Coil Occlusion for Patent Ductus Arteriosus Larger Than 3 mm

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Background  Coil occlusion of patent ductus arteriosus (PDA) is now widely accepted as the first-line treatment, but there are few reports of age-dependent differences in the complications associated with this technique.

Methods and Results  Sixteen patients (11 adults, 5 children) with a PDA larger than 3 mm, who underwent coil occlusion at Sapporo Medical University Hospital between September 1995 and August 2004, were enrolled. Immediate and intermediate outcomes and complications were analyzed. Procedural success rate was 72.7% (8/11) in the children and 100% (5/5) in the adults. Coil migration occurred in 4 children and 1 adult, and 3 adult patients had hemolysis.

Conclusion  Hemolysis was more frequent in adults than in children even though the residual shunt was trivial.

Key Words: Adult congenital heart disease; Coil occlusion; Hemolysis; Patent ductus arteriosus

Patent ductus arteriosus (PDA) is a common congenital defect that accounts for approximately 7–10% of patients with congenital heart disease. Survival into adulthood with uncorrected PDA is uncommon, although patients as old as 90 years have been reported. The 2 major complications, and hence, causes of death in patients with PDA, are heart failure and bacterial endocarditis. Intravenous indomethacin administration in premature infants with a PDA is now well-established. Successful outcomes are reported in adults with mild to moderate pulmonary hypertension and exclusively left to right shunting, but the risk of surgery in adults is greater than that in children. The risk may be especially high in elderly patients with a calcified and hence fragile PDA. When a significant shunt is detected in the elderly, surgical closure for PDA occasionally needs cardiopulmonary bypass.

Transcatheter coil embolization is an attractive procedure for treatment of PDA or coronary artery fistula and is now commonly performed in children and adults with a high occlusion rate, particularly those with a small or medium-sized PDA. Although the Amplatzer duct occluder, which can effectively close a medium- to large-sized PDA, is currently available in many countries, it has not been approved for use in Japan. Consequently most transcatheter closures of PDA in Japan use either Flipper, 0.038- or 0.052-inch Gianturco coils, but because there are only a few reports on age-dependent differences in complications of this procedure, we conducted the present study of coil occlusion of PDA larger than 3 mm in children and in adults.

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Methods

Sixteen patients with a PDA of minimal diameter larger than 3 mm and who underwent coil occlusion at Sapporo Medical University Hospital between September 1995 and August 2004 were the study subjects. Angiographic morphology of the ductus was classified as described by Krischenko et al from a lateral aortogram and the minimal diameter was measured in this view. Closure of the ductus was performed progradely from the pulmonary artery (PA), retrogradely via the aorta, or simultaneously from both sides. The PDA was considered to be completely occluded if no residual shunt was detected by aortography in the catheterization laboratory or by Doppler echocardiography during follow-up. Statistical analysis was performed using student's t-test and Fisher's exact probability test, with a p-value <0.05 as significant.

Background of Pediatric Patients

The patients' ages and weights at occlusion ranged from 3 to 72 months (median, 11 months) and 4.0 to 19.0 kg (median, 8.5 kg), respectively. There were 10 girls and 1 boy. The minimum diameter of the ductus ranged from 3.2 to 4.6 mm (median, 3.4). The angiographic appearance of the ductus was type A in 8 patients, type D in 1 patient and type E in 2 patients.

All had a continuous murmur. Patient 2 also had mitral regurgitation and 21 trisomy, and patient 9 had aortic stenosis and regurgitation. Nine patients, excluding patients 6 and 11, had pulmonary hypertension (mean pulmonary pressure ≥25 mmHg), and in patients 5, 9, and 10 the mean pulmonary pressure exceeded 60 mmHg. Coil occlusion for all patients involved multiple coils (Gianturco and/or Flipper coil), except for patient 1 for whom we used a Rashkind PDA occluder with coils (Table 1). Vigorous attempts were made to achieve complete closure in the catheterization laboratory. Several factors were compared between patients with successful and unsuccessful implan-
Background of Adult Patients

The patients’ ages and weights at occlusion ranged from 53 to 71 years (median, 61 years) and 38.0 to 66.0 kg (median, 52.0 kg), respectively. There were 4 women and 1 man. The minimum diameter of the ductus ranged from 1.7 to 4.9 mm (median, 3.7 mm) and the angiographic appearance was type A in 4 patients and type E in 1 patient. All had a continuous murmur. Patients 3 and 4 had dyspnea on exertion and the latter also had paroxysmal atrial fibrillation. We implanted multiple coils in all patients (Gianturco coil and/or Flipper coil), except for case 3, in which we used a Rashkind PDA occluder with coils (Table 2).

Results

Children

We performed 13 procedures in 11 patients and in 8 (73%) the coils were successfully deployed. Three (25%) of these 8 patients had complete occlusion on angiography 5–10 min after coil deployment (patients 1-3, 2, 4), and in 4 patients excluding patient 6 PDA was closed within 24 h after the procedure. Patient 6 had a residual leak at the time of hospital discharge, but the ductus was completely occluded 1 month later. In patient 1, multiple coils migrated and were retrieved at the first and second attempt. One Rashkind PDA occluder and 3 Flipper coils were successfully deployed at the third attempt and resulted in immediate complete occlusion. Although the minimal diameter of the ductus was significantly larger in patients with failed implantation than in those with successful implantation (p<0.01), there was no significant difference in age, weight, mean PA pressure or pulmonary blood flow/systemic blood flow between these groups (Table 3). None of the patients who had successful coil deployment experienced hemolysis, late coil migration, pulmonary stenosis, death or other serious complications.

Coils could not be deployed in 3 patients (27%), who were eventually referred for elective surgery. The coils migrated to either the PA (2 patients) or the aorta (1 patient). All coils were retrieved successfully with a snare catheter.

Adults

Seven procedures were performed in the 5 patients, and coils were successfully deployed in all (100%). Two patients (40%) had total occlusion on angiography immediately after coil occlusion (patients 2 and 5), but a tiny leak persisted in the other 3 patients (nos. 1, 3 and 4) who all

Table 1 Pediatric Patients and Procedure Details

<table>
<thead>
<tr>
<th>Case no.</th>
<th>Age (months)</th>
<th>BW (kg)</th>
<th>Qp/Qs</th>
<th>PDA* (mm)</th>
<th>PDA type¹</th>
<th>Coil type</th>
<th>Coil diameter (mm)</th>
<th>Outcome</th>
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<td>8x1, 8x1, 5x1</td>
<td>M</td>
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<td>E</td>
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*minimum diameter; †angiographic appearance.

BW, body weight; Qp/Qs, pulmonary blood flow/systemic blood flow; PDA, patent ductus arteriosus; y, years; m, month; 038 G, 0.038-inch Gianturco coil; F, Flipper coil; M, migration; NS, no residual shunt; TS, tiny residual shunt; 052 G, 0.052-inch Gianturco coil.

Table 2 Adult Patient and Procedure Details

<table>
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<tr>
<th>Case no.</th>
<th>Age (months)</th>
<th>BW (kg)</th>
<th>Qp/Qs</th>
<th>PDA* (mm)</th>
<th>PDA type¹</th>
<th>Coil type</th>
<th>Coil diameter (mm)</th>
<th>Outcome</th>
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<td>8x2, 6.5x1</td>
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<td>2</td>
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<td>E</td>
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<td>8x1, 5x1</td>
<td>NS</td>
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<td>Rashkind, Fx1</td>
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<td>4.9</td>
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<td>10x1, 8x2</td>
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Abbreviations as for Table 1.

Table 3 Comparison of Successful and Unsuccessful Coil Implantation Group in the Pediatric Cases

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<th>Successful implantation</th>
<th>Unsuccessful implantation</th>
<th>p value</th>
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<td>11.7±5.2</td>
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<td>4.0±24</td>
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</tr>
<tr>
<td>2.1±0.6</td>
<td>3.3±1.4</td>
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</table>

Mean±SD. PA, pulmonary artery. Other abbreviations as for Table 1.
Two 0.052-inch Gianturco coils were initially implanted in patient 1, using the prograde approach, but because aortography confirmed a moderate residual shunt, we implanted an additional Flipper coil (diameter 6.5 mm) by the retrograde approach. However, all coils had migrated to the right PA by the next day. After complete retrieval of the coils with a goose neck snare, two 0.052-inch Gianturco coils and 1 Flipper coil (diameter 8 mm) were simultaneously implanted in the appropriate position using prograde and retrograde approaches. There was still a tiny leak with mild hemolysis, but it subsided over time. This patient was started amiodarone bisatrate because the systolic blood pressure increased to 140-160 mmHg after the PDA occlusion.

One Rashkind PDA occluder and 1 Flipper coil were used in patient 3, but after coil occlusion, Doppler echocardiography revealed a trivial shunt and several hours later the urine became dark. Urinalysis revealed hemoglobinuria. Five days after the first procedure, there was an elevation of both lactate dehydrogenase (LDH) (5.0901U/dl) and total serum bilirubin (3.2mg/dl), with a decrease in hemoglobin from 12.0 to 7.5g/dl. She was given a blood transfusion, but hemolysis continued and 1 month after the first procedure, we implanted additional coils (one 0.038-inch Gianturco coil and 2 Flipper coils), which almost completely eliminated the shunt. Subsequently, the hemolysis ceased without further complications.

Two 0.052-inch Gianturco coils and 3 Flipper coils were used for patient 4, but there was a tiny residual leak. The next day, her urine became dark and LDH was elevated to 8291U/dl; however, severe anemia did not develop and the hemolysis subsided within several days. One week after the first procedure, Doppler echocardiography revealed no residual shunt.

In summary, 3 of the 5 adult patients developed hemolysis and there was 1 case of complicated migration. None of the patients experienced pulmonary stenosis, death or other serious complications. Although there was no significant difference in the rate of migration of the coils between the children and adult patients, hemolysis was significantly more frequent in the adults (p<0.05).

**Discussion**

A non-surgical method of closing a PDA using a transfemoral occlusion sponge plug device was first reported by Porstmann et al in 1967 and since then many occlusion devices have been developed. In 1976, Rashkind et al introduced a device known as an umbrella occluder, which became widely used. Its efficacy, though less than that of surgical closure, was well established in children and it was also used successfully in adults. Schenck et al achieved a success rate of 80% with this device in adult patients with a residual shunt and a PDA of 5-6 mm in diameter. In the present study transcatheter coil occlusion, in addition to the use of a 17 mm-Rashkind occluder, was performed in a child (patient 1; 46 months) and an adult (patient 3; 61 years) with the result of complete occlusion and a trivial residual leak, respectively. Hemolytic anemia occasionally complicating the use of this device has been described. In addition, the Rashkind device is expensive, and even though a transvenous route is used, a large-sized sheath is usually required. Recently Cambier et al reported successful transcatheter occlusion of a small PDA (diameter <2.5 mm) in 4 children using Gianturco coils introduced via a 5Fr femoral artery sheath.

Although PDA is usually discovered in early childhood, it may remain undetected until adulthood, most commonly presenting as dyspnea, heart failure, and palpitation. Because the mortality in adults with PDA is estimated to be 1.8% per year, closure of the ductus is usually recommended if there is not severe pulmonary vascular obstructive disease.

Previous studies have shown that success rate of PDA closure with coils is inversely related to the ductus size, so the success rate of coil occlusion is high for a PDA smaller than 3 mm, whereas the risk of some complications may increase when closing a PDA larger than 3.0-3.5 mm. Coil migration and left PA stenosis are the 2 most prevalent complications with hemolysis occurring in approximately 1-2%. In the present study, coil implantation was complicated by migration in 4 children and although all the migrated coils were retrieved with a snare catheter, 3 patients underwent surgical closure of the ductus. Implantation was also complicated by coil migration in 1 adult patient; however, the ductus was closed on the second attempt.

Consequently, successful coil occlusion was achieved in 73% (8/11) of the children, and 100% (5/5) of the adults in this study. Surgical division and ligation of the PDA in adults may be technically more difficult than in children because of the increased likelihood of calcification of the ductus. Patch closure of a PDA requires cross-clamping of the aorta or cardiopulmonary bypass and a longer recovery time for the patient. Furthermore, complications are not infrequent and include recurrent laryngeal nerve injury, aortic dissection, and left PA ligation. For these reasons, transcatheter closure of the ductus in adolescents and adults has become an attractive alternative to surgery.

None of the children developed hemolysis, but 3 adult patients did, despite the residual shunt after coil delivery appearing to be trivial. A sclerotic aortic wall or PDA with calcification might explain the frequency of hemolysis. Once hemolysis occurs, there is a chance of renal failure and renal shutdown, so leakage must be minimized to reduce the risk of hemolysis. Several approaches to hemolysis following ductus occlusion have been described. Mild hemolysis may require no intervention and even severe hemolysis may resolve after 2-3 weeks in children managed conservatively with blood transfusion; however, it may occasionally require additional coil deployment as in adult case 3. Surgical or transcatheter removal of the coils may rarely be indicated.

**Conclusion**

The outcome of coil occlusion for a PDA >3 mm in children depends on the technical difficulty of deploying the coil. Once the coil is successfully deployed, late complications such as hemolysis, delayed migration, recanalization or left PA stenosis are unlikely in this age group. In adults with a sclerotic PDA with calcification, hemolysis is a common complication, even when the residual leak is tiny. It sometimes recovers spontaneously after late complete occlusion; however, additional coil deployment may be required in some patients.
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References