Transcatheter Occlusion of Patent Ductus Arteriosus in Pre-Term Infants

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Objectives  The aim of this study was to describe our institutional experience with transcatheter coil occlusion of patent ductus arteriosus (PDA) in symptomatic low birth weight pre-term infants.

Background  Transcatheter treatment of PDA in very small infants (<2 kg) is technically challenging and therefore often not considered as an alternative to traditionally accepted modalities (surgical or medical treatment).

Methods  Coil occlusion was offered as an option to selected infants with symptomatic PDA. Case selection for the transcatheter procedure was determined by the patient’s weight, PDA size, size of ampulla, and the anticipated coil mass required for complete closure (determined through echocardiography). The PDA occlusion was achieved with coils delivered with assistance of a 3-F bioptome. Arterial access and catheter manipulation within the cardiac chambers were avoided whenever feasible.

Results  Eight pre-term infants underwent coil occlusion. Gestational age ranged from 27 to 32 weeks (28.7 ± 1.9 weeks). The median birth weight was 1,040 g (range 700 to 1,700 g), and the median weight at the time of procedure was 1,100 g (range 930 to 1,800 g). Three patients were receiving mechanical ventilation before intervention. Duct sizes ranged between 2 and 3.5 mm. Complete occlusion of the duct was instantly achieved in 7 patients, and 1 patient had a small residual flow for 24 h. There were no major procedure or access-related complications; 4 patients were discharged within 72 h; 1 patient was discharged on Day 10. Three patients required prolonged ventilation (34 and 150 days) due to pulmonary pathology.

Conclusions  It is technically feasible to undertake transcatheter coil closure of PDA in carefully selected symptomatic pre-term infants, and it is a safe alternative to surgical ligation. (J Am Coll Cardiol Intv 2010;3:550–5) © 2010 by the American College of Cardiology Foundation
Patent ductus arteriosus (PDA) often complicates the hospital course of pre-term newborns (1). Traditional treatment options include medical treatment with nonsteroidal anti-inflammatory agents, surgical ligation, or clipping. Surgery has been shown to be safe and can be accomplished in the neonatal intensive care unit itself. However, it involves thoracotomy with attendant morbidity and mortality (2). Mortality associated with PDA ligation varies and is dependent on the characteristics of the patients (2,3). Surgery is often challenging in the face of common neonatal problems such as thrombocytopenia and sepsis.

Catheter closure can potentially overcome several of these limitations. However, the transcatheter procedure in small newborns is technically challenging with most currently available hardware. We had previously described a technique that allows occlusion of large PDAs in small infants (4,5). We also reported a modification of this technique to close an aorta–right atrial tunnel in a newborn (6). We have modified the same technique for coil occlusion of PDA in selected pre-term infants. In this article we describe our experience in 8 pre-term infants with PDA.

Methods

We retrospectively reviewed the medical records of all low birth weight pre-term infants who underwent coil closure of PDA at our institute from January 2002 to August 2008. Patient selection for coil occlusion. All pre-term infants referred to our department with symptomatic PDA as evidenced by tachypnea or failure to thrive or those who were dependent on assisted ventilation were evaluated for suitability of coil occlusion. Medical treatment with indomethacin or ibuprofen was attempted in all these patients unless contraindicated. A thorough echocardiogram was performed, and views of the PDA were obtained as described previously (4,5). A number of considerations dictated suitability for coil occlusion. Echocardiographic criteria for selection were based on assessment of size of the ampulla, minimal duct diameter, and weight of the patient. The ampulla had to be large enough to accommodate coils with diameters of approximately twice the diameter of the duct (Fig. 1). An additional concern related to the diameter of the descending thoracic aorta in these small infants. The small descending aorta precluded the use of coils with diameters of 6 mm or more. Consequently, ducts >3.5 mm in diameter were not considered for coil occlusion. Finally the patient’s weight was considered. We did not offer coil occlusion for infants <800 g, because we were uncertain whether a 4-F delivery system could be safely introduced in these infants.

Informed consent. Informed consent was obtained from the families of all patients after carefully explaining the potential risks and alternative treatment options.

Sedation and anesthesia. The procedure was done under conscious sedation in 5 babies with a combination of intravenous ketamine and midazolam. Two patients were ventilator-dependent, and 1 patient who had significant respiratory distress was electively ventilated. Euthermia was maintained by bear huggers and by use of warm saline as flush solution. A neonatologist and an anesthesiologist monitored the patient’s condition during the procedure.

Access. The femoral vein was cannulated with a 24 gauge cannula, and 0.014-inch coronary guidewire was inserted. Once the wire was well into the vessel the cannula was advanced into the femoral vein. The coronary wire was removed, a 0.018-inch short guidewire was introduced, and a 4-F microcatheter sheath (Cook, Inc., Bloomington, Indiana) was introduced over this wire. The microcatheter sheath was then exchanged for a short introducer sheath (4-F in 7 patients, 5-F in 1 patient). Arterial access was avoided unless the femoral artery was accidentally punctured or previously accessed. Heparin (100 U/kg) was used only if arterial access was obtained.

Crossing the duct. As far as possible, catheter manipulation within the cardiac chambers was avoided. A 4-F right coronary catheter was positioned at the inferior vena cava and right atrial junction. A 0.025-inch Terumo guidewire (Terumo Medical Corporation, Somerset, New Jersey) was manipulated across the right ventricle, into the pulmonary artery, and across the PDA into the descending aorta (see Online Video 1). A 25-cm, 4-F introducer sheath (Cook) was tracked over this wire into the aorta. Ductal angiograms were performed in the lateral view (Fig. 2, Online Video 2) and right anterior oblique views through the long delivery sheath positioned at the aorta end of PDA with the technique described previously (4,5). Landmarks for coil placement were identified in relation to trachea-bronchial air shadow or the nasogastric tube (Fig. 2).

Selection and preparation of coils. Ductal anatomy was evaluated by both transthoracic echocardiography and angiography, and the size of the Gianturco coils (Cook) were based on the narrowest diameter of the PDA and the adequacy of the ampulla. Multiple coils (2 in 6 patients, 3 in 1 patient) were used in all but 1 patient. Multiple coils were tied after gentle stretching of their ends with 3-0 prolene suture. The tied coil mass was held with a bioptome and loaded into a 4-F loader sheath. The loader sheath was advanced into the delivery sheath well past the bleed-back valve to avoid the coils catching the bleed-back valve. A 5-F loader and delivery sheaths were used for the patient requiring 3 coils.

Coil delivery. The prepared coil mass was delivered via the long sheath, with the sheath positioned just beyond the ampulla (Online Video 3). This allowed more space for the coils to form. The coils were brought out into the aorta.

Abbreviations and Acronyms

PDA = patent ductus arteriosus
until 1 to 2 mm was retained in the sheath. The entire delivery system was then gently withdrawn until the coil mass was within the ampulla on the basis of the previously identified landmarks. Confirmation of the position of coil mass and absence of any obstruction to adjacent structures was determined by dye injections from the side-arm of the introducer sheath and by echocardiography (Online Video 4). The coil was then released from the bioptome (Online Video 5).

Assessment of results and follow-up. Immediate results were assessed by echocardiography in the cardiac catheterization laboratory. Color Doppler evaluation was done for determination of residual flows and any turbulence at the origin of the left pulmonary artery.

Results

Immediate outcome. Eight pre-term infants underwent coil closure of PDA. The demographic details and preprocedural characteristics are shown in Table 1. The gestational age was 28 ± 1.9 weeks with a range of 27 to 32 weeks. The median birth weight was 1,120 g (range 700 to 1,700 g), and the median weight at the time of procedure was 1,100 g (range 930 to 1,800 g). All patients had poor weight gain. They were all tachypneic and had symptoms of heart failure. Three patients (Patient #1, #6, and #8) required assisted ventilation before the procedure. Seven patients had failed trial of medical management, and in 1 (Patient #8) (Table 1) it was not considered safe because of severe thrombocytopenia. Size of the PDA was 2.5 ± 0.46 mm. Complete occlusion of the duct was achieved immediately in 7, and 1 had tiny residual flows that disappeared in 24 h. Average fluoroscopy time taken for the procedure was 8.1 ± 1.9 min (Table 2). There were no unsuccessful attempts at coil occlusion.

Complications. One patient required transient bag and mask ventilation for apnea during the procedure. There were no procedural complications in other patients.

Subsequent hospital stay. Four patients were fit to be discharged or referred back to the parent hospital for the continuation of pre-term care. One patient remained with us for the continuation of pre-term care and was discharged after 10 days, because there was adequate weight gain. Of the 3 patients who required mechanical ventilation before the procedure, 1 patient was extubated on the third post-procedure day. Patient #6 had multiple congenital anomalies secondary to congenital rubella syndrome, bronchopulmonary dysplasia, and retinopathy of prematurity. He required prolonged ventilation for 34 days and was discharged 52 days after the procedure. Patient #8 had developed bronchopulmonary dysplasia at the time of interven-
tion and was ventilator-dependent for 5 months and finally discharged 6 months after the procedure.

Follow-up. There were no residual PDA flows or recanalization of PDA on follow-up. Follow-up echocardiograms at 1 month and 6 months showed no impingement on adjacent structures or left pulmonary artery turbulence. Median follow-up was 9 months (range 3 to 72 months). Patient #6 died of a lower respiratory tract infection 6 months after the coil closure. Others were doing well on follow-up and had appropriate catch-up weight growth.

Discussion

Transcatheter coil occlusion of small and moderate-size PDA in older infants is well established (4,5). It is considered technically challenging in pre-term small infants. Our experience demonstrates its feasibility in selected pre-term infants. In our view a careful assessment of anatomy of the duct by echocardiography before the procedure is a critical step. The procedure should be planned, as far as possible, during the echocardiography. The assessment of the am-

<table>
<thead>
<tr>
<th>Patient #</th>
<th>Gestation (Weeks)</th>
<th>Age at Procedure (Weeks)</th>
<th>Weight (g)</th>
<th>Symptoms</th>
<th>Trial of Medical Management</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Birth</td>
<td>At Procedure</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>28</td>
<td>8</td>
<td>700</td>
<td>1100</td>
<td>Heart failure, failure to thrive ROP stage II</td>
</tr>
<tr>
<td>2</td>
<td>31</td>
<td>3</td>
<td>1,700</td>
<td>1,300</td>
<td>Heart failure, failure to thrive</td>
</tr>
<tr>
<td>3</td>
<td>27</td>
<td>4</td>
<td>1,200</td>
<td>1,050</td>
<td>Oxygen dependent, failure to thrive, heart failure</td>
</tr>
<tr>
<td>4</td>
<td>28</td>
<td>16</td>
<td>770</td>
<td>1,800</td>
<td>Heart failure</td>
</tr>
<tr>
<td>5</td>
<td>32</td>
<td>4</td>
<td>1,400</td>
<td>1,200</td>
<td>Failure to thrive</td>
</tr>
<tr>
<td>6</td>
<td>28</td>
<td>10</td>
<td>1,200</td>
<td>1,100</td>
<td>Congenital rubella syndrome, ventilator dependent, bronchopulmonary dysplasia, ROP stage III</td>
</tr>
<tr>
<td>7</td>
<td>27</td>
<td>4</td>
<td>1,040</td>
<td>940</td>
<td>Heart failure, failure to thrive</td>
</tr>
<tr>
<td>8</td>
<td>30</td>
<td>4</td>
<td>930</td>
<td>930</td>
<td>Ventilator dependent</td>
</tr>
</tbody>
</table>

*Indomethacin or ibuprofen was not administered because of severe thrombocytopenia.
PDA = patent ductus arteriosus; ROP = retinopathy of prematurity.
Pulla to determine whether enough space is available for the coils of appropriate diameter to be lodged in it is particularly important (4,5,7,8). The diameter of the descending aorta is also an important variable, because the coils have to be opened in the proximal aorta.

There are specific technical steps that are vitally important while catheterizing these very small babies. Attention to specific details relating to access and obtaining the appropriate miniaturized hardware is the first step. Catheter manipulations within the heart have to be minimized to prevent injury and to avoid causing arrhythmias and hemodynamic instability. With a 4-F right coronary catheter positioned at the inferior vena cava–right atrial junction, the PDA was consistently crossed with an angled hydrophilic (Terumo) guidewire that was maneuvered and parked in the distal descending aorta.

A 4-F long introducer sheath was used. Angiography of the PDA was performed via the side arm, and arterial access could be avoided in most (Fig. 1). This allowed simultaneous delivery of 2 0.038-inch coils with a 3-F bioptome. The smallest baby in this series weighed 930 g. The 4-F introducer sheath was easily introduced in this child. We are uncertain about the lowest weight that would allow the safe passage of a 4-F sheath. Although it is conceivable that a 3-F sheath would allow the delivery of a single coil with the same 3-F bioptome, we did not attempt closure with the 3-F sheath.

There have been limited reports of coil occlusion of PDAs in babies <2 kg. Roberts et al. (9) reported attempted coil closure in 10 pre-term neonates with median weight of 2.2 kg (range 1.6 to 2.6 kg). They could achieve transcatheter closure in all except 1. The smallest reported infant was a 1,180-g infant born near term in which PDA was closed with single coil (10). The only other case report that we could identify was that of a 1.4-kg infant who underwent coil closure (11).

Occlusive devices (such as the Amplatzer Duct occluder, AGA Medical Corporation, Plymouth, Minnesota) are now generally accepted for transcatheter treatment of the PDA in older infants >5 kg (12). In smaller infants there is a possibility of narrowing of the adjacent aorta from protrusion of the aortic retention disc (13). Modifications in designs in the second-generations duct occluder (Amplatzer Duct occluder II or ADO II, AGA Medical Corporation) device might mitigate this concern. However, its use in very small and pre-term infants is not recommended (14,15).

Our specific concern with the ADO II is the potential for the retention discs to produce narrowing of the aorta or the pulmonary artery adjacent to the PDA. Therefore, for this select group of very small infants, the only option for catheter-based occlusion of the PDA is coil occlusion, because the coils can be delivered almost entirely within the ampulla.

Our case series clearly demonstrates the feasibility and safety of transcatheter coil occlusion in selected pre-term sick newborns. The most important factors determining success are the weight of the baby, ductal size and anatomy, and the availability of suitable hardware. With attention to anatomic details and planning of hardware, procedural risks can be minimized and success rate can be maximized. Further developments in miniaturization of hardware together with development of newer devices can potentially improve the scope of catheter closure for ducts in pre-term infants (16).

**Study limitations.** This was a retrospective observational study. We did not attempt to make any comparisons between coil occlusion and surgical ligation of PDA, because the decision to do either was based on the anatomy of the duct and body weight. A carefully selected subgroup was offered coil occlusion. Coil occlusion is unlikely to be feasible in pre-term infants with large (>4 mm) ducts. Additionally those infants with a small ampulla are also unlikely to be suitable for coil closure. During the study

<table>
<thead>
<tr>
<th>Patient #</th>
<th>Weight (g)</th>
<th>Access</th>
<th>PDA Size</th>
<th>Coils Chosen</th>
<th>Fluoroscopy Time (min)</th>
<th>Hospital Stay After Procedure (Days)</th>
<th>Follow-Up Duration (Months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1,100</td>
<td>4</td>
<td>24 gauge cannula</td>
<td>2.5</td>
<td>2</td>
<td>0.035–5–5</td>
<td>Complete occlusion</td>
</tr>
<tr>
<td>2</td>
<td>1,300</td>
<td>4</td>
<td>None</td>
<td>2.5</td>
<td>2</td>
<td>0.038–5–5</td>
<td>Complete occlusion</td>
</tr>
<tr>
<td>3</td>
<td>1,000</td>
<td>4</td>
<td>None</td>
<td>2</td>
<td>2</td>
<td>0.038–5–5</td>
<td>Complete occlusion</td>
</tr>
<tr>
<td>4</td>
<td>1,800</td>
<td>5</td>
<td>None</td>
<td>3.5</td>
<td>3</td>
<td>0.038–5–6</td>
<td>Complete occlusion</td>
</tr>
<tr>
<td>5</td>
<td>1,200</td>
<td>4</td>
<td>None</td>
<td>2.5</td>
<td>1</td>
<td>0.038–3–4</td>
<td>Complete occlusion</td>
</tr>
<tr>
<td>6</td>
<td>1,100</td>
<td>4</td>
<td>3-F pigtail</td>
<td>3</td>
<td>2</td>
<td>0.038–3–4</td>
<td>Complete occlusion</td>
</tr>
<tr>
<td>7</td>
<td>940</td>
<td>4</td>
<td>3-F pigtail</td>
<td>2.5</td>
<td>2</td>
<td>0.038–3–4</td>
<td>Complete occlusion</td>
</tr>
<tr>
<td>8</td>
<td>930</td>
<td>4</td>
<td>24 gauge cannula</td>
<td>2.2</td>
<td>2</td>
<td>0.038–3–4</td>
<td>Complete occlusion</td>
</tr>
</tbody>
</table>

*Coil specification: wire thickness (inches = coil length [cm] = coil diameter [mm]).
FA = femoral artery; FV = femoral vein; other abbreviations as in Table 1.
period 74 babies below the age of 3 months underwent surgical closure of ducts at our institute, because their anatomy was not suitable for coil occlusion.

Thus, on the basis of our overall experience, approximately 10% of these very small patients were suited for coil occlusion. However, it seems that with increasing experience a greater proportion of patients can be offered coil occlusion, recognizing that 7 of 8 procedures happened in the last 3 years. This suggests that the proportion of babies with suitable anatomy is small with the available hardware. We did not encounter embolization in this small group of patients. However, coil embolization is likely to have serious consequences. Attempts at retrieval would be very challenging and potentially hazardous. Therefore careful case selection is critical.

Conclusions

Coil occlusion of PDA is possible and can be safely accomplished in carefully selected pre-term low birth weight infants. Thorough echocardiographic delineation of ductal anatomy and attention to specific technical details are vital to the success of this procedure.

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REFERENCES


Key Words: patent ductus arteriosus ▶ pre-term infants ▶ transcatheter intervention.

For accompanying videos, please see the online version of this article.