Spring coil retraction in coil occlusion of persistent ductus arteriosus

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Abstract

Aims—To present the short and intermediate term results of coil occlusion of persistent ductus arteriosus and the results of radiographic measurements of spring coils implanted to treat patent ducts.

Patients—22 children underwent coil occlusion. Their ages ranged from 2 years 9 months to 12 years 10 months (mean (SD) age, 6.5 (3.6) years). The duct diameter ranged from 1.0 to 3.5 mm at the narrowest point (mean 2.6 (0.7) mm). In 11 of the children regular coils were implanted using the non-attached system, while in the other 11 the detachable coil embolisation system was used.

Results—12 children (55%) had no significant residual leaks immediately after procedures involving a single coil delivery. The remaining 10 (45%) had residual leaks immediately after the procedure, although no patient with a large duct showed residual leakage 18 months after the procedure. Radiographic measurement of the coils showed that all implanted coils retracted to 65–85% of their original size immediately after occlusion. This retraction was more evident in patients showing spontaneous closure of the residual shunt or having a coil 8 mm in diameter.

Conclusions—Coil embolisation is an acceptable method for occluding persistent ductus arteriosus. Retraction of implanted coils is common in the follow up period. Such retraction may be related to spontaneous closure of residual shunt after embolisation.

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Keywords: persistent ductus arteriosus; catheter occlusion; coil embolisation

With recent advances in catheter interventions, catheter occlusion has become the most attractive method for treating a persistent ductus arteriosus. The percutaneous closure technique for persistent ductus arteriosus was first described by Porstmann *et al* in 1971,¹ and more recently another system was developed by Rashkind in 1979.² This technique has been widely used.^{2–4} Occluding spring coils have recently been applied to small to medium sized ducts, with acceptable results on short and intermediate term follow up results.^{5–8} However, no information is available on the fate of the implanted spring coil. This report presents the short and intermediate term results of coil occlusions performed in our institute and the results of radiographic measurements of spring coils implanted to treat persistent ductus arteriosus.

Methods

PATIENTS

Between October 1994 and January 1996, 30 consecutive patients with persistent ductus arteriosus were enrolled into the protocol. Of these, 22 have complete follow up data during 18 months after the embolisation procedure. The patients ranged in age from 2 years 9 months to 12 years 10 months (mean (SD) age, 6.5 (3.6) years). Their weights ranged from 10.4 to 40.2 kg (mean 22 (11) kg). There were 10 boys and 12 girls. Twenty one patients had an isolated persistent ductus arteriosus and the remaining patient had coarctation of the aorta and a ventricular septal defect. In this patient, balloon coarctation angioplasty had been performed at the age of 1 year.

MODIFIED OCCLUDING COIL

Between October 1994 and June 1995, we used a non-attached system with Dacron stranded, stainless steel coils (Cook Inc, Bloomington, Indiana, USA). We increased the length of the coil with a helical diameter of 5 mm (MWCE-38-8-5) from 5 cm to 8 cm and the 8 mm diameter coil (MWCE-38-12-8 or MWCE-38-15-8) from 8 cm to 12 or 15 cm.⁹ These long coils made more than five helical loops when fully released. In July 1995, the Jackson detachable coil embolisation system (Cook Inc) became available in our institution.⁹

PROTOCOL OF THE OCCLUSION PROCEDURE

The procedure of the coil implantation was performed as described previously.^{5–9} In the Jackson detachable system, the delivery wire and coil were firmly connected by using the screw shaped system. This system allows the coil to be detached by turning the delivery wire after confirming that it has been fixed in the duct. Ten minutes after releasing the coil, aortography was repeated. After this procedure, the patients were allowed to recover in the paediatric ward. Colour flow imaging studies were performed to look for residual shunts the morning after the procedure. At this time, chest x rays and ECG were repeated. Patients were discharged on the following day.

FOLLOW UP EVALUATION BY COLOUR FLOW IMAGING

An outpatient follow up examination was performed one week, and one, three, six, 12, and 18 months after the procedure. On each visit, a cardiovascular examination was performed, which included chest x rays, an ECG, and a colour flow imaging study. Each patient was subject to a complete echocardiographic study, including colour flow imaging,

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Figure 1 Scheme of quantitative measurement of implanted coil. On the anteroposterior view (A), the distance between the upper and lower margins of the coils was measured (a). On lateral view (B), the longest distance was measured (b). The mean value $[(a+b)/2]$ was calculated. AO, aorta; PA, pulmonary artery. Chest radiographs show an implanted coil of 5 mm in diameter immediately after occlusion (C), at six months (D), and at 12 months (E). Coil retraction is evident.

to assess residual ductal flow in the main pulmonary trunk, left pulmonary arterial stenosis, and aortic stenosis, using previously reported techniques.^{10, 11}

QUANTITATIVE MEASUREMENT OF THE SPRING COIL WITH CHEST RADIOGRAPHY

To assess the relation between the spontaneous closure of residual shunts and the coil configuration following occlusion, quantitative measurement of coil implanted was performed in anteroposterior and lateral views on chest x rays. The distance between one edge of the coil loop and another was measured, as shown in fig 1. On anteroposterior projection the distance between upper and lower margins of the coils (a) was measured, and on lateral projection the greatest distance between the coil loops in the aortic and pulmonary ends (b) was also measured. The mean of (a) and (b) was calculated, and this value on follow up x rays was expressed as a percentage of each value immediately after occlusion (% retraction value). Serial measurements were performed on follow up chest x rays at each visit. If two coils were delivered, the longest distance between one edge and another edge was also measured. To obtain an accurate measurement of anteroposterior and lateral chest x rays, the angle produced by the centre lines of trachea and ribs overlapping the coil was measured as a reference. If this angle was beyond $\pm 5^\circ$, a further chest x ray was obtained or the result was excluded from the quantitative measurement.

STATISTICAL ANALYSIS

The age, body weight, and minimum diameter of the patent duct were expressed as mean (SD). The prevalence of residual shunts and the % retraction values were evaluated by actuarial analysis. A Wilcoxon test was used to compare the % retraction value and coil diameters of patients with and without residual shunts or spontaneous closure. A probability (p) value of < 0.05 was considered significant.

Results

ACUTE RESULTS OF COIL OCCLUSION

The smallest internal duct diameters were 1.0 to 3.5 mm (average 2.6 (0.7) mm). Angiographic classification¹² revealed a core shaped aortic ampulla (type A) in 14 of the 22 patients, a tubular duct (type C) in three, and a long duct with remote narrowest area (type E) in five. Twelve patients had complete closure with size MWCE-38-8-5, and three patients each with MWCE-38-15-8 and MWCE-38-10-8. Five patients required two coils simultaneously. Complete occlusion was confirmed in 12 of the 22 patients (55%) by aortography 10 to 15 minutes after the procedure and by colour flow imaging. The remaining 10 patients (45%) had persistent residual leakage. Postimplantation aortograms revealed small residual leaks in only five of these 10 patients, and colour flow imaging performed on the same day revealed trivial or trace leakage in the other five patients. The only complication encountered was a coil migrating into the distal left pulmonary artery in one patient, in whom the migrated coil was retrieved successfully and another coil implanted.

FOLLOW UP RESULTS OF RESIDUAL LEAKAGE

The follow up period ranged from 18 to 32 months (mean (SD), 23 (8) months). For all 10 patients with immediate residual leakage, no shunt flow was detected by colour flow imaging during the 3–18 month follow up period. Spontaneous closure of residual shunts was confirmed in these patients. One patient had a recanalisation six months to one year after embolisation but had complete occlusion due to spontaneous closure 18 months after the procedure. Actuarial analysis therefore showed a % residual shunt (number of residual shunts/total number of patients) of 0% after 18 months.

RESULTS OF COIL MEASUREMENTS ON CHEST x RAYS

The angle between the centre line of trachea and rib ranged from 67° to 89° (median 83°). In all 22 patients, this angle was within $\pm 5^\circ$ throughout the follow up period and therefore all chest x rays were retrospectively available for measurement. In all patients with single or double coils, the % retraction value gradually decreased during the follow up period. This value (mean (SD)) was 95(2)% after one week, 93(3)% after one month, 88(7)% after three months, 79(7)% after six months, and 72(13)% after 12 months. There was a significant positive correlation between the % retraction value after six months and the initial coil

Figure 2 The prevalence of % residual shunt and the % retraction value in the follow up period, assessed by actuarial analysis.

size ($r = 0.76$, $p < 0.005$). In four patients with a single coil of 8 mm in diameter, the % retraction value after one month and six months was more evident than in those with a single coil of 5 mm in diameter (88(5)% *v* 95(4)% after one month, $p < 0.05$; 76(12)% *v* 82(9)% after six months, $p < 0.01$). In addition, the % retraction values of a single coil from one month to 12 months of follow up were significantly greater in patients with residual shunts than in patients with complete occlusion immediately after the procedure (fig 2).

Discussion

Since the first reports by Cambier *et al* in 1992 describing percutaneous closure of persistent ductus arteriosus with spring coils,⁶ the technique has been used by several other workers.^{5-9 13 14} The technique is considered to be safe and effective, particularly in the case of small ducts measuring less than 2.5–3.0 mm in diameter, while a recent investigation has shown that the multiple coil technique could be used to completely occlude a large duct with a diameter of more than 3.0 mm.⁷⁻⁹ To our knowledge, however, there has been no report on coil retraction following coil embolisation for closure of persistent ductus arteriosus. Our results indicate that all coils implanted in the patent duct retract to approximately 70% of their original size during the 12 months after coil occlusion. This retraction may be related to the interaction between velocity of endothelialisation (fibrous tissue retraction) and thrombus formation, and a retracting force parallel to the long axis of the coil. The greater the initial size of the implanted coil immediately after the procedure, the greater will be the retraction. This indicates that coils with more stretch may subsequently have greater retraction. However, the actuarial analysis curves of the % residual shunt and the % retraction value were not correlated. Despite these negative results, our study suggests that coil retraction may be related to the histological mechanism of vascular response following coil occlusion. Acute incomplete thrombus formation in the coil loop first occurs immediately after embolisation, resulting in residual leakage. However, retraction and changes in the position of the coil may lead to new thrombus formation and complete occlusion. In addition, coil retraction in the left pulmonary artery is potentially

advantageous in that it may help to avoid left pulmonary arterial stenosis in the long term, even if a larger coil of 8 mm diameter is implanted. However, this study only followed the natural history of the spring coil in the short term. A long term follow up study is necessary to clarify whether such retraction will ultimately prove advantageous.

Recent investigations have shown that recanalisation rarely occurs after coil embolisation in cases of the aortopulmonary collateral artery and persistent ductus arteriosus.^{9 15} In our study series, however, only one patient experienced recanalisation. The mechanism of recanalisation remains unclear, although minor changes in coil position and thrombolysis or clot retraction have been suspected by Shim *et al*.⁸ The results of our study support their hypothesis and suggest that recanalisation may occur owing to the delayed dynamic phase of thrombus maturation, with coil retraction until the coil loop is completely covered by a neo-endothelial layer.

In conclusion, both non-attached and detachable systems may be an effective device to ensure complete occlusion in cases of persistent ductus arteriosus. Additionally, coils implanted in patent ducts retract to 65–85% of their original size immediately after occlusion. This may affect the endothelialisation process involved in the spontaneous closure of the residual shunt after embolisation.

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