Problems encountered during introduction of Gianturco coils for transcatheter occlusion of the patent arterial duct

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Objective To define the problems encountered during transcatheter occlusion of the patent arterial duct using Gianturco coils.

Methods Between January 1994 and November 1995, 93 patients were admitted in whom it was intended to occlude the patent arterial duct using Gianturco coils. Anterograde transcatheter coil occlusion was performed via the femoral vein in 81 patients. In the remaining 12 the procedure was done via the femoral artery.

Results Coils were implanted successfully in 82/93 (88%) patients. In 11 patients the procedure was a failure. In 19/93 patients (20%), inadvertent embolization of the coil occurred. The coils were retrieved in all except one patient. In 17 of these patients, new coils were then reimplanted successfully. Doppler echocardiography after the procedure showed that in 9/82 (11%) patients the left pulmonary artery Doppler peak velocity exceeded 1.5 m. s⁻¹ (mean 1.2 m. s⁻¹) raising concern about left pulmonary artery branch stenosis. The complete occlusion rate at discharge from hospital was 72/82 (88%). Follow-up ranges from 1 day to 14 months (mean 2/12 months) in the 82 patients in whom successful deployment of coils was possible. In two patients, the arterial duct became occluded at follow-up. One additional patient had complete occlusion after reocclusion using another coil. Thus, after short-term follow-up a total of 75/82 patients (91.4%) have a completely occluded arterial duct after coil implantation.

Conclusion Transcatheter occlusion of the patent arterial duct using Gianturco coils is an effective and safe technique. In the learning curve there is a relatively high rate of inadvertent embolization, but the coils can be retrieved in the vast majority of patients. The complication rate is offset by the high early occlusion rate and the inexpensiveness of the procedure.

Key Words: Gianturco coils, transcatheter occlusion, patent arterial duct.

Introduction

Transcatheter occlusion of patent arterial ducts using the double umbrella device is now an established technique in most paediatric cardiology centres. However, it is costly and appears to be more expensive than surgery. Furthermore, there is some concern about the development of left pulmonary artery stenosis when the larger umbrella device is used in small children. In addition, residual flow through the umbrella may occur in approximately 20% of patients, necessitating implantation of a second device.

As an alternative to both surgery and umbrella closure, we have used Gianturco coils to close the patent arterial duct and present our early experience and results, with emphasis placed on the problems and complications encountered whilst introducing this technique.

Patients and methods

Between January 1994 and November 1995, 93 patients (69 (74%) females, 24 (26%) males) were admitted to our unit in whom it was intended to occlude the patent arterial duct using Gianturco coils. In three patients, two procedures were performed on different occasions and only the second procedure was evaluated in this report. The median age of the 93 patients was 36 months (range 2 to 366 months), and the median weight was 13.7 kg (range 5.5 kg to 87 kg). Thirty-five
of the patients have been reported on previously. Twelve (13%) patients were less than 1 year old and 25 (27%) weighed less than 10 kg. Seven patients (7.5%) had a residual flow after previous surgical ligation of the arterial duct and 16 (17.2%) had residual flow after implantation of the Rashkind double umbrella device (Fig. 1(a) and (b)). In nine patients attempts at Rashkind device implantation had previously been unsuccessful. In four of these patients the size of the arterial duct was such that a 17 mm device was needed for implantation; one patient had an interrupted inferior vena cava, which had been overlooked on the echocardiogram; in two patients the device embolized and after retrieval the procedure was abandoned; in the remaining two patients the arterial duct was felt to be too small for the 12 mm device.

Twelve patients had symptoms of mild congestive heart failure. Additional defects included a patent foramen ovale or a small atrial sepal defect in three patients, a small restrictive ventricular septal defect in one patient, peripheral pulmonary artery branch stenosis in four patients and a right aortic arch in two patients. Five patients had Down's syndrome and six rubella syndrome. One patient had dextrocardia with situs inversus and a right aortic arch and another had interruption of the inferior vena cava in addition to the arterial duct. Three patients had additional valvular pulmonary stenoses, and underwent balloon dilatation of the valve while the arterial duct was being closed.

**Procedure**

All patients underwent a clinical examination, electrocardiography, a chest X-ray and cross-sectional Doppler. Informed signed consent was obtained from the parents or the patient. Premedication included intramuscular administration of a mixture containing demerol 14 mg . ml$^{-1}$, promethazine 6-25 mg . ml$^{-1}$ and chlorpromazine 6-25 mg in a dose of 0·1 ml . kg$^{-1}$, and a maximum dose of 2 ml was given 30 min prior to cardiac catheterization. This was supplemented with ketamine 0·5-1 mg . kg$^{-1}$ during the procedure when necessary. Where appropriate, additional supplements of diazepam or morphine were also given. With this regime, endotracheal intubation and general anaesthesia were required in two patients who did not respond adequately to ketamine and a further two patients had general anaesthesia electively. One patient had congenital atrioventricular block and a permanent transvenous pacemaker was implanted during the same procedure. In the other patient, who had rubella syndrome and congestive heart failure with severe failure to thrive, it was thought safer to carry out the procedure under general anaesthesia. For angiography, non-ionic contrast medium (ultravist, Shering, Berlin, Germany) was used.

The procedure was performed using a previously described technique. Coil implantation was attempted by the anterograde approach using the femoral vein in all except 12 patients, in whom the retrograde femoral arterial approach was used. These latter had a very small arterial duct (median narrowest diameter 1 mm), where anterograde access was thought to be difficult or had failed. In three of the 12 patients duct ligation had been performed previously; in four other patients there was residual leak post Rashkind device occlusion.

A 4 Fr sheath was inserted into the right femoral vein and another into the left or right femoral artery. When the size of the arterial duct showed that multiple coils would be needed, a second 4 Fr sheath was placed in the other femoral vein (Fig. 2(a) and (b)). Heparin was not given routinely. A biplane descending aortogram in antero-posterior and left lateral projections was performed to define the size, position and morphology of the arterial duct. The branch and main pulmonary arteries were evaluated by angiography in the four-chamber projection in patients with the rubella
Problems on introducing Gianturco coils

Figure 2 (a) Aortography in the lateral projection showing a moderate patent arterial duct before transcatheter occlusion. (b) Aortography in the lateral projection showing the same duct after successful complete occlusion using two Gianturco coils. For occlusion, two 4 F Microvena catheters are used simultaneously.

Figure 3 (a) Aortography in the lateral projection showing a very large patent arterial duct with an elongated ampulla before transcatheter occlusion. (b) Aortography in the lateral projection showing the same duct after successful complete occlusion using multiple Gianturco coils.

Syndrome. Oximetry and pressure measurements in the right and left sides of the heart were performed. Single or multiple 0.038 inch Gianturco coils were deployed, having taken into account the narrowest diameter of the duct. The coil diameter was selected to be at least twice the minimum dimension of the arterial duct. If the narrowest diameter of the duct was less than 2.5 mm, usually a single Gianturco coil of 2, 3 or 5 mm diameter was used. If the duct was larger than 2.5 mm, two or more coils are usually used, all being inserted from the venous approach (Fig. 3(a) and (b)). A final aortogram was performed 10 min after deployment of the coils. Cephaloxine 30 mg kg⁻¹ was given intravenously during the procedure and the same dose was repeated 6 h later.

Results

Fifty-three (57%) patients had the procedure performed as a day case. The median pulmonary artery systolic pressure was 32 mmHg (range 13–69 mmHg) and the Qp/Qs ranged between 1 and 9.4 (mean 1.72/1). The median fluoroscopy time was 12 min (range 4–89 min). The longest fluoroscopy time occurred in those patients in whom embolization of the coils necessitated their retrieval.

Coils were successfully implanted in 82/93 (88.2%) patients. In 59 out of the 82 patients in whom coil deployment was successful (72%) a single coil and in 23 (23%) patients between two and seven coils were implanted. The commonest size of coil (5 mm x 5 cm)
was used in 33/59 (56%) of the patients who received a single coil and in 23 patients 26 times during multiple coil implantation. The mean fluoroscopy time was 14-8 min (range 4-2-50 min) for implantation of single coils compared with a mean of 22 min, (range 8-66 min) for implantation of multiple coils.

On angiography, 65 (70%) patients had a conal shaped arterial duct, seven ducts were short (8%), five (5%) tubular, two (2%) had complex forms, 14 (15%) were found to be elongated. The median narrowest diameter of the arterial duct was estimated to be 2 mm (range 0-5-7 mm, mean 2-5 m). Seventeen arterial ducts (18-3%) were less than 1 mm, 33 (35-4%) were between 1-1-2 mm, 21 (22-6%) between 2-1-3 mm and 12 (12-9%) between 3-1-4 mm; in 10 patients (10-8%) the narrowest diameter was greater than 4 mm.

We compared the outcome of the 10 patients who had a duct larger than 4 mm with the 83 patients with a duct smaller than 4 mm in diameter. There were significantly more patients less than 2 years old in the smaller duct group as compared to the group with the larger duct (27 vs seven patients; Chi square 3-968, P=0-0474). The embolization rate was comparable (20% vs 20%; ns). There was no difference in the rate of abandoned procedures (8/83 vs 3/10; ns). The immediate total occlusion rate in the patients in whom deployment of coils was successful was comparable in both groups (6/7 vs 66/75; Chi square 0-0312; P=0-873).

The procedure failed in 11 (12%) patients, who were consequently referred for elective surgery. In six of these 11, the coils embolized to the left pulmonary artery, and were retrieved successfully. In three of these six, the retrograde arterial approach had been used. In three other patients, the coils were pulled through the duct into the pulmonary artery and were retrieved successfully; the procedure was then abandoned (Fig. 4).

Problems and complications

Coil embolization occurred in 19/93 (20%) patients. The coils embolized to the branches of the pulmonary artery in all patients except one in whom one coil embolized to the descending aorta at the level of the renal arteries. However, it was easily retrieved using a gooseneck snare through a 4 F Microvena catheter. In one patient with two coils late embolization occurred. The coils were in a satisfactory position across the duct, but embolization had occurred by the time echocardiography was performed on the ward a few hours later. The patient was taken back to the cardiac catheterization laboratory on the same admission, the coils were retrieved and new coils were successfully deployed with complete occlusion.

The embolized coils were successfully retrieved in all but one patient, in whom the coil was left in a small branch of the left pulmonary artery. In 17 of these patients, a further coil was successfully deployed across the arterial duct during the same procedure. In seven patients, coils were inadvertently pulled through the duct into the pulmonary artery whilst they were partially extruded out of the catheter. In five patients, the catheter together with the extruded coil was withdrawn successfully out of the 4 F sheath. In the remaining two patients in whom a Microvena gooseneck snare catheter of 4 Fr diameter introduced via the other femoral vein was used, the coils were retrieved successfully. In four of these seven patients, another coil was successfully deployed across the duct during the same procedure.

Only one patient had occlusion of the femoral artery after the procedure and required streptokinase and heparin infusions. Pulses were normal 24 h later.

Occlusion rates

In 54/82 (66%) patients in whom successful deployment of coils was possible, complete occlusion of the arterial duct, judged by angiography, had occurred 10 min after implantation of the coil(s). A further 18/82 (22%) had complete occlusion, judged by colour Doppler echocardiography, before discharge. Thus the complete occlusion rate at discharge was 88% (72/82 patients).

Of the 16 patients with residual flow after a previous Rashkind double umbrella device, 15 (94%) had become completely occluded after coil implantation. In seven patients with residual flow after previous surgical ligation, six (86%) had complete occlusion.

Follow-up

Colour Doppler echocardiographic studies were performed in all patients before discharge. The median
velocity across the left pulmonary artery was 1.4 m. s\(^{-1}\) (range 0.7–2.6 m. s\(^{-1}\)), and the median velocity across the descending aorta was 1.3 m. s\(^{-1}\) (range 0.9–1.8 m. s\(^{-1}\)). In nine patients the Doppler velocity in the left pulmonary artery exceeded 1.5 m. s\(^{-1}\) suggesting mild branch stenosis. The velocity in the descending aorta exceeded 1.5 m. s\(^{-1}\) in only three patients.

The follow-up ranged from 1 day to 14 months (mean 2.5 months) in the 82 patients in whom successful coil deployment was possible and who underwent detailed Doppler echocardiographic studies. In an addition two patients, the arterial duct became occluded at follow-up. In one patient, another coil on a second occasion led to complete occlusion. Thus a total of 75/82 (91.4%) patients have completely occluded arterial ducts after coil implantation.

**Discussion**

The Rashkind double-umbrella technique for the transcatheter closure of patent arterial ducts is the accepted procedure at our centre as well as numerous centres throughout the world\(^\text{[6-4]}\). In our centre, over 200 patients have been treated with this device and various problems have been identified with its use. These include a significant incidence of residual flow, left pulmonary artery stenosis and a technique that is cumbersome and needs considerable attention to detail\(^\text{[6.7.9]}\). The problem of a residual shunt can be overcome by implantation of a second umbrella\(^\text{[8-10]}\). Left pulmonary artery stenosis caused by the umbrella device, although rare, may be avoided by not using the large device in small children\(^\text{[6,7]}\). The umbrella device requires the placement of a large sheath, which is not ideal in small children. A major disadvantage of the umbrella device is its expense.

Since January 1994 the majority of patent arterial ducts at our institution are occluded by the transcatheter coil technique. With any new technique there is a learning curve and different problems are encountered. It was the aim of this study to identify the problems and complications encountered while trying to establish this alternative technique of coil implantation.

Coil implantation can be performed via the arterial or venous routes. Both approaches have their proponents. In some of our patients with small arterial ducts, the retrograde arterial approach was used initially, but due to a high incidence of coil embolization, this approach was later avoided when possible. We then used the antegrade approach in the next 10 patients with success and since then have used this in all except 12 patients. The relatively high overall embolization rate is of some concern. It is possible that in our population there are many patients with relatively large ducts necessitating the deployment of more than one coil, which may increase the likelihood of embolization. An advantage of the antegrade approach is that coil delivery is from the femoral vein and the use of the arterial catheter enables check angiograms to be performed to confirm the position of the coil prior to deployment. It is important to emphasize that the choice of approach is very much up to the individual operator with advantages and disadvantages of both the venous and arterial approaches.

Inadvertent coil embolization generally occurs immediately after deployment. Usually it occurs because the coil has not been deployed in the correct position or the minimum diameter of duct has been underestimated, leading to the selection of a coil that is too small. However, retrieval of embolized coils using gooseneck snares is a relatively easy procedure and can be accomplished in the vast majority of patients. A potential problem of greater concern arises when multiple coils migrate, as happened in one of our patients with two coils. In these, the coils were in a satisfactory position across the duct, but embolization had occurred by the time echocardiography was performed on the ward a few hours later. It is possible that the arterial duct may have changed its size and thus undersized coils may have been used. There were no other instances of late embolization of coils.

When we compared our first patients who underwent coil occlusion of their duct with the first patients who underwent umbrella device occlusion at our institution\(^\text{[4]}\), there were more complications with the coil method. The embolization rate of coils is much higher than that with the umbrella device\(^\text{[11]}\), but the majority can be easily retrieved. When embolization of the umbrella device occurs, it is much more difficult to retrieve it, although it can be done. The high rate of embolization is partly due to the fact that the Gianturco coils are not as steerable nor is the release controlled as with the umbrella device. It is recognized that coil embolization and its subsequent retrieval and implantation of another coil lengthens the procedure and the fluoroscopy time. The longest fluoroscopy time was in a patient with embolization of multiple coils. Embolization occurred both with single and multiple coil implantation. In both cases it is probable that the narrowest diameter had been underestimated. This demonstrates the importance of measuring the arterial duct exactly, which is likely to improve with better angiography equipment. It is also possible that the controlled-release patent duct coil will reduce the incidence of complications and problems. Our early experience with these later coils is encouraging.

With the coil technique, it is worrying that when multiple coils are being deployed to close residual flow after the first coil, it is occasionally possible to dislodge the first coil. In one patient, as reported above, two coils embolized after deployment, because an attempt was made to implant another coil for residual flow. In such cases, simultaneous deployment of coils via a combined arterial and venous approach may prevent this problem. It is again likely that the size of the duct may have been underestimated. In some cases it is probably safer to leave the patient with a small residual leak to see whether spontaneous closure occurs during follow-up.
To achieve occlusion of an arterial duct, current practice is to use a coil twice the size of the narrowest diameter of the duct\(^{13}\). However, correct selection of coils is probably not so simple, because ducts encountered in clinical practice come in a variety of shapes and sizes. At present, the commonest coil used is 5 mm \(\times\) 5 cm, whether for a single or multiple placement. We now feel that apart from taking the size and shape of the duct into account, more emphasis is probably needed on the ampulla. If a coil was selected of a similar diameter to the ampulla of the duct, the chances of embolization may be reduced. We feel that this needs further study.

One of the important indications for coils is the need to occlude residual flow after previous surgical ligation or after umbrella implantation. In our series, 16 patients had residual flow after previous umbrella device closure of their arterial duct. In all of them, it was easy to cross the usually small residual duct using a 4 F catheter and deploy the coils. By the time of discharge, the complete occlusion rate was 94%. Coil occlusion in these patients not only results in a high occlusion rate but also keeps the cost of closing the duct low. In 6/7 patients with residual flow after surgical ligation, the duct was completely occluded at the end of the procedure of coil implantation. In these patients, it would be difficult to place a 8 Fr or 11 Fr sheath through the duct for umbrella implantation. Thus, coil implantation is clearly preferable in these patients. It is of interest that in most cases with residual leak a single coil was enough to achieve total occlusion.

Overall, the occlusion rate of 88% at discharge was higher than that reported previously with the umbrella device\(^{11-19}\). Our report shows that transcatheter occlusion of the patent arterial duct using Gianturco coils is a safe, economic and effective procedure. Initially during the learning phase, there is a high embolization rate, and thus there is a need for retrieval catheters to be available.

References


