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TECHNIQUE

Transcatheter closure of large patent ductus arteriosus ($\geqslant$ 4 mm) with multiple Gianturco coils: immediate and mid-term results

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Abstract

***Objective*—To assess the immediate and mid-term results of transcatheter closure of patent ductus arteriosus (PDA) $\geqslant$ 4 mm with multiple Gianturco coils. (Transcatheter closure of large PDAs using the Rashkind occluder or the buttoned device is associated with a 7–38% incidence of residual shunt.)**

***Methods*—19 patients (7 male, 12 female) underwent an attempt at anterograde transcatheter closure with multiple Gianturco coils of a large PDA at a median age of 3·8 yr (range 2 weeks–34 yr) and median weight of 14 kg (range 2·3–80 kg).**

***Results*—The median PDA diameter at the narrowest segment was 4·3 mm (range 4–7 mm) and the mean (SD) Qp/Qs was 1·9 (0·8). Each patient had left atrial and left ventricular volume overload. A 4F catheter was used to deliver the coils in all patients. There was immediate and complete closure in 16/18; one patient had residual shunt that was closed at a second procedure and the other had spontaneous disappearance of the residual shunt at the six week visit. A short ductus (angiographic type B) in one patient could not be closed. The median number of coils placed at the first attempt to close the ductus was 4 (range 2–6 coils) and the median fluoroscopy time was 40 minutes (range 13–152 minutes). Mild left pulmonary artery stenosis occurred in the two smallest patients. Coil migration to the lung occurred in 3 patients with retrieval of coils in two patients. All procedures but one were done on an outpatient basis. At a median follow up of 1·6 yr (range 2 weeks–2·2 yr) all patients had complete closure with no new complications.**

***Conclusions*—Anterograde transcatheter closure with multiple Gianturco coils is an effective treatment for most patients with large PDA of diameters up to 7 mm. This technique can be performed in small infants on an outpatient basis without the need for general endotracheal anaesthesia.**

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Experience with transcatheter closure of large PDAs ($\geqslant$ 4 mm) using the Clamshell,[1] buttoned,[2] devices or Gianturco coils[3 4] is limited. We report our entire experience with transcatheter closure of large PDAs ($\geqslant$ 4 mm) using Gianturco coils.

Patients and methods

PATIENTS

From December 1993 to February 1996, 19 patients underwent an attempt at transcatheter closure of a large ($\geqslant$ 4 mm) PDA in our institution as an alternative to standard surgical ligation. Informed consent was obtained from all patients or their parents. All patients had clinical and echocardiographic findings of a PDA. The patients ages ranged from two weeks to 34 years. (median 3·8) and their weights ranged from 2·3 to 80 kg (median 14). All patients were asymptomatic except patients 8, 18, 19 who had pulmonary artery hypertension (mean 53, 42, 50 mm Hg respectively). All patients had evidence of left atrial and left ventricular volume overload. Patient 8 was a premature neonate (2·3 kg) with Down's syndrome, Hirschprung's disease, and colostomy. Patients 1 to 8 and patients 2, 8, and 9 have been included in previous reports (references 3 and 4 respectively).

METHODS

The protocol we follow has been reported previously.[3 4] Because we found that the initial coil was dislodged from the ductus when a second coil was being placed, we modified the protocol to deliver the first two coils simultaneously.[4] The figure demonstrates the steps of the protocol for multiple coil embolisation. The following are important points to remember about our technique. *(a)* Procedures are performed using a 4F sheath without heparin or general anaesthesia on an outpatient basis; *(b)* The anterograde approach is used to deliver all the coil(s) unless the ductus cannot be crossed anterogradely. If that limitation is encountered, retrograde closure is employed. *(c)* An attempt is always made to close the PDA completely while the patient is in the catheterisation laboratory. An echocardiogram

is performed to confirm closure before the procedure is terminated.

FOLLOW UP

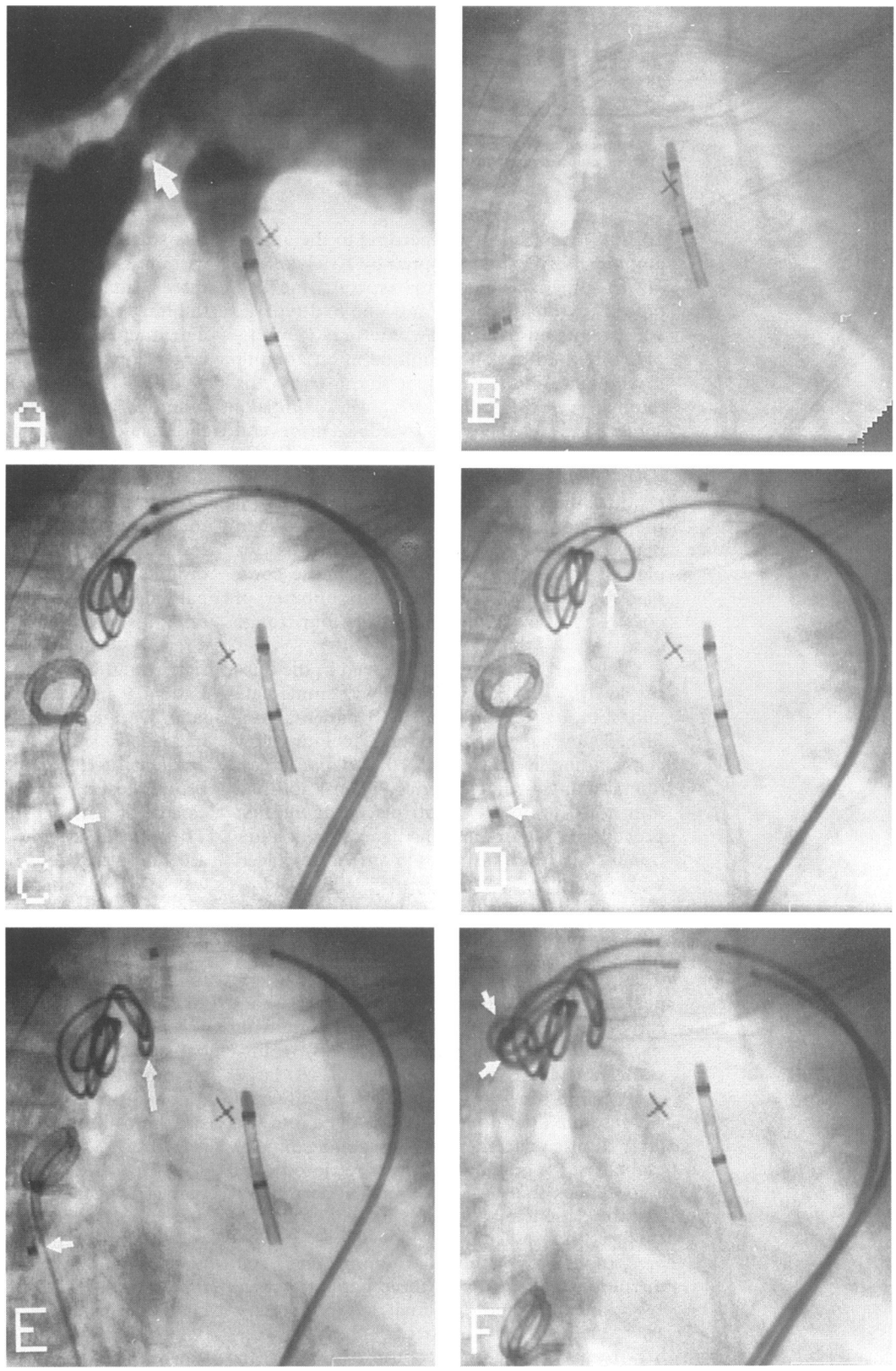
All patients underwent colour flow mapping and Doppler echocardiography before the sheath was removed, at six weeks follow up, and at one year follow up to assess flow across the coils, the left pulmonary artery, and descending aorta. All patients underwent chest radiography at six weeks post closure to assess coil position.

STATISTICAL ANALYSIS

Results are expressed as median or mean (SD). Pre and post embolisation variables in individual patients were compared by Student's*t* test for paired values. A P value of 0·05 was regarded as statistically significant.

Results

The table lists the clinical data in the 19 patients. The median PDA diameter was 4·3 mm (range 4–7 mm) and the mean Qp/Qs was



Still frames in the lateral projection showing the steps of multiple coil closure technique in a 13 month old, 8 kg infant. In all frames there is a piece of marker catheter (10 mm leading edge-to-leading edge) on the patient's chest. (A) An angiogram of the descending aorta shows a large PDA (5·7 mm in diameter) (arrow). (B) Three multipurpose 4F catheters (Microvena) crossing the PDA anterogradely to the descending aorta.

(C) The first two coils (0·038 inch, 8 mm × 8 cm) are being extruded from two catheters, while the third catheter (no coil) is still in the descending aorta (arrow). (D) The first coil is completely extruded while the second coil is not released yet.

(E) The second coil is completely extruded (long arrow), while the third catheter (no coil) is still in the descending aorta (short arrow). (F) Two catheters in the descending aorta have two loops (0·038 inch, 5 mm × 5 cm) from each coil opened just posterior to the first two coils (arrows).

Clinical data and results in patients who underwent an attempt at coil closure of patent ductus arteriosus

Case	Age (yr)	Weight (kg)	PDA d (mm)	Qp/Qs	PDA (type)	No of coils (mm × cm)	FT (min)	Result
1	10·3	40	4·3	1·5	A	3 (two 8 × 5, 5 × 5)	55	No S
2	0·5	7·6	4·3	1·8	B	—	82	F
3	0·7	10·3	4·0	1·3	A	3 (two 8 × 5, 5 × 5)	16	No S
4	1·7	10	4·2	1·6	E	3 (two 8 × 5, 5 × 5)	20	No S
5	4·0	16	4·0	1·5	A	3 (two 8 × 5, 5 × 5)	13	No S
6	3·8	13	4·0	1·3	A	3 (two 8 × 5, 5 × 5)	21	No S
7	2·0	14	4·0	1·4	A	4 (two 8 × 5, two 5 × 5)	25	No S
8	0·1	2·3	5·2	4·0	C	5 (three 8 × 5, two 5 × 5)	40	No S*
9	0·4	6·3	4·7	1·8	C	5 (two 8 × 5, three 5 × 5)	40	No S
10	6·4	30	7·0	1·6	A	4 (all 8 × 5)	15	SS
11	2·2	10·7	5·0	3·2	A	5 (three 4 × 6, 8 × 5, 5 × 5)	51	No S
12	7·6	23	4·0	1·9	A	4 (8 × 5, three 4 × 6)	22	No S
13	7·3	25	4·7	1·9	A	5 (four 8 × 5, 5 × 5)	84	No S
14	15·2	75	5·9	1·4	A	5 (two 8 × 8, three 8 × 5)	67	No S
15	11·7	42	4·0	1·5	A	3 (two 8 × 8, 5 × 5)	19	No S
16	34·1	80	4·7	2·1	A	5 (10 × 10, two 8 × 10, two 8 × 8)	57	No S
17	0·7	9·0	4·0	2·5	A	2 (8 × 10, 5 × 8)	152	SS
18	15·2	35	5·0	1·0	A	5 (two 10 × 10, three 5 × 5)	52	No S*
19	1·1	8·0	5·7	2·9	A	6 (two 8 × 8, four 5 × 5)	26	No S*

PDA D, patent ductus arteriosus narrowest diameter; FT, fluoroscopy time; SS, small residual shunt that closed either with a second procedure (case 10) or spontaneously (case 17); F, failed attempt at closure; No S, no residual shunt.
*Patient with significant pulmonary artery hypertension.

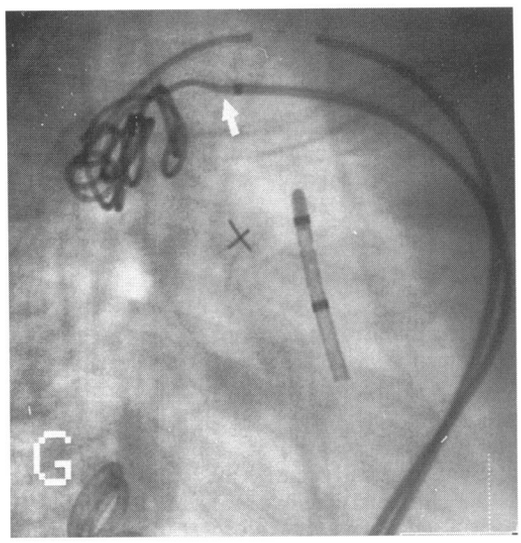
1·9 (0·8) (range 1–4). According to the angiographic classification adopted by Krichenko *et al*,[5] 15 patients had ductus type A, one had type B, two had type C, and one had type E. All patients underwent the anterograde multiple coil embolisation technique in an attempt to eliminate the left-to-right shunt across the ductus. All embolisations were initially achieved from the venous side. On several occasions after the first two to three coils had been placed from the venous side a small residual ductus could not be recrossed from the pulmonary end; the catheter was then placed retrogradely across the ductus for placement of one or two coils to close completely the ductus. The median number of coils used to close the ductus was four (range 2–6).

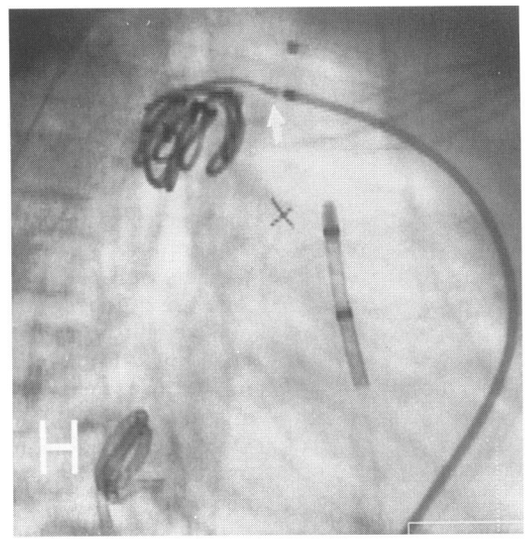
Coils were successfully deployed in the ductus in 18/19 patients. There was immediate and complete closure in 16/18 patients confirmed by angiography and colour flow echocardiography. Patient 10 had the largest ductal diameter in the series (7 mm) and had four coils (8 mm × 5 cm) placed at the first procedure. Three months later three additional coils (each 5 mm × 5 cm) were placed with complete elimination of the residual shunt. Patient 17 had trivial residual shunt after placement of two coils, the ductus could not be recrossed to place a third coil. At the six week follow up the residual shunt had disappeared spontaneously. In one patient (case 2) early in our experience and the only one with short ductus (angiographic type B) transcatheter closure was unsuccessful. A large short coil (8 mm × 5 cm) was placed individually into the ductus and was dislodged into the lung during placement of a second coil. All embolised (migrated) coils were retrieved with a gooseneck snare (Microvena, Vadnais, MN) and the patient subsequently underwent surgical ligation.

Complications included immediate coil migration to the lung in three patients (cases 1, 2, and 17) and proximal left pulmonary artery stenosis in two patients. The coils were fully retrieved in each except in patient 17. In this small patient (9 kg) with a 4 mm ductus we initially tried to simultaneously deliver three 5 mm × 5 cm coils. All coils migrated to the lung and only one coil could be retrieved. The ductus was successfully closed by placing larger, longer coils (8 mm × 10 cm and 5 mm × 8 cm). The two patients who developed left pulmonary artery stenosis (cases 8 and 9) were the smallest in the series (2·3 and 6·3 kg) and both received five coils for complete closure of a large ductus (5·2 and 4·7 mm). Patient 8 had a 26 mm Hg gradient at the completion of the procedure and a 23 mm Hg gradient at a repeat cardiac catheterisation performed 13 months later. Lung perfusion scan in this patient was performed one day after the procedure; it showed 60% flow to the right lung and a repeat scan at 13 months showed 67% to the right lung, indicating no significant change. Patient 9 had a 7 mm Hg gradient, one year later Doppler interrogation showed that this had resolved. For all patients the mean systolic gradient across the left pulmonary artery before closure was 1·1 (2·3) mm Hg and after closure it was 3·1 (6·4) mm Hg, $P = 0·23$. The mean systolic gradient between the ascending and descending aorta before closure was 0·7 (2·4) mm Hg and after closure was 0·3 (0·8) mm Hg, $P = 0·53$.

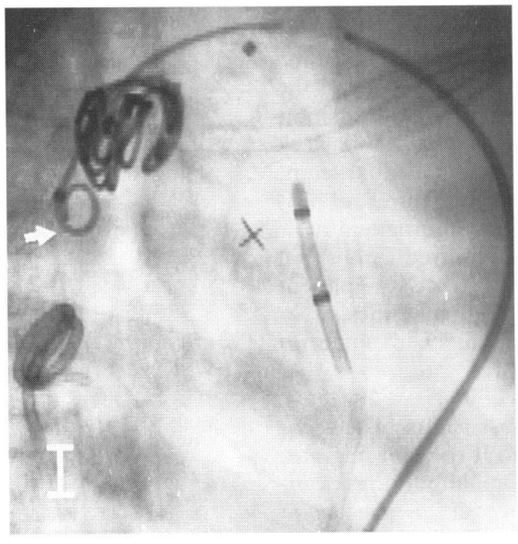
The median fluoroscopy time was 40 minutes (range 13–152). The longest fluoroscopy time occurred in patient 17 who had coil embolisation and an attempt at retrieval. All procedures were performed on an outpatient basis except for that in patient 8 who required continued inpatient care for non-cardiac conditions (prematurity, Hirschprung's disease, and colostomy). No patient required blood transfusion.

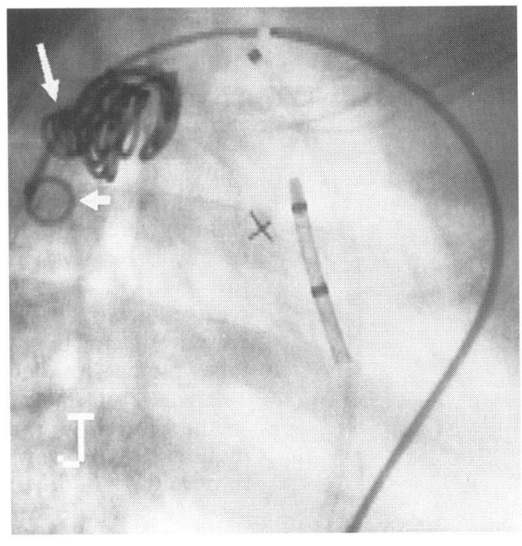
During a median follow up interval of 1·6 years (range two weeks–2·2 year) there have been no episodes of endocarditis or delayed coil migration. In the patients in whom complete closure was documented by echocardiography on the day of the procedure there have been no instances of recurrent ductal flow detected by auscultation or Doppler colour flow echocardiography.



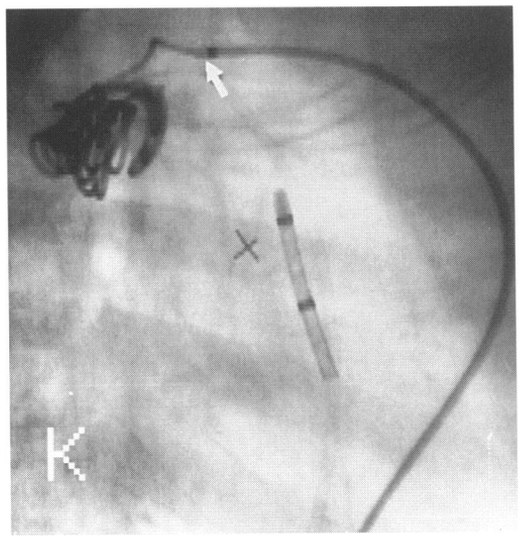


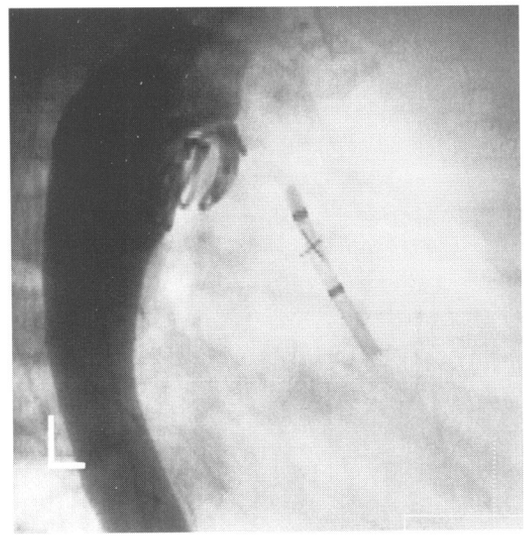
(G) The third coil is almost completely extruded (arrow) while the fourth coil is still partially inside its catheter. (H) The fourth coil is almost completely extruded (arrow).





(I) A catheter was repositioned in the descending aorta for the fifth coil (0·038 inch, 5 mm × 5 cm) which has one loop opened in the descending aorta (arrow). (J) The fifth coil is released (long arrow) and the final sixth coil (short arrow, 0·038 inch, 5 mm × 5 cm) is opened in the descending aorta.





(K) The sixth coil is almost completely extruded (arrow). (L) Final angiogram demonstrating all coils positioned in the ductus and no residual shunt.

Discussion

Transcatheter closure techniques using various devices including the Rashkind device, the buttoned device, or the Botalloocluder have been reported with a high success rate of implantation but with a somewhat high rate of residual flow across the ductus ranging from 3% to 38%.[2 6-8] These devices also require large sheaths (7–16 F), which precludes their use in small paediatric patients. Recently, we reported a new technique of multiple coil closure from the venous side closing PDAs up to 5·2 mm in diameter.[3]

In this study we report our total experience using this technique to close PDAs ⩾ 4 mm and up to 7 mm in diameter. The venous route has several advantages including confirmation of PDA and diverticulum position before coil deployment (because the arterial catheter can be used for injection of contrast),

avoidance of a femoral arterial injury in the small infant, potential application of this technique to the very young infant with PDA, and placement of multiple catheters through the ductus to permit simultaneous implantation of coils. Closure in one patient with a ductal diameter of 4·3 mm was unsuccessful because the ductus was short (angiographic type B). The multiple coil technique is effective in patients with longer PDAs of similar diameter. The use of longer coils to provide more loops and stability may be helpful for this ductal anatomy.[9] Further clinical testing will be important to determine any potential size and anatomical shape limitations of this technique. Only one patient had residual shunt across the ductus immediately after coil placement that persisted at the six week evaluation. This patient (case 10) underwent a second procedure which produced complete closure after three additional coils were placed. We now deploy as many coils as necessary to close the ductus completely before the patient leaves the catheterisation laboratory. The residual shunt had disappeared spontaneously at the six week visit in the other patient with residual shunt (case 17) at the end of the procedure. All procedures were performed on an outpatient basis except for one patient who stayed in hospital for non-cardiac conditions. No patient received general endotracheal anaesthesia. No episode of coil migration has been noted on follow up chest radiography.

The use of Gianturco coils is an attractive method for closure of most PDAs. The technique is easy to learn and if the coil migrates retrieval is not difficult. One important advantage is the cost of the procedure. A package of two coils costs about $35. Therefore, the cost of the coil embolisation technique should be much less than the surgical approach or the use of other devices. One limitation to this technique may include the large short ductus (angiographic type B). Further experience is necessary to determine whether such a ductus is best treated by placement of longer coils, Rashkind or buttoned devices, or by surgery.

Although our follow up is limited, we believe that coil embolisation of the large ductus is safe and has excellent results. Eighteen out of 19 patients had complete closure of their ductus, 17 with one procedure and one after a second catheterisation. We regard this technique as the best treatment for most patients with PDA.

We thank the entire staff of paediatric cardiology in our institution for their help.

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