September 1977, blade atrial septostomy was performed in two patients with TGA and five patients with mitral atresia complex. Each patient had an inadequate interatrial opening and was at an age where BAS was unlikely to be effective (table 1). Five of the seven patients were infants less than 7 months old and two were more than 1 year old. Before the procedure, informed consent was obtained from the parents.

No medication was given to infants under 6 months of age. The infants between 6 months to 1 year of age received 0.1 mg/kg of morphine sulfate intramuscularly. Children over 1 year of age received a combination of meperidine (2 mg/kg), promethazine (0.5 mg/kg) and chlorpromazine (0.5 mg/kg). The catheter was introduced into the saphenous vein by cutdown or the femoral vein by percutaneous sheath technique. The catheter tip was passed across the interatrial communication into the left atrium. The location of the catheter tip in the left atrium was confirmed by fluoroscopy, pressure measurement and injection of contrast material. The blade control wire was then advanced to extend the blade (fig. 3). In order to make an incision in the fossa ovalis rather than the posterior-superior portion of limbus, the catheter was rotated so that the blade faced inferiorly, anteriorly and to the left. The entire catheter was then gently withdrawn into the right atrium with the blade extended. Usually some resistance was met as the blade cut through the interatrial septum, followed by a sudden loss of resistance as the blade reached the right atrium. The blade was folded into the catheter lumen by withdrawing the wire. In each patient a single pass with the blade was sufficient to initiate an incision in
FIGURE 1. The catheter assembly with the blade extended. The proximal portion of the catheter is connected to a "Y" shaped plastic extension; one branch (A) is for fluid infusion or pressure measurement and the other branch (B) is for the guide wire.

the interatrial septum. A #5 French Fogarty septostomy catheter was then used to further enlarge the interatrial opening. Pressure was recorded on withdrawal of the catheter from the left atrium to the right atrium. The size of the interatrial opening was measured before and after the blade septostomy and after BAS. The balloon of a Swan-Ganz or Fogarty septostomy catheter was inflated in the left atrium and pulled gently against the interatrial septum. As the balloon was gradually deflated, slight tension was maintained on the catheter until it suddenly passed into the right atrium. This sequence was recorded on cine film and the magnification factor was subsequently calculated from film of a premeasured metal block placed at the level of the right atrium. The diameter of the balloon at the time of passage through

FIGURE 2. Close-up view of the catheter tip. A) Superior view showing a slit along the long axis of the catheter tip. B) Lateral view with the blade extended.
the interatrial communication was taken to be the diameter of the interatrial opening. The accuracy of this technique for estimating the size of an interatrial communication has been well-established in animal studies and at autopsy.\textsuperscript{10, 11}

**Results and Follow-Up**

The diagnoses and ages of the patients at the time of the procedure are listed in Table 1.

**TGA Group**

Two newborn infants with TGA and intact ventricular septa had successful BAS at the initial cardiac catheterization. At 1 and 4 months of age cardiac catheterization was performed because of increasing cyanosis; the catheterization showed inadequate interatrial mixing. The interatrial openings were enlarged to 15 mm in diameter using the blade catheter. Following the procedures oxygen saturations rose 20–30%. Patient 1 is 9 months of age and remains in excellent condition. Patient 2 underwent a Mustard operation at 10 months of age. At operation, an interatrial opening 15 mm in diameter was noted.

**Mitral Atresia Group**

Patient 3 had equal pressures in both atria at initial cardiac catheterization at 2 days of age. Repeat cardiac catheterization at 7 months of age demonstrated a restrictive interatrial opening with mean left atrial pressure of 20 mm Hg. After blade atrial septostomy mean left atrial pressure decreased to 7 mm Hg (fig. 4). At 9 months of age, the patient underwent surgery for resection of coarctation of the aorta, ligation of a patent ductus arteriosus and pulmonary artery banding. The patient died of pulmonary complications 40 hours later, and postmortem examination showed a thick interatrial septum and a 12 × 14 mm interatrial opening (fig. 5).

Patient 4 had mitral atresia with subpulmonic stenosis. At 4 months of age a Waterston shunt was performed. At 3½ years of age the patient was admitted because of increasing congestive heart failure and spiking fever. Cardiac catheterization demonstrated a restrictive interatrial opening and mean left atrial pressure of 36 mm Hg. After blade atrial septostomy the mean left atrial pressure decreased significantly, to only 3 mm Hg higher than right atrial pressure. The enlarged interatrial opening was documented by angiography (fig. 6). Within 12 hours after the procedure the patient became afebrile and improved clinically. Eleven months after the procedure, he remained in good condition.

Three additional patients with mitral atresia complex and restrictive interatrial communication underwent blade atrial septostomy at 2 months, 4 months and 9 years of age, respectively. Each patient had a significant decrease in the mean left atrial pressure and prompt clinical improvement. All procedures were done without complications.

**Discussion**

The introduction of BAS by Rashkind and Miller\textsuperscript{1} has resulted in significant reduction in the mortality of infants with TGA. This technique has been used for other congenital heart defects in which an adequate interatrial opening is essential for survival.\textsuperscript{2, 3, 5}

The efficacy of BAS in enlarging the interatrial opening was established in animal experiments and in a few human infants. However, it is a suboptimal technique for treatment of TGA with intact ventricular septa, especially in the neonatal period. The majority of patients in this study had improved oxygen saturations and cardiac indices after BAS. However, in some cases the interatrial opening was inadequate for adequate mixing of oxygenated and deoxygenated blood. In these cases the patients required additional surgical interventions to improve oxygen saturation and cardiac output.

**Table 1. Clinical Experience with Blade Atrial Septostomy**

<table>
<thead>
<tr>
<th>Patient</th>
<th>Cardiac lesion</th>
<th>Age and weight</th>
<th>Mean atrial pressure (mm Hg)</th>
<th>Interatrial opening*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Before</td>
<td>After</td>
<td>Before</td>
</tr>
<tr>
<td>1</td>
<td>TGA BAS</td>
<td>1 mo 3.4 kg</td>
<td>11 7</td>
<td>7 7</td>
</tr>
<tr>
<td>2</td>
<td>TGA BAS</td>
<td>4 mos 5.8 kg</td>
<td>4 2</td>
<td>4 4</td>
</tr>
<tr>
<td>3</td>
<td>Mitral atresia DORV PDA CoAo</td>
<td>7 mos 6.3 kg</td>
<td>20 7</td>
<td>7 4</td>
</tr>
<tr>
<td>4</td>
<td>Mitral atresia SIV + PS Waterston shunt</td>
<td>3½ yrs 10.8 kg</td>
<td>38 10</td>
<td>18 15</td>
</tr>
<tr>
<td>5</td>
<td>Mitral atresia DORV + PDA PA banding</td>
<td>2 mos 3.4 kg</td>
<td>26 4</td>
<td>7 3</td>
</tr>
<tr>
<td>6</td>
<td>Mitral atresia DORV, Post B-H and PA banding</td>
<td>9½ yrs 17.4 kg</td>
<td>38 5</td>
<td>12 5</td>
</tr>
<tr>
<td>7</td>
<td>Mitral atresia DORV PDA + CoAo</td>
<td>4 mos 3.1 kg</td>
<td>21 2</td>
<td>6 1</td>
</tr>
</tbody>
</table>

* Diameter of the interatrial opening measured with a balloon pullback.

Abbreviations: BAS = balloon atrial septostomy; B-H = Blalock-Hanlon procedure; CoAo = coarctation of the aorta; DORV = double outlet right ventricle; IAO = interatrial opening; LA = left atrium; PA = pulmonary artery; PDA = patent ductus arteriosus; PS = pulmonary stenosis; RA = right atrium; SIV = single ventricle; TGA = transposition of the great arteries.
**FIGURE 3.** Sequence of the blade atrial septostomy procedure: 1) catheter tip positioned in the left atrium; 2) blade extended; 3) blade is facing inferiorly, anteriorly and to the left; and 4) pullback to the right atrium.

**FIGURE 4.** Pressure tracings on withdrawal of the catheter from the left atrium to the right atrium in patient 3 before and after atrial septostomy. LA = left atrium; RA = right atrium.
FIGURE 5. Postmortem examination of the interatrial septum in patient 3 (after fixation) showing an adequate interatrial opening and a thickened and rolled rim of the interatrial septum (arrows). CS = coronary sinus; TV = tricuspid valve.

opening has varied in different reports.\textsuperscript{1-6, 12-13} Furthermore, management of those infants who either failed to improve immediately after BAS or who deteriorated after initial improvement varies in different centers. The technique of profound hypothermia with circulatory arrest has enabled repair of small, young infants with complex cardiac lesions.\textsuperscript{12, 14, 15} A few reports describe primary repair with low mortality in infants under 6 months of age.\textsuperscript{12, 16} However, in most centers the morbidity and mortality remain high at this age. Therefore, in infants who have an inadequate BAS, two-stage surgical correction with initial surgical atrial septectomy and later Mustard operation has been recommended.\textsuperscript{13, 17}

Although the problem of early pulmonary vascular disease in TGA is well-known,\textsuperscript{18-21} the incidence of

FIGURE 6. Selective left atrial angiogram in patient 4 A) before the procedure, demonstrating a markedly restrictive interatrial opening, and B) after the blade atrial septostomy showing a large interatrial opening with free flow from the left atrium to the right atrium.
irreversible pulmonary vascular change is extremely rare in infants under 1 year of age who have TGA and intact interventricular septum. Thus, the primary reason for early repair in simple TGA is inadequate interatrial mixing. Although Kratzen et al.\(^7\) report only a single death in a series of 36 Blalock–Hanlon operations, surgical atrial septectomy still carries a substantial risk according to other reports.\(^3,\,22,\,23\) and adds to the problem of fibrous adhesions in the operative area at subsequent Mustard operation.

The blade septostomy technique was effective in enlarging the interatrial opening even in older infants and children with a thick interatrial septum. It is unlikely that the thick interatrial septum in patient 3 (fig. 5) could have been torn by balloon atrial septostomy alone.

The technique was particularly useful in critically ill patients such as patient 4, in whom surgical septectomy under general anesthesia would have carried an even higher risk. Patients with the mitral atresia complex (patients 3 and 7) required pulmonary artery banding and/or coarctectomy. If these patients had had surgical atrial septectomy instead of blade atrial septostomy, a bilateral thoracotomy with its attendant morbidity and mortality would have been required.

The long-term results of this procedure are unknown, and follow-up of the six survivors ranged from two to 11 months (mean 6.5 months). So far, all surviving patients have been doing well, and no patient has developed clinical evidence of restenosis of the interatrial opening. In addition to postmortem confirmation of adequate enlargement of the interatrial opening in one patient, the 4-month-old infant with TGA had a large interatrial opening at the time of Mustard operation, six months after the blade septostomy procedure.

This procedure should be useful when a restrictive interatrial opening occurs after an initially adequate BAS, since repeat BAS alone has usually been ineffective.\(^6,\,9\) In older infants and children, the interatrial septum is usually thick and BAS is almost never effective. Blade atrial septostomy may therefore be indicated in these patients as an initial therapeutic modality.

In our limited experience with this procedure, there have been no complications during or after the procedure. More experience with this procedure is needed to further evaluate its efficacy and safety. Potential hazards include inadvertent laceration of other cardiovascular structures during manipulation of the blade catheter. Careful fluoroscopic monitoring is essential during passage of the catheter to and from the heart to ensure that the blade is within the catheter lumen. In the blade septostomy procedure, the catheter must be pulled across the interatrial septum as gently as possible, and should not be jerked as in balloon septostomy. The blade must be directed anteriorly, inferiorly and to the left before it is pulled back to the right atrium. The septum in this area is thinner and easier to incise. In addition, there is less chance of lacerating the posterior wall of the atrium.

In conclusion, this new septostomy technique has been valuable in creating an adequate interatrial opening without thoracotomy in infants and children with various congenital heart defects, even in the presence of a thick interatrial septum.

Acknowledgment

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References

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Anomalous Aortic Origin of Coronary Arteries

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SUMMARY Among 7,000 patients who underwent diagnostic coronary arteriography at Hahnemann Medical College and Hospital, we found 45 patients (0.64%) with anomalus aortic origin of one or more coronary arteries. There were 31 men (69%) and 14 women (31%). The patients were classified into the following groups: 1) anomalous origin of the circumflex coronary artery (26 patients, 57.8%); 2) both coronary arteries arising from the left sinus of Valsalva (12 patients, 26.7%); 3) both coronary arteries arising from the right sinus of Valsalva (four patients, 8.9%); 4) anomalous origin of the left anterior descending coronary artery from the right sinus of Valsalva (two patients); and 5) anomalous origin of the first septal perforator from the right sinus of Valsalva (three patients); in one of these patients it was an isolated finding, and in the other two there were other anomalous vessels. Associated valvular heart disease was present in 14 patients (31%); coronary artery disease in 11 (24.5%); idiopathic hypertrophic subaortic stenosis in two; miscellaneous heart diseases in eight (17.8%); and no heart disease in 11 (24.5%). Angina pectoris was present in 42.2%; atypical chest pain in 28.9%; syncope in 17.7%; palpitations in 46.7%; and a history of hypertension in 40%. We conclude that 1) anomalous coronary arteries are associated with a high incidence of hypertension and valvular heart disease in the sample of patients studied; 2) there was a high incidence of palpitations, but this and the other symptoms were difficult to evaluate because of the associated disease; 3) in certain patients with anomalous origin of the left main coronary artery (LM) from the right sinus of Valsalva, myocardial perfusion is probably impaired and may be associated with serious cardiac events whether the initial course of the LM is posterior to the aorta, between the aorta and the pulmonary artery, and/or anterior to the pulmonary artery. Course of the anomalous LM coronary artery between aorta and the pulmonary artery may be associated with sudden death. Atherosclerosis of a single coronary artery proximal to its branching is an additional liability to the anomaly.

Since sudden death occurs most commonly in young individuals with anomalous origin of the LM, special care should be taken to evaluate young patients with chest pain resembling angina. A maximal treadmill exercise test should be performed first, and if there is evidence of ischemia, a coronary arteriogram should be performed. Recognition of anomalous origin of coronary arteries and their course also is important in patients undergoing surgery for aortocoronary bypass or for valvular heart disease when perfusion of coronary arteries is needed.

MANY VARIATIONS of the aortic origin of one or both coronary arteries exist1-2 and have been considered minor coronary anomalies without clinical significance.3 With the increasing use of coronary arteriography, the anomalies are being recognized more frequently and their clinical significance is becoming better appreciated.3-8

The variations in the initial course of the coronary arteries with anomalous origin are more important than the anomalous origin itself. Unrecognized coronary anomalies may lead to errors in clinical diagnosis, and surgical problems may follow if an anomalous coronary artery is excluded from perfusion during open heart surgery or if the surgeon unwittingly incises the anomalous coronary artery.

Most recent reports indicate that certain anomalous coronary arteries are associated with sudden death, myocardial infarction and anginal syndrome.4, 5, 7, 9-18

In this report we describe our experiences with 45 patients in whom anomalous aortic origin of the coronary arteries was found during coronary arteriography of 7,000 patients.

Materials and Methods

From 1966–1977, approximately 7,000 adult patients underwent diagnostic coronary arteriography at the Cardiac Catheterization Laboratory of the Hahnemann Medical College and Hospital.

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