# Transcatheter Coil Occlusion of Patent Ductus Arteriosus

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**Abstract**

Between May 1995 and October 1997, 17 cases of small patent ductus arteriosus (PDA) underwent percutaneous coil occlusion at the Department of Pediatrics, Chulalongkorn Hospital. The mean age was 5.3 ± 3.6 years (range, 1 year 4 months to 12.0 years); mean weight was 18.9 ± 11.7 kg (range, 9 to 48 kg). The mean minimum diameter of the PDA was 2.8 ± 0.6 mm (range, 1.7 to 4.0 mm). PDA occlusion was achieved with one coil in 9 patients and two coils in 8 patients. One patient required the second coil occlusion procedure to occlude the residual PDA leakage. Of the 17 patients, coils were successfully implanted in 15 patients; complete closure of PDA was obtained in 14 patients, confirmed by aortography or by color flow echo imaging or both. In the two unsuccessful coil implantation cases, coils migrated to the distal left pulmonary artery (1 case) and the distal right pulmonary artery (1 case). They could not be retrieved. Both patients had surgical closure of PDA on the following day after the failed procedure. No clinical and chest X-ray showed any evidence of pulmonary complication from the migrated coils up to 1-year follow-up.

PDA coil occlusion provides an alternative to surgical closure. The procedure is safe and has a good result.

**Key word :** Coil Occlusion, Patent Ductus Arteriosus

Patent ductus arteriosus (PDA) occurs in 9 per cent to 12 per cent of patients with congenital heart disease[1]. Hemodynamic consequence includes left to right shunt from aorta to pulmonary artery via PDA causing volume loading to the pulmonary vascular bed, left atrium and left ventricle which may lead to congestive heart failure and pulmonary hypertension in moderate to large PDA.

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Small PDA may cause no symptoms. All PDAs may be complicated by infective endocarditis with a risk as high as 0.45 per cent per year[2], so closure of PDA is recommended in all PDAs that have no irreversible pulmonary vascular disease. In 1939, Gross and Hubbard reported the first successful case of surgical PDA ligation[3]. PDA is not only the first congenital cardiac lesion that was corrected surgically, but it is also one of the first to be corrected nonsurgically which was reported in 1971 by Porstmann et al using Ivalon plug[4]. Several devices designed to occlude PDA have been developed over the past three decades after Porstmann Ivalon plug. These include Rashkind PDA umbrella device,[5,6] Sideris adjustable button device,[7] Botallooccluder device[8] and coil occlusion device [9]. We began our first case of nonsurgical closure of PDA using Gianturco coil in May 1995. This report describes our experience of coil occlusion of PDA using Gianturco coil and Cook detachable coil in 17 patients.

## PATIENTS AND METHOD

Between May 1995 and October 1997, 17 patients with small PDA diagnosed by physical examination, two-dimensional echocardiography and color flow imaging studies underwent cardiac catheterization to have coil occlusion of PDA.

**Technique.** The patients received a combination of intravenous midazolam and morphine for sedation. Conventional right and left heart catheterization were performed to assess hemodynamics. Heparin (30-50 U/kg) was administered intravenously. An aortogram was obtained in the anteroposterior and lateral views. The minimum diameter of the PDA was measured in the lateral projection. A 5F end-hole multipurpose catheter used for coil loading was advanced from the femoral artery to the descending aorta and across the PDA to the pulmonary artery.

In the Gianturco coil case, the coil was loaded and advanced through the multipurpose catheter with a 0.038 inch guide wire. It was deployed by extruding one loop of coil through the catheter into the pulmonary artery, withdrawing the extruded loop to the pulmonary orifice of the duct and then withdrawing the catheter to deposit the remaining loops inside the duct and in the aortic ampulla (Fig. 1).

In the detachable PDA coil case, if one coil was used, the coil was rotated clockwise to connect it to the delivery wire. The coil connected to the delivery wire was loaded and advanced through the multipurpose catheter, and was delivered in the same way as that of the Gianturco coil. If two coils were used, the second coil was delivered through another multipurpose catheter that was advanced from the femoral vein to the right heart and passed from the pulmonary artery through PDA to the descending aorta. Two to three loops of the coil were extruded through the catheter in the descending aorta. The whole catheter with the coil partly extruded was withdrawn into the ampulla of the duct and the remaining loop was then released on the pulmonary side of the duct. After the satisfactory position of the coils was achieved, the coils were detached by making several anti-clockwise turns to the delivery wire (Fig. 2).

Fifteen minutes after the coil deployment, an aortogram was performed to evaluate the result.

Cefazolin 50 mg/kg was administered intravenously during the procedure and followed by 25 mg/kg, six hours later.

**Follow-up.** Chest X-ray, two-dimensional echocardiographic study and color-flow mapping were performed within 24 hours after the procedure. Subsequently echocardiographic assessments were studied at one, three and six months later.

## RESULTS

Of the 17 patients, there were 5 boys and 12 girls. Age at the time of the procedure ranged from 1 year 4 months to 12 years (mean 5.3 $\pm$ 3.6 years), and weight ranged from 9.0 to 48.0 kg (mean 18.9 $\pm$ 11.7 kg). The minimum diameter of PDA ranged from 1.7 to 4.0 mm (mean 2.8 $\pm$ 0.6 mm) (Table1). Patient 11 also had an associated moderate valvular pulmonary stenosis (with pressure gradient across the pulmonary valve of 49 mmHg) which was treated by balloon pulmonary valvuloplasty in the same cardiac catheterization.

**Type of Coils.** Gianturco 0.038-inch stainless steel fibre coils, 5 mm in helical diameter and 5 cm in length were deployed in the first 4 cases and patient 11. One coil was used in each case except patient 2 in whom a Gianturco coil was deployed in the first catherization and a detachable PDA coil, 5 mm in diameter with 5 loops was deployed ten months later to occlude the residual leakage. Detachable PDA coils of 0.038-inch wire diameter were used in the remainings of the 17 cases (patient 5-17, except 11). One coil was deployed in patients 5,6,7,

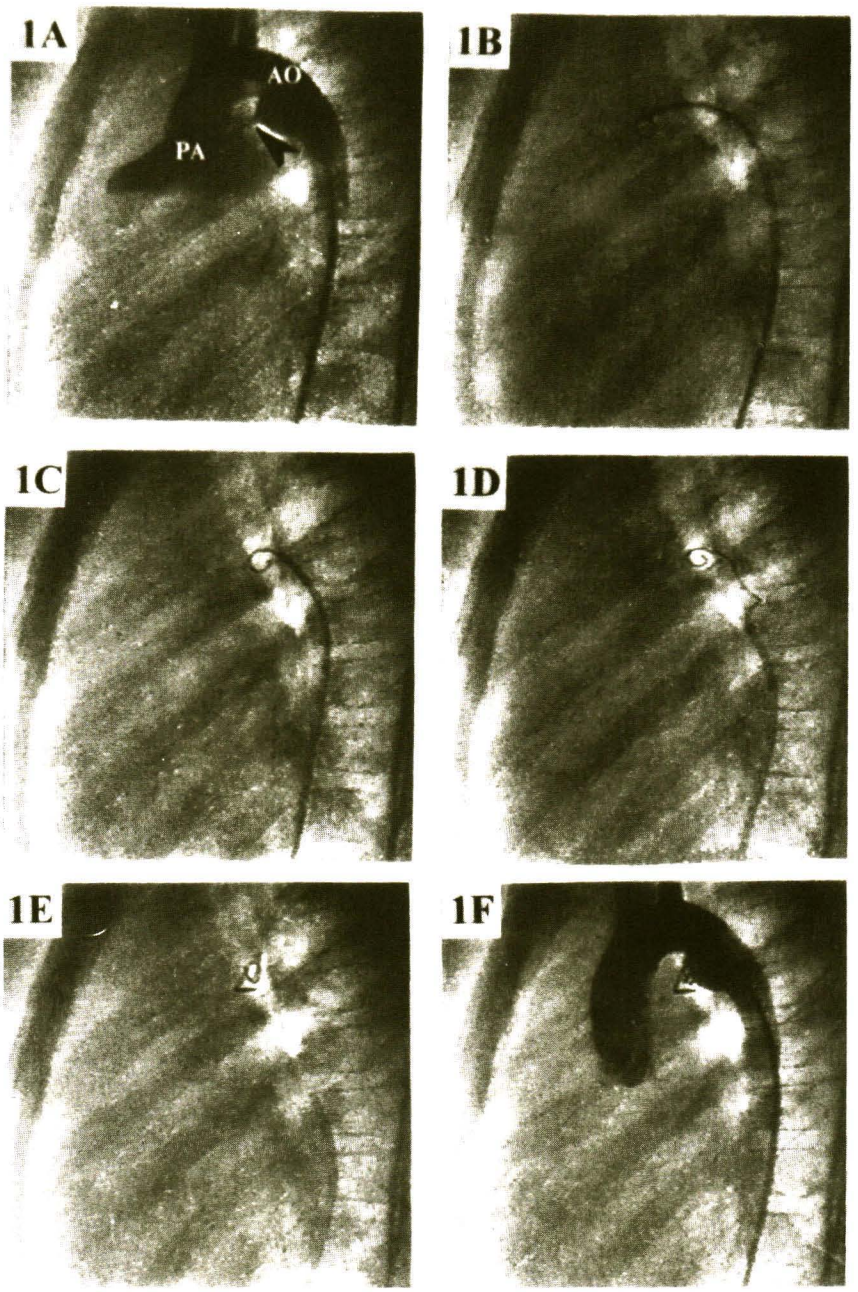


Fig. 1. Lateral cineangiographic frames demonstrate the sequence of steps in transcatheter occlusion of PDA with a 5-cm length, 5-mm helical diameter Gianturco coil in patient 1. 1A, Lateral aortogram shows left to right shunt from aorta (AO) to pulmonary artery (PA) through PDA (arrow head). 1B, A full loop of coil was pushed by using guide wire through the tip of end-hole catheter which was advanced from aorta through PDA into the main pulmonary artery. 1C, The catheter was pulled back until the extruded loop of the coil was observed being resisted by the pulmonary end of PDA. 1D and 1E, The catheter was further pulled back causing the remainder of the coil to be pushed out and completely deployed into the PDA. 1F, Repeated lateral aortogram after coil delivery reveals complete occlusion of PDA.

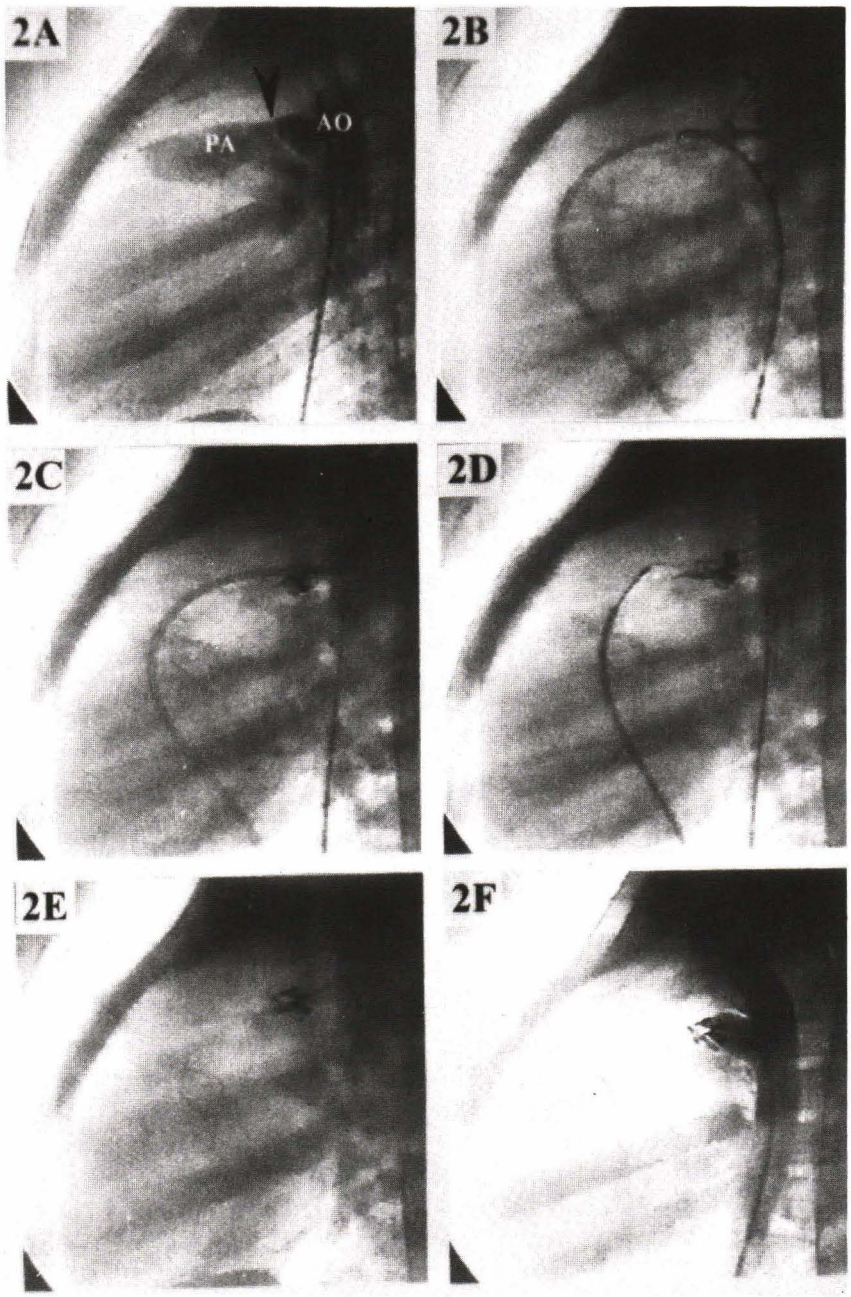


Fig. 2. Lateral cineangiographic frames demonstrate sequence of steps in coil occlusion of PDA using 2 detachable coils (5-mm in diameter with 5 loops) in patient 9. 2A, Lateral aortogram reveals left to right shunt from aorta (AO) to pulmonary artery (PA) through PDA (arrow head). 2B, Two end-hole catheters were advanced through PDA, the first one from AO to PA and the second one from PA to AO. The first loop of coil was extruded from the tip of the first catheter. 2C, The first coil was completely delivered from the first catheter while still connected to the delivery wire. 2D, The second coil was completely delivered from the second catheter while still connected to the delivery wire. 2E, After the coils were in satisfactory position, both coils were disconnected from the delivery wires. 2F, Repeated lateral aortogram after coil delivery reveals complete occlusion of PDA.

**Table 1. Summary of the patient characteristics and results.**

| Patient No. | Age (yr) | Wt (kg) | PDA (mm) | Coils | Results Within 24 hours | Last F/U |
|---|---|---|---|---|---|---|
| 1 | 6 | 15.5 | 2.5 | 5-5* | complete | complete |
| 2 | 2 | 9 | 3.0 | 5-5* | incomplete | complete |
| | | | | 5x5# | incomplete | |
| 3 | 4 | 15 | 2.9 | 5-5* | fail@ | fail@ |
| 4 | 9 | 21 | 2.7 | 5-5* | complete | complete |
| 5 | 12 | 45 | 2.7 | 5x5# | incomplete | complete |
| 6 | 2 | 11.5 | 1.7 | 5x5# | complete | complete |
| 7 | 2 | 12 | 2.8 | 5x5# | fail@ | fail@ |
| 8 | 3 | 13 | 2.2 | 5x5# | incomplete | incomplete |
| 9 | 1.8 | 9 | 2.8 | 5x5#, 5x5# | complete | complete |
| 10 | 3 | 14 | 1.9 | 5x5# | complete | complete |
| 11 | 3 | 15 | 1.8 | 5-5* | complete | complete |
| 12 | 5 | 13 | 3.3 | 5x5#, 5x5# | complete | complete |
| 13 | 1.4 | 8.5 | 2.6 | 5x5#, 5x3# | complete | complete |
| 14 | 10 | 29 | 3.6 | 8x4#, 8x4# | complete | complete |
| 15 | 6 | 20 | 3.2 | 8x4#, 8x4# | complete | complete |
| 16 | 11 | 48 | 4.0 | 8x4#, 8x5# | complete | complete |
| 17 | 9 | 23 | 3.0 | 8x4#, 5x5# | complete | complete |

Wt, weight; PDA, minimum PDA diameter; F/U, follow-up; Coils, type of coils;
* Gianturco coil: diameter of coil (mm) - length of coil (cm).
\# Detachable coil: diameter of coil (mm) x number of loops.
@ The coil was migrated into the distal pulmonary artery.

8,10 and two coils were deployed in the other cases (patient 9, 12-17) (Table 1).

Fifteen patients had successful implantation with one or two coils. Two patients with unsuccessful coil placement will be described later.

Twelve of 15 patients with successful coil implantation had complete closure of PDA within 24 hours after the procedure, confirmed by aortogram and color flow echocardiography. This results in an immediate success rate of 70.6 per cent (12/17 cases). Patients 2, 5 and 8 had a residual leak demonstrated by both aortogram (15 minutes after coil occlusion) and color flow study on the day after catheterization. Patient 2 whose PDA diameter was 3 mm, had PDA closure with one Gianturco coil. There was residual PDA leak at the 6-month follow-up study; the patient still had a grade II/VI continuous murmur and color flow study of PDA. Ten months later, she underwent a second cardiac catheterization; from which, mild left pulmonary artery stenosis was found with a pressure gradient of 15 mmHg due to inappropriate placement of the first coil. Second PDA coil occlusion was attempted with a detachable coil. There was no residual leakage at 3-month follow-up study after the second catheterization. Patient 5 had complete closure of PDA demonstrated by color flow study at 3-month follow-up. Patient 8 still had a grade I-II/VI systolic ejection murmur over the upper left sternal border on auscultation and a tiny PDA leakage demonstrated by color flow study at 1-year follow-up. This results in a success rate of 82.4 per cent (14/17 cases).

Two patients (patients 3,7) had coil migration after coil implantation. Patient 3 who had PDA with minimum diameter of 2.9 mm, underwent PDA closure by using one Gianturco coil. The coil migrated to the distal left pulmonary artery immediately after it was completely delivered through the catheter. Patient 7 who had PDA minimum diameter of 2.8 mm, was attempted to have PDA closure with one detachable coil (5 mm in diameter with 5 loops). The coil was in a satisfactory position before it was detached from the delivery wire. Five minutes after detachment, it migrated to the distal right pulmonary artery. Retrieval of the migrated coil was unsuccessful in both patients. Both of them had an operation for PDA division and suture on the

day after cardiac catheterization. No evidence of pulmonary infarction was detected by physical examination and chest X-ray up to 1-year follow-up.

**Follow-up.** There was no flow through the PDA by echocardiography in all patients except patient 8 at a mean follow-up of 13.1±7.7 months (range, 6 to 29 months). Patient 2 still had mild left pulmonary artery stenosis with a pressure gradient of 16 mmHg by Doppler echocardiography at the 24-month follow-up.

## DISCUSSION

Coil occlusion of a small PDA with minimum diameter of < 2.5 mm was first reported in 1992 by Cambier et al[9]. After that, there were reports about PDA coil occlusion using one or more than one coil with good results[10-16]. The outcome of 523 patients from the 38-center PDA registry included 75 per cent complete occlusion within 24 hours after the procedure, 5 per cent failure to implant coil, 94.3 per cent complete occlusion at the mean follow-up of 8.1±7.8 months and 2.7 per cent requiring a repeated coil occlusion procedure[17,18].

Of our 17 cases, we had 15 successfully implanted cases. Complete occlusion within 24 hours after procedure occurred in 70.6 per cent (12/17 cases). At the mean follow-up of 13.1±7.7 months, we had 82.4 per cent (14/17 cases) complete occlusion (one case required the second coil occlusion procedure). Due to our learning curve, we had 2 failure results in our early cases (patients 3,7). In patient 2 who had mild left pulmonary artery stenosis, the aortogram in the second catheterization demonstrated that nearly two and a half loops of coil had protruded in the pulmonary artery. This explains the cause of mild left pulmonary artery stenosis. After using detachable coils for a few cases, we had technical improvement in coil implantation to have satisfactory position and alignment of coil and used 2 detachable coils in our later cases who had minimum PDA diameter > 2.5 mm (patients 9-17); all had complete occlusion within 24 hours. According to the migrated coil that was left in the distal pulmonary artery, we did not find any pulmonary complications on follow-up, as in previous reports[11,14,16].

In conclusion, our result suggests that coil occlusion provides an alternative to surgical closure of small PDA. The procedure is uncomplicated and safe. The complete occlusion can be achieved by careful selection of cases (minimum PDA diameter < 4 mm), appropriate size, type and number of coils, and technical experience to have a good position and alignment of coils.

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## การปิด Patent Ductus Arteriosus โดยใช้ขดลวดผ่านทางสายสวนหัวใจ

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ได้ทำการศึกษาถึงผลของการปิด patent ductus arteriosus (PDA) โดยใช้ขดลวดผ่านทางสายสวนหัวใจ ระหว่างเดือนพฤษภาคม พ.ศ. 2538 ถึงเดือนตุลาคม พ.ศ. 2540 มีผู้ป่วยที่ได้รับการวินิจฉัยว่าเป็น PDA ขนาดเล็กและได้รับการปิด PDA โดยใช้ขดลวดจำนวน 17 ราย เป็นเด็กชาย 5 ราย และเด็กหญิง 12 ราย มีอายุตั้งแต่ 1 ปี 4 เดือน ถึง 12 ปี (เฉลี่ย 5.3±3.6 ปี) น้ำหนักตั้งแต่ 9 ถึง 48 กิโลกรัม (เฉลี่ย 18.9±11.7 กิโลกรัม) เส้นผ่าศูนย์กลางของ PDA มีขนาดตั้งแต่ 1.7 ถึง 4.0 มิลลิเมตร (เฉลี่ย 2.8±0.6 มิลลิเมตร) ผู้ป่วย 9 รายได้รับการปิด PDA โดยใช้ขดลวด 1 ขด และ 8 รายได้รับการปิด PDA โดยใช้ขดลวด 2 ขด มี 1 รายได้รับการใส่ขดลวดเพื่อปิด PDA 2 ครั้งเนื่องจากพบว่า PDA ยังปิดไม่สนิทหลังการทำครั้งแรก ผลการศึกษาพบว่าผู้ป่วย 15 ใน 17 รายได้รับการใส่ขดลวดตรงตำแหน่ง PDA เป็นผลสำเร็จ การตรวจโดยการฉีดสารทึบรังสี aortography และ/หรือ การตรวจด้วย color flow echocardiography พบว่าการใส่ขดลวดปิด PDA สามารถทำให้ PDA ปิดสนิทในผู้ป่วย 14 ราย มีผู้ป่วย 2 ราย ประสบความล้มเหลวในการใส่ขดลวดตรงตำแหน่ง PDA และหลุดไปอยู่ในหลอดเลือดพุลโมนารีย์ส่วนปลาย ทั้ง 2 รายได้รับการทำผ่าตัดปิด PDA ในวันต่อมา จากการติดตามเป็นเวลาอย่างน้อย 1 ปี พบว่าผู้ป่วยทั้ง 2 รายไม่มีอาการผิดปกติหรือภาวะแทรกซ้อนทางปอดจากการที่ขดลวดหลุดไปอยู่ในหลอดเลือดพุลโมนารีย์ส่วนปลาย

การปิด PDA โดยใช้ขดลวดผ่านทางสายสวนหัวใจเป็นวิธีการรักษาอีกวิธีหนึ่งนอกจากการผ่าตัดปิด PDA, มีความปลอดภัย และได้ผลดี

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