Transcatheter closure of patent arterial ducts using controlled-release coils

A. Celiker*, S. A. Qureshi†, A. Bilgic*, M. Carminati‡, R. Kirk§, E. Rosenthal†, D. Alehan*, S. Giusti‡, E. J. Baker† and M. Tynan†

*Hacettepe University, Ankara, Turkey; †Guy’s Hospital, London, U.K.; ‡Children’s Hospital, Massa, Italy; §University Hospital of Wales, Cardiff, U.K.

Objective To determine the efficacy of transcatheter closure of patent arterial ducts using controlled-release coils.

Design Transcatheter closure of patent arterial ducts was attempted in 52 patients using controlled-release coils.

Setting For the study, four tertiary paediatric cardiology units were used, two of which were in the U.K., one in Italy and one in Turkey.

Patients The 52 patients ranged in age between 3-5 months and 61 years (median 3-5 years), and weighed between 4-5 kg and 62 kg. The duct diameters were 1 mm to 6-5 mm.

Results In four patients the ducts were too large for safe release of the coils. In the remaining 48, one coil was inserted in 33 patients, two coils in nine, three coils in four and four coils in two patients. Immediately at the end of the procedure, the duct was completely occluded in 26/47 (55%) patients. Haemolysis occurred in one patient, in whom the coil was removed by a snare catheter and a large umbrella device was implanted with resolution of the haemolysis. Coil embolization to the pulmonary artery occurred in five (10%) patients. All were easily retrieved and replaced by larger coils. At the latest follow-up by colour Doppler echocardiography, the duct was completely occluded in 44/47 (94%) patients.

Conclusions Transcatheter closure of patent arterial ducts by controlled-release coils is effective and safe. Even when more than one coil is inserted the technique is still less cumbersome and considerably cheaper than transcatheter umbrella closure.

Key Words: Controlled-release coils, transcatheter closure of patent arterial duct.

Introduction

Over the last 10 years, transcatheter closure of patent arterial ducts using the Rashkind double umbrella device has been widely used worldwide. However, this method has several disadvantages for the poorer countries in Eastern Europe, Middle East and Asia. The device is expensive and if more than one device is required, the cost becomes prohibitive. Even though the femoral venous route is employed, a 8 Fr or 11 Fr sheath is required, making it unsafe to implant such a device in children less than 8-10 kg.

Conventional Gianturco stainless steel coils with Dacron fibres attached were recently used for transcatheter coil occlusion of the patent arterial duct. These coils are inexpensive and can be introduced through 4 or 5 Fr catheters by either femoral arterial or venous routes. The important disadvantage, however, is the lack of a controlled-release mechanism. Once the coil is extruded out of the catheter, the procedure is irreversible. Controlled-release coils have become available recently for the closure of patent arterial ducts. We report our initial experience of attempted occlusion of the patent arterial duct in 52 patients using these coils.

Patients and methods

Patients

Between September 1994 and December 1995, transcatheter closure of patent arterial ducts using controlled-release PDA coils was attempted in 52 patients in four institutions. There were 18 males and 34 females. Their ages ranged between 3-5 months and 61 years (median 3-5 years) and their weight between 4-5 kg and 62 kg (median 14 kg). Seven patients had had previous...
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procedures on the arterial duct, including implantation of an umbrella device in four, surgical ligation in two and implantation of a duct-occlud coil in one. Two patients had Down's syndrome, two had additional restrictive ventricular septal defects and one mild aortic stenosis.

Details of technique

The procedures were performed under sedation with ketamine without endotracheal intubation, but occasionally in smaller infants and children, under general anaesthesia. The femoral artery was cannulated with either 4 or 5 Fr introducer sheaths and an 18 or 20 gauge cannula was inserted in the femoral vein. In older patients, a 6 Fr sheath was inserted in the artery for the introduction of 6 Fr angiographic catheters. Heparin 50–100 u. kg\(^{-1}\) was given. The arterial catheter was placed opposite the arterial duct in the descending aorta and an aortogram was performed in the lateral and, if available, antero-posterior and lateral projections. The lateral projection was used for fluoroscopy throughout the procedure. The size of the arterial duct was measured and the landmarks defined, in particular the narrowest point of the duct in relation to the anterior wall of the trachea. A 4 Fr (Microvena Corporation, White Bear Lake, U.S.A.) or 5 Fr guiding catheter (William Cook Europe A/S, Bjaerskov, Denmark) was passed from the aorta through the arterial duct and placed in the main pulmonary artery.

Coils

Controlled-release PDA coils (William Cook Europe A/S, Bjaerskov, Denmark) were used in all patients. They are made of stainless steel, with Dacron fibres embedded into the steel throughout the length of the coil. At the proximal end of the coil is a 5 mm long thread, which is screwed onto a similar but smaller thread at the distal end of the delivery wire for attachment (Fig. 1). The coils are available in diameters of 3 mm, 5 mm and 8 mm, and have four or five loops. The delivery wire consists of a screw thread on the wire at its distal end attached to the main part of the delivery wire. Inside this is a mandril, which is inserted inside the coil in order to straighten it. The coil is provided in a loading cartridge. The straightening mandril is carefully introduced into the thread of the coil and advanced inside it. The delivery wire is rotated four to six turns clockwise using a pin vice. Once satisfactorily attached, the coil is pushed out of the cartridge into the guiding catheter, already placed across the arterial duct, by advancing the delivery guide wire until the coil is pushed out of the catheter into the pulmonary artery. The mandril is withdrawn fully to allow the coil to form loops. The catheter is withdrawn from the pulmonary artery until the coil is at the pulmonary artery end of the duct. Between one and one and a half loops are placed in the pulmonary artery end of the duct. The catheter is then withdrawn into the descending aorta to allow the remaining loops (usually about 2–3) to form at the aortic end of the duct. At this point, if it appears that the coil is advancing into the pulmonary artery, either it can be withdrawn into the catheter and repositioned or a larger coil implanted. Once the position of the coil seems satisfactory, the pin vice is turned anti-clockwise to release it. An aortogram is repeated. If there is a significant residual flow, the duct is re-crossed with an ordinary guide wire, over which the guiding catheter is re-advanced into the pulmonary artery. Another coil can then be implanted into the duct using the above technique. A final aortogram is performed. When a large duct is encountered, placing two coils simultaneously using a combined arterial and venous approach may prevent their embolization. For ducts less than 2 mm minimum in diameter, a 3 mm coil with four loops was selected. For ducts between 2 mm and 3·5 mm, a 5 mm coil with four or five loops and for ducts between 3·5 and 6–7 mm, an 8 mm coil with four or five loops were selected. In these latter ducts, two or three coils may need to be implanted simultaneously and released for safe placement. It is to be emphasized that the measurement of the arterial duct is not always absolutely accurate and so selection of coils can be subjective, but the above are approximate guidelines.

Cross-sectional and colour Doppler echocardiography were performed the next day and at subsequent follow-up visits to the out-patient department.

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Results

The arterial ducts measured between 1 mm and 6.5 mm (mean 3.2 mm) and the systolic pulmonary artery pressure was between 25 mmHg and 42 mmHg. Implantation of controlled-release coils in arterial ducts was successfully achieved in 48 (92%) of the 52 patients. The catheters for coil implantation were 5 Fr in 36 patients and 4 Fr in 12 patients. Thirty-three (69%) of the 48 patients received a single coil, nine patients received two coils, four received three coils and two received four coils at the initial procedure. Eight (11%) of the 71 coils were 3 mm in diameter, 51 (72%) were 5 mm in diameter and 12 (17%) were 8 mm in diameter. In six patients, coils were implanted simultaneously using both the femoral arteries or a combined femoral venous and arterial approach. However, one patient, aged 5 years, had a 6 mm diameter duct. An 8 mm coil was placed across the duct but not released. It showed a tendency to migrate into the pulmonary artery. Therefore implantation of two 8 mm coils, one via the femoral artery and one via the femoral vein was attempted. After satisfactory positioning of the two coils, angiography showed a significant leak. A second arterial catheter was passed through the previous two coils, which had still not been released, and a 5 mm coil was implanted. One by one the coils were released without any problems. At the end of the procedure, angiography showed a tiny amount of residual flow.

The overall procedure time varied between 35 min and 2.5 h. The fluoroscopy time varied between 5 min and 78 min, mean 21 min.

Complications and problems

Inadvertent embolization of coils after release to the pulmonary artery occurred in five (10%) patients. All were easily retrieved using a 4 Fr snare catheter. Embolization of coils generally occurred because the size of the arterial duct had been underestimated. After retrieval of the coil, two coils were implanted in the duct serially in three patients and simultaneously in two patients, using a combined arterial and venous approach in one and both the femoral arteries in the other.

In four patients (all in Turkey), coil implantation had to be abandoned because the ducts were too big for the coils and the patients were referred for surgery. In one of these patients, coil implantation was not attempted. In the remaining three, coils had to be removed whilst still attached to the delivery wire. In these, the arterial ducts were 5–7 mm in diameter. In all three, between one and three coils (5 and 8 mm in diameter) implanted across the duct simultaneously, but still attached to the delivery wire, showed a tendency to migrate into the pulmonary artery. All the coils were easily withdrawn and the patients referred for elective surgery.

One patient, who had an 8 mm coil implanted, developed severe haemolysis over 24 h. The coil was retrieved with a snare catheter and a 17 mm double umbrella device implanted with complete occlusion of the duct.

Occlusion rates

The follow-up ranged between 1 and 14 months, with three patients followed-up for more than 12 months. Immediately at the end of coil implantation, angiography showed complete occlusion of the duct in 26/47 (55%) patients. The ducts were completely occluded at the end of the procedure in 17 (52%) out of 33 patients who received a single coil (Fig. 2), compared with complete occlusion in six (67%) out of nine who received
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Figure 3 Angiogram of a large arterial duct (a) is completely occluded by 3 coils (b).

Figure 4 A significant leak following implantation of a 12 mm Rashkind umbrella 2 months previously in a 6-month old infant (a) is completely occluded by implanting three coils (b).

two coils, two (50%) out of four who received three coils (Fig. 3) and one (50%) out of two who received four coils. Figure 4 shows an angiogram in a patient with a residual leak after a 12 mm umbrella, in whom three coils were implanted to achieve occlusion.

Follow-up colour Doppler echocardiography 24–48 h later, showed complete occlusion of the arterial duct in 40/47 (85%) of the patients. Four to 6 weeks later, the occlusion rate was 44/47 (94%). In one patient, although the coil protruded into the left pulmonary artery, there was no increase in Doppler velocity. In no patient was an increased Doppler flow velocity encountered in the descending aorta.

Discussion

Transcatheter closure of the patent arterial duct is widely accepted as an alternative to surgery in all except pre-term babies. Since the first report of the umbrella device, this method has become popular throughout the world[1-3]. With this device, occlusion rates in excess of 80% with a single device are obtained, but with a second umbrella, the occlusion rates may be up to 95%[9-10]. The major limitations are their expense and the large diameter sheaths (8–11 Fr) required for implantation[2-4, 9-10].

Stainless steel coils are considerably cheaper and have been used since 1975[11]. Recently, Gianturco coils have been used to close patent arterial ducts[15-8]. Apart from the cost, these have other advantages over the umbrella device. They can be implanted through a 4 Fr or 5 Fr catheter. If embolized inadvertently, they can be retrieved easily. Even if more than one coil is required to close the duct, the procedure remains inexpensive. This is relevant to less affluent countries. Furthermore, coil implantation is less cumbersome than umbrella implantation and so the duration of the procedure is shorter. However, such coils also have disadvantages, the most important being the lack of a controlled-release mechanism. Once the coil is extruded out of the catheter, the procedure is irreversible. To overcome this disadvantage, controlled-release coils have been developed and have become available recently for the closure of arterial ducts. The coils have a screw attachment to the delivery wire and can be introduced and withdrawn easily through 4 Fr catheters. They are also inexpensive. The coils are usually straddled across the duct with one to one and a half loops at the pulmonary artery end and the remainder at the aortic end of the duct. If during implantation, too many loops form at the pulmonary artery end, the coil is withdrawn into the catheter and another attempt made at satisfactory positioning.
Occasionally this is unavoidable, and in this situation, there will be concerns about left pulmonary artery stenosis developing in the medium term.

Coils can be used to close ducts up to 6 mm in diameter. However, in larger ducts, if a single coil is deployed, there is a strong likelihood of significant residual flow, resulting in haemolysis. After experiencing this in one patient, we elected to implant multiple coils in larger ducts with the intention of completely occluding the duct, or reducing the residual flow to a trivial amount by the end of the procedure. With this policy, it is possible that much higher occlusion rates of 90-95% will be achieved than was the case with the umbrella device. In larger ducts, it is also possible to deploy up to four coils using both the femoral veins and the femoral arteries, and once placed satisfactorily, to release them one by one. This technique reduces the risk of embolization of a single coil prior to implantation of a second coil in a large duct.

Inadvertent embolization, haemolysis and vascular trauma are the main complications. The 4 Fr catheters do not produce much trauma to the femoral artery. Embolization may be avoidable if relatively larger diameter coils are used in small ducts. However, even if coils embolize, they can be retrieved easily using snaring catheters. Haemolysis can be avoided, if an attempt is made to close the duct completely at the first procedure.

Whilst both the femoral venous and arterial routes can be used, the arterial route has a straighter approach to the duct and allows easier control of deployment and release of the coils. However, the route of implantation is subject to personal preference.

Coil implantation is a safe and effective method for closing arterial ducts by transcatheter techniques. It is cheaper than both the umbrella and surgical methods and occlusion rates are comparable.

References