

Transarterial occlusion of patent ductus arteriosus with Gianturco coils in pediatric patients: a preliminary result in central Taiwan

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Received 5 November 1998; accepted 22 December 1998

Abstract

Objective: We wish to present the preliminary result of transarterial occlusion of patent ductus arteriosus (PDA) with Gianturco coils in pediatric patients in central Taiwan. **Materials and Methods:** We attempted occlusion of PDA with Gianturco coils in a total of 26 consecutive patients, 13 infants and 13 children, 23 female and three male, between July 1 1997 to September 30 1998. Median patient age was 2.57 years (from 0.25 to 14.02 years old). Median patient weight was 10.8 kg (4.0 to 36.0 kg). Premature babies with PDA, full-term babies who were less than three months old and patients who had other congenital heart disease were not included in this study. All PDAs were approached transarterially from the femoral artery. Coils were selected to provide a helical diameter that was twice or more the minimum ductus diameter and a length approximating five loops. In five patients who had a PDA diameter ≥ 3.5 mm, we used a snare technique to assist coil delivery beforehand, and to test coil stability, or to retrieve coil that had migrated to the pulmonary artery afterwards. Physical auscultation, chest radiographs and echocardiography with color Doppler were done in all patients within 24 h, and one, two, three, six and 12 months after coil occlusion. **Results.** The median ductus minimum diameter was 2.3 mm (range, 1.0 to 4.7 mm). Fifteen patients had the megaphone type (type A), four had the window type (type B), five had the tubular type (type C), one had the aneurysmal type (type D) and one had the elongated conical type (type E). Twenty-one patients underwent single coil occlusion and five had multiple coils occlusion. Twenty-one patients had immediate angiographic closure of the ductus and disappearance of heart murmur at 15 min after the procedure. Dark-brown urine (hemoglobinuria) was found in one patient, 10 h after the first procedure, due to a mild residual ductal shunt. Two more coils were implanted in a second procedure that was performed within 24 h, and the ductus was completely occluded. The dark-brown urine regressed. At one month follow-up, four patients had mild residual ductal shunts, which were completely occluded by one more coil in three patients and by two more coils in the other patient. Malpositioned coils were deployed in five patients immediately after the procedure. In total, the closure rate at 15 min, within 24 h, and at one, two, three, six and 12 months were 81, 85, 85, 100, 100, 100 and 100%, respectively. In one year of follow-up, there was no instance of coil migration, ductus reopening or stenosis of the left pulmonary artery. **Conclusions.** Transarterial occlusion of PDA, with a Gianturco coil having approximately five loops, can be effectively achieved in patients with a minimum ductus diameter up to 4.7 mm. In patients with a ductus of more than 3.5 mm, the snare-assisted technique was employed advantageously to control coil delivery with accuracy and stability. Coil malposition or migration can be easily retrieved using a 10-mm Nitinol snare catheter. Hemoglobinuria, due to intravascular hemolysis, may regress within 24 h after the second attempt at coil implantation. © 1999 Elsevier Science Ireland Ltd. All rights reserved.

Keywords: Transarterial occlusion; Patent ductus arteriosus; Gianturco coil

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1. Introduction

Gianturco coils were originally designed more than two decades ago for renal artery occlusion [1,2]. Since then, there have been reports on the transcatheter closure of patent ductus arteriosus (PDA) using Gianturco coils (Cook Inc.), which has become increasingly popular by virtue of its smaller and easier delivery system, high rate of complete occlusion, low rate of complications and low cost [3–11]. We report our clinical experience about percutaneous transarterial occlusion of PDA with Gianturco coils.

2. Materials and methods

2.1. Patients

From July 1 1997 to September 30 1998, a total of 26 patients (13 infants and 13 children, 23 female and three male) underwent cardiac catheterization and attempted occlusion of their PDA with Gianturco coils (Cook Inc.). Their ages ranged from 0.25 to 14.02 years (median, 2.57 years) and their weights ranged from 4.0 to 36.0 kg (median, 10.8 kg). PDA in premature babies, in full-term babies less than three months old and in patients who had other congenital heart disease for which surgery was indicated were excluded from the study. Two patients had Down's syndrome, which was proved by a chromosomal study. One patient had congenital rubella syndrome. Fourteen patients had overt clinical manifestations of congestive heart failure and a characteristic continuous murmur due to PDA. Twelve patients had a faint systolic murmur of a small PDA, which was only detected by color flow mapping. Informed written consent was obtained from the parents of all of the patients before the procedure was carried out. Complete blood counts, electrolytes, electrocardiograms, plain chest films, bleeding time, prothrombin time and activated partial thromboplastin time were determined/performed for all patients beforehand. No antibiotic was administered before or after the procedure to any of patients.

2.2. Procedure

After standard cardiac catheterization, using a 5F

or 6F Berman catheter (Arrow), the pulmonary-to-systemic flow ratio (Q_p/Q_s) was calculated from oxygen saturation levels. With the side hole Berman catheter near the ductus, right anterior oblique (RAO) 30° and lateral projections of descending aortography were obtained. The PDAs were morphologically classified, according to the method of Krichenko et al. [12].

The minimum diameter and the length of the PDA were determined according to Daniels et al. [13]. We used a 5.2F Judkins Right 3.5 coronary catheter (Cordis) as the delivery system, as it can easily pass through a standard 5F intravascular sheath. In patients with a small PDA (<2.5 mm), we employed a 5F Berenstein catheter (MediTech) as the delivery system, instead. Gianturco coils, of a 0.038 in. (0.096 cm) modality (Cook Inc.), were selected to provide a helical diameter that was at least twice that of the minimum diameter of the ductus [4], and a length was approximately five loops [11]. The Gianturco coil was pushed through the catheter with a standard 0.038 in. (0.096 cm) straight guide wire (Cook Inc. or USCI). The whole course of delivery was monitored by right anterior oblique (RAO) 30° and lateral fluoroscopy. The coil was initially pushed into the main pulmonary artery but with one loop extruded from the delivery system. The delivery catheter was subsequently pulled back, with the tracheal air shadow as a landmark on the reference lateral aortography, until the extruded loop of coil was observed being impinged upon the pulmonary end of the PDA. Then, the delivery catheter was pulled across the ductus into the aorta and the remaining length of coil was pushed out into the aortic ampulla of the ductus smoothly. In patients with a PDA diameter ≥ 3.5 mm, we used the snare technique (Microvena, White Bear Lake, MN, USA) to control coil delivery beforehand, and to test coil stability, or to retrieve migrated coil in the pulmonary artery afterwards [14]. A 15-min delay descending aortography was performed to grade any residual shunt after deployment of the coil. The severity of the shunt was assessed quantitatively from the cine-aortography according to Lloyd et al. [4]. More coil(s) was (were) added if a small or mild left-to-right shunt was visualized. After the implantation, we recorded pull-back pressure tracings from the left pulmonary artery to the main pulmonary trunk to assess the stenosis of

the left pulmonary artery. If coil protrusion into the left pulmonary artery was suspected after implantation, a main pulmonary arteriography (15° left anterior oblique and 30° cranial) was done to visualize the main and branch pulmonary artery. Physical auscultation was performed to document loss of the continuous murmur. Chest radiographs and two-dimensional echocardiography with color Doppler were performed on all patients within 24 h of PDA occlusion, to confirm the proper lie of the coil and to determine the presence or absence of a PDA shunt. All patients in the study were evaluated by chest auscultation, chest radiographs and echocardiography with color Doppler within 24 h, and at one, two, three, six and 12 months after PDA coil occlusion.

2.3. Coil retrieval

Malpositioned coils were retrieved through the femoral vein using a 6F sheath (Cook Inc.), 5Fr Berenstein catheter and a 10-mm Nitinol snare (Micro Vena), due to coil protrusion into the descending aorta and the left pulmonary artery, and distal migration of coil into the left pulmonary artery.

2.3.1. Follow-up

After the procedure, physical auscultation was performed to document loss of the continuous murmur. Chest radiographs and echocardiography with color Doppler were carried out for all patients within 24 h of PDA occlusion to confirm the proper lie of the coil and to determine the presence or absence of a PDA shunt. All patients were discharged from the hospital the next day. Outpatient follow-up was at one, two, three, six and 12 months after coil occlusion. On each visit, all patients had chest auscultation, chest radiographs and Doppler echocardiography carried out.

3. Results

Clinical profiles of the 26 patients are listed in Table 1. The median PDA diameter was 2.3 mm (range, 1.0 to 4.7 mm). Fifteen patients had the

megaphone type (type A), four had the window type (type B), five had the tubular type (type C), one had the aneurysmal type (type D) and one had the elongated conical type (type E), according to the angiographic classification described by Krichenko et al. [12]. Twenty-one patients underwent single coil occlusion and five had multiple coils occlusion (see Figs. 1 and 2). All PDAs were approached retrogradely through the femoral artery. Twenty-one patients had immediate angiographic closure of the ductus and loss of heart murmur at 15 min after the procedure. Patient 13 had dark-brown urine (hemoglobinuria) due to a mild residual ductal shunt, which was detected at 10 h after the procedure. Two more coils were implanted in a second procedure. The ductus was completely occluded, which was documented by a delayed angiography and by color echocardiography with Doppler within 24 h. The dark-brown urine regressed within 24 h. Mild residual ductal shunts were detected in four patients (numbers 5, 15, 19 and 23) by color Doppler at 24 h and at one month follow-up. These mild residual ductal shunts were totally occluded by one more coil in patients 5, 19 and 23, and by two more coils in patient 15, in a second procedure at one month. Malpositioned coils were retrieved in five patients immediately after the procedure. Malpositioning was due to distal migration of coils to the left pulmonary artery in patients 2 and 17, coil protrusion into the descending aorta in patient 13, coil protrusion into the left pulmonary artery in patient 15 and, in patient 25, the coil was dislodged at the junction of the internal and external iliac arteries. In patient 15, the retrieved coil became dislodged, from the snare catheter, in the inguinal subcutaneous tissue and required femoral cutdown to complete the retrieval. In patient 25, the retrieved coil, which was dislodged from the snare catheter, was removed by surgery. In total, the complete closure rates at 15 min, within 24 h, and at one, two, three, six and 12 months were 81, 85, 85, 100, 100, 100 and 100%, respectively. Our data showed successful coil occlusion for PDA in 26 pediatric patients. There was no instance of destructive hemolysis, coil malposition, coil migration, stenosis in the proximal pulmonary artery or at the aortic arch, and ductus reopening in the follow-ups. Neither endocarditis nor endarteritis occurred. In our experience, neither absolute ductus size nor ductus

Table 1
Profiles of 26 patients with PDA who underwent transarterial Gianturco coil occlusion

Number	Age/weight/sex (years/kg/M,F)	PDA type/size (mm)	sPA (mm Hg)	Coil size* (in.–cm–mm)	Q_p/Q_s B/A	Results		
						15 min	<24 h	Month
1	2.94/13.0/F	A/1.0	25	0.038–5–3	1.1/1.0	NS	NS	NS (12)
2	6.25/16.0/F	A/3.0	31	0.038–8–5	4.2/1.0	NS	NS	NS (12)
3	4.00/12.0/F	B/1.0	25	0.038–5–3	1.1/1.0	NS	NS	NS (11)
4	0.50/6.0/F	A/2.0	26	0.038–8–5	1.3/1.0	NS	NS	NS (11)
5	0.61/4.4/F	C/2.2	45	0.038–8–5	3.3/1.4	MS	MS	
6	0.42/8.9/F	A/2.2	27	0.038–8–5	1.4/1.0			NS (11)
7	0.58/7.1/F	C/2.5	29	0.038–8–5	1.3/1.0	NS	NS	NS (11)
8	0.25/5.4/M	A/2.5	28	0.038–8–5	1.7/1.0	NS	NS	NS (10)
9	0.25/4.0/F	A/2.5	28	0.038–8–5	1.8/1.0	NS	NS	NS (10)
9	0.25/4.0/F	C/3.7	45	0.038–10–8	3.4/1.0	NS	NS	NS (9)
10	4.25/15.0/F	E/2.2	25	0.038–8–5	1.5/1.0	NS	NS	NS (9)
11	1.08/9.3/F	A/1.8	28	0.038–6–4	1.1/1.0	NS	NS	NS (8)
12	0.50/8.2/F	A/2.3	24	0.038–8–5	1.5/1.0	NS	NS	NS (8)
13 ^a	0.33/4.5/F	A/3.8	40	0.038–11–7	2.6/1.6	MS		
				0.038–8–5 ^a				
				0.038–6–4a	1.6/1.0		NS ^a	NS (7)
14	1.25/7.1/F	A/1.7	29	0.038–6–4	1.3/1.0	NS	NS	NS(6)
15 ^b	1.58/8.0/F	C/4.2	33	0.038–15–10				
				0.038–8–5	3.0/1.3	MS	MS	
				0.038–8–5 ^b				
				0.038–6–4 ^b	1.3/1.0			NS ^b (6)
16	0.50/6.7/F	A/1.2	17	0.038–5–3	1.1/1.0	NS	NS	NS (6)
17 ^c	0.25/4.2/F	D/2.5	51	0.038–11–7	1.8/1.0	NS	NS	NS (6)
18	5.47/20.5/F	A/1.5	22	0.038–5–3	1.1/1.0	NS	NS	NS (5)
19	5.02/17.0/M	A/3.8	20	0.038–11–7	1.9/1.3	MS	MS	
				0.038–5–3	1.3/1.0			NS (4)
20 ^d	1.00/7.9/M	B/1.0	27	0.038–5–3	1.1/1.0	NS	NS	NS (4)
21	3.55/19.0/F	A/1.2	26	0.038–6–4	1.2/1.0	NS	NS	NS (4)
22	1.27/9.2/F	A/3.2	17	0.038–11–7	3.1/1.0	NS	NS	NS (2)
23	14.02/36.0/F	A/4.7	13	0.038–15–10	2.0/1.5	MS	MS	
				0.038–8–5	1.5/1.0			NS (2)
24	0.58/7.3/F	B/1.2	23	0.038–5–3	1.1/1.0	NS	NS	NS (1)
25 ^e	0.59/5.8/F	C/1.5	47	0.038–6–4	1.3/1.0	NS	NS	NS (1)
26	9.81/26.0/F	B/1.2	17	0.038–5–3	1.1/1.0	NS	NS	NS (1)

MS, mild shunt; NS, no shunt; PDA, patent ductus arteriosus; Q_p/Q_s B/A, pulmonary-to-systemic flow ratio before/after occlusion procedure; sPA, systolic pressure of main pulmonary artery.

*Coil size: wire gauge (in.)–length (cm)–helical diameter (mm).

^aAt 10 h after initial coil embolization, patient 13 had dark-brown urine (hemoglobinuria) due to a mild residual ductal shunt, which underwent complete occlusion when two more coils (0.038–8–5, 0.038–6–4) were implanted at subsequent cardiac catheterization within 24 h.

^bPatient 15 had complete occlusion of the ductus at one month, when two more coils (0.038–8–5, 0.038–5–3) were placed at subsequent cardiac catheterization.

^cPatient 17 was a Down's baby with a type D ductus and tracheo-esophageal fistula.

^dPatient 20 had suffered from complete atrioventricular block at three months of age, when a permanent pacemaker of the VVIR type was implanted subcutaneously.

^ePatient 25 was a victim of congenital rubella syndrome, which was associated with peripheral pulmonary stenosis, with a pressure gradient of 34 mmHg between the main pulmonary trunk and branch pulmonary arteries.

shape influenced success. However, the limitations of our study included a retrospective study of small sample size with only five patients having a large ductus (≥ 3.5 mm), and a follow-up period of one year.

4. Discussion

Since 1992, there were many reports concerning the excellent results of transcatheter closure of PDA with Gianturco coils [3–11]. We had a complete

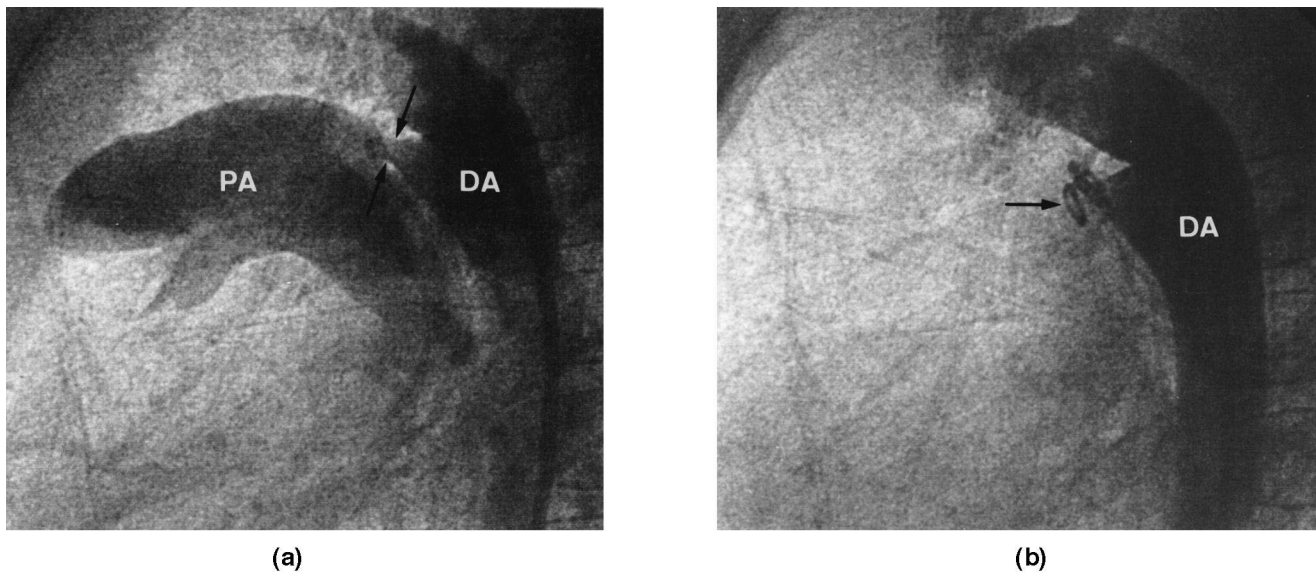


Fig. 1. Transarterial occlusion of patent ductus arteriosus with a single Gianturco coil. (A) The pre-occlusion descending aortography showed a patent ductus arteriosus that had a minimum diameter of 3 mm (black arrows) at the pulmonary end. (B) The post-occlusion angiography of the descending aorta showed complete occlusion of the ductus. Note that there is one loop of the coil (black arrow) outside the pulmonary end of the ductus. DA, descending aorta; PA, pulmonary artery.

closure rate of 85% at 24 h and at 1 month follow-ups, and of 100% at 2, 3, 6, and 12 months follow-ups. There were no instances of ductus reopening and

coil migration to the left pulmonary artery in the 1 year follow-up. We discuss the anatomic, hemodynamic and technical factors that may influence the successful closure rate.

4.1. Anatomic and hemodynamic factors

As we know, the larger ductus had the larger shunts, in which the presence of shear force may render possible a significant incidence of residual leak after coil embolization. PDA reopening, which is highly associated with wide-diameter/short-length PDA (type B PDA), may occur after successful coil occlusion [13]. Early thrombus formation may be involved in the early closure of the ductus [15]. As we can imagine, there will be a smaller and thinner thrombus formation in wide-diameter/short-length PDA (type B PDA). The thrombus would have less surface contact with a type B ductus, which may entail ductal reopening [13].

4.2. Delivery method

There was no difference in the complete closure rate of the ductus between the transarterial and

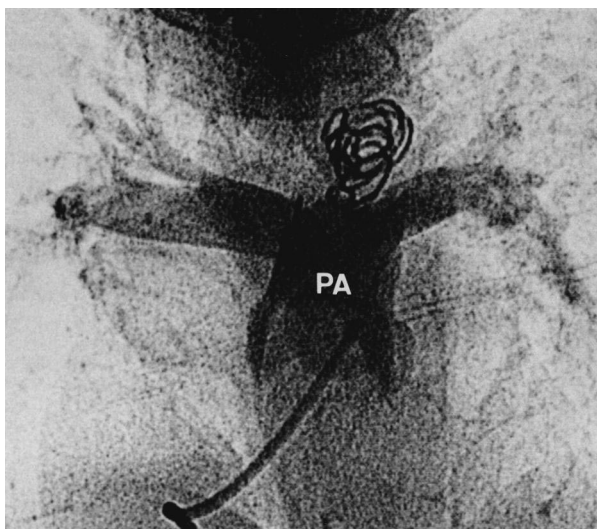


Fig. 2. Transarterial occlusion of patent ductus arteriosus with multiple Gianturco coils. There is no evidence of stenosis or obstruction of the branch pulmonary arteries in the main pulmonary arteriography (15° left anterior oblique and 30° cranial). PA, pulmonary artery.

transvenous delivery methods. Owada et al. [10] recommend the transvenous method for delivery of larger coils (0.052 in.), to optimize apposition to the ampulla in PDA ≥ 3.5 mm. We think that the transarterial approach would be more feasible in patients with a small residual shunt after surgery or with a small ductus [3,4]. It is also advantageous when more coils are needed for the residual shunt. Before pushing off the last loop of the intracatheter coil by the straight guidewire, we tried to minimize the intensity of coil spring to the ductal ampulla, by ascending the coil-housed catheter (Judkins or Berenstein) to compress the catheter gently against the coil in the ampulla (upstream-and-push), rather than just pushing off to let the remainder of the coil go below the ductus in the descending aorta (push-and-go). We think that this gentle upstream-and-push maneuver makes coil delivery smooth, and may be conducive for effective looping geometry of coil in the ductal ampulla. We used a snare-assisted technique in five patients with large PDA (≥ 3.5 mm), to hold and manipulate the coil as it was being delivered. We found that this technique improved both control of the coil and the accuracy of coil placement, as reported previously [14]. Transvenous delivery of coil may be another treatment of choice for larger ducti [16–18].

4.3. Coil geometry

The coils were ordered specially to provide about five loops. Following the modified guidelines set forth by Lloyd et al. [4], we found that the remaining four loops of coil stacked tightly in the ampulla well. In our experience and as found by others [11], five-loop Gianturco coils are effective, safe and capable of occluding PDAs. It was found that two and three more 0.038 in. coils were needed to occlude large PDAs (≥ 3.5 mm) in two of four patients. Owada et al. [10] have recommended the use of 0.052 in. coils, instead of 0.038 in. coils, to close large PDAs [10]. The application of these larger, stiffer coils, which have greater stability in large PDAs and have tightly stacked an enough height in the ductal ampulla, may lower the helical/minimum PDA diameter ratio to 1.7:1, minimize the risk of coil protrusion into the left pulmonary artery and descending aorta, and reduce

the number of coils needed for complete occlusion [10].

4.4. Complications

Major complications include coil migration to the pulmonary artery [4–6,9,10,16], stenosis of the pulmonary artery [6,9,10,17,20], reopening [13], endarteritis [19], hemolysis, hemoglobinuria and acquired coarctation of the aortic arch. In the one year follow-up of our patients, no significant complications occurred. Hemolysis or hemoglobinuria can be overcome by a second attempt at coil implantation within 24 h, as occurred for one of our patients.

5. Conclusions

In our experience, transarterial occlusion of PDAs, using Gianturco coils with a helical diameter twice or more the minimum ductus diameter and a length approximating five loops, can be safely and effectively achieved in patients with minimum ductus diameters up to 4.7 mm. In patients with ductus diameters ≥ 3.5 mm, a snare-assisted technique can be employed advantageously to control coil delivery with accuracy and stability. Malpositioned or migrated coils can be retrieved using a 10-mm Nitinol snare catheter. We think that the gentle upstream-and-push maneuver, which makes coil delivery smooth, may be conducive for effective tight stacking of coil loops in the ductal ampulla and for a high complete closure rate. There was no incidence of significant stenosis at the aortic arch or in the proximal pulmonary artery. Hemoglobinuria, due to intravascular hemolysis, may regress within 24 h after a second procedure of coil implantation.

Acknowledgements

We thank the personnel of the Laboratory of Cardiovascular Catheterization: Shu-Lin Chang, Li-Ping Hwang, Ruey-Wen Peng, Shu-Ching Theng, Yang-Chyuan Chern, Yea-Fang Wu, for their help and patience.

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