Stretching of the Ductus
—— An Important Factor in Determining the Outcome of Coil Occlusion ——

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The present study measured the minimal diameter of the ductus (minimal D), the stretched minimal diameter (stretched D), and the stretch index (SI) before coil occlusion in 25 patients with a patent arterial duct. The following factors were compared in the success group (22 cases, coil successfully placed after initial deployment) versus the failure group (3 cases): minimal D, stretched D, SI, the sum of the loop diameter of coils (the loop diameter), the sum of the product of the loop diameter and the number of loops (the loop diameter and number), the loop diameter/minimal D, the loop diameter/stretched D, the loop diameter and number/minimal D, and the loop diameter and number/stretched D. In the failure group, minimal D, stretched D, SI, the loop diameter, and the loop diameter and number were larger than in the success group. The loop diameter/stretched D, and the loop diameter and number/stretched D were smaller in the failure group. Although the loop diameter and number/minimal D was slightly smaller in the failure group, the loop diameter/minimal D was comparable. It is concluded that the stretched D is more reliable than minimal D to determine the appropriate size of coil for successful initial deployment. (Jpn Circ J 1999; 63: 593–596)

Key Words: Coil occlusion; Persistent arterial duct; Stretched minimal diameter

In transcatheter closure of atrial septal defects, the size of the device used is determined not only by the diameter of the defect, but also on its stretched diameter. In coil occlusion of a patent arterial duct (PDA), the size of coil is usually chosen by the simple minimal diameter of the ductus (minimal D); that is, the coil loop diameter should be twice or more than the minimal D. Hijazi et al recommended using multiple coils for PDAs with a minimal D greater than 2.5 mm or more. However, occasionally the coil fails to remain fixed in the ductus and leaks are not unusual, even when the coil size is selected according to these criteria. We previously reported that stretching of the ductus possibly caused size mismatch of the coil with the ductus. In the present study, we investigated whether the size of the coil, minimal D, and the stretched minimal diameter of the ductus (stretched D) determines the outcome of coil occlusion.

Methods

Subjects
We measured the minimal D and stretched D in 25 patients with a PDA. All patients underwent routine diagnostic catheterization followed by coil occlusion of the ductus using detachable PDA coils with 0.038 inch wire (William Cook Europe, Bjaeverskov, Denmark) resulting in complete closure in 24 cases. The loop diameters of coils were 5 or 8 mm with 3–5 loops. The patients ages and body weights ranged from 6 to 210 (51±53, mean±SD) months, and from 5.5 to 48 (15.8±10.9) kg, respectively. Coil occlusion was performed in a single center by one pediatric interventionalist.

Minimal D and stretched D were measured as reported previously. Briefly minimal D was measured on a lateral or anteroposterior view of a flat panel imaging system immediately prior to coil occlusion. Stretched D was measured as follows. (1) A 5F balloon catheter placed across the ductus was retracted and compressed while balloon was gradually inflated with diluted ioxaglate. As soon as slight compression of the balloon was observed as it passed across the narrowest diameter of the ductus, the compressed diameter of the balloon was measured as the stretched D. (2) When a 5F balloon catheter could not be advanced across the ductus, the largest shaft size of a catheter that could be passed across the ductus was taken as the stretched D. The stretch index (SI) was calculated as the stretched D divided by the angiographically documented minimal D. Measurements were corrected for magnification using an appropriately positioned grid. Stretched D was determined as follows. (1) Under cine fluoroscopy, a 5F or 6F wedge balloon catheter placed across the ductus was retracted while the balloon was gradually inflated with diluted ioxaglate. As soon as slight compression of the balloon was observed as it passed across the narrowest diameter of the ductus, the compressed diameter of the balloon was measured as the stretched D. (2) When a 5F balloon catheter could not be advanced across the ductus, the largest shaft size of a catheter that could be passed across the ductus was taken as the stretched D. The stretch index (SI) was calculated as the stretched D divided by the angiographically documented minimal D. Informed consent to measure the stretched D was obtained from the patients’ parents.

Initial coil deployment was successful in 22 cases (success group), but coils failed to stabilize in the ductus in 3 cases (failure group). Coils were retrieved before detachment in 2 cases. A second deployment was successful in these cases using coils with the larger loop diameter. In 1 patient 2 coils migrated to the left pulmonary artery. Although all coils were retrieved by a snare catheter, in that case we abandoned the procedure, judging the minimal D as too large. Of these 24 cases, there was no leak at the end of the procedure in 22 cases. A tiny leak was found in 2 cases, although this disappeared during late follow-up.
Table 1 Results of Coil Occlusion of Persiolent Ductus Arteriosus

<table>
<thead>
<tr>
<th></th>
<th>Success (n=22)</th>
<th>Failure (n=3)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Months</td>
<td>56±55</td>
<td>14±9</td>
<td>0.103</td>
</tr>
<tr>
<td>Weight</td>
<td>16.9±11.2</td>
<td>8.3±2.4</td>
<td>0.104</td>
</tr>
<tr>
<td>Type of Ductus</td>
<td>A=11, C=2, E=9</td>
<td>A=3</td>
<td>0.262</td>
</tr>
<tr>
<td>Minimal D of ductus</td>
<td>1.7±0.9</td>
<td>3.4±0.8</td>
<td>0.004</td>
</tr>
<tr>
<td>Loop diameter</td>
<td>5.2±1.3</td>
<td>10.3±4.6</td>
<td>0.014</td>
</tr>
<tr>
<td>Loop diameter and number</td>
<td>25.4±7.0</td>
<td>34.5±8.1</td>
<td>0.043</td>
</tr>
<tr>
<td>Loop diameter/minimal D</td>
<td>3.8±1.7</td>
<td>5.0±1.0</td>
<td>0.198</td>
</tr>
<tr>
<td>Loop diameter and number/minimal D</td>
<td>17.5±7.4</td>
<td>10.2±1.4</td>
<td>0.036</td>
</tr>
<tr>
<td>Stretched D</td>
<td>2.9±1.6</td>
<td>7.3±3.7</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>SI</td>
<td>1.7±0.3</td>
<td>2.1±0.6</td>
<td>0.047</td>
</tr>
<tr>
<td>Loop diameter/stretched D</td>
<td>2.3±1.0</td>
<td>1.5±0.3</td>
<td>0.076</td>
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<tr>
<td>Loop diameter and number/stretched D</td>
<td>10.5±4.4</td>
<td>5.3±1.7</td>
<td>0.028</td>
</tr>
</tbody>
</table>

Minimal D, minimal diameter; loop diameter, sum of the loop diameter of all coils deployed; loop diameter and number, sum of the product of the loop diameter and number of loops deployed; Stretched D, stretched minimal diameter of the ductus; SI, stretch index.

Fig 1. Distribution and mean (±SD) of minimal D, the loop diameter, the loop diameter and number, the loop diameter/minimal D, and the loop diameter and number/minimal D in the successful group (open circles) and failure group (closed circles). minimal D, minimal diameter of the ductus; stretched D, stretched minimal diameter of the ductus; the loop diameter, sum of the loop diameter of all coils deployed; the loop diameter and number, sum of the product of the loop diameter and the number of the loops deployed.

Fig 2. Distribution and mean (±SD) of stretched D, SI, the loop diameter/stretched D, and the loop diameter and number/stretched D in the successful group (open circles) and failure group (closed circles).
following factors were compared in the success versus the failure group: weight, minimal D, stretched D, SI, the sum of the loop diameter of all coils for deployment (the loop diameter), the sum of the product of the loop diameter and the number of the loops (the loop diameter and number), the loop diameter/minimal D, the loop diameter/stretched D, the loop diameter and number/minimal D, and the loop diameter and number/stretched D. If we deploy 2 coils, 5 mm with 5 loops and 8 mm with 4 loops, the sum of the loop diameter of all coils, and the sum of the product of the loop diameter and the number of the loops are calculated, respectively, as follows:

\[ 5 \times 4 + 8 \times 5 = 57 \]

**Statistical Analysis**

All data are expressed as mean ± SD. Statistical analysis was performed by Mann-Whitney's U test (the loop diameter, and the loop diameter and number) or unpaired t-test (other parameters) using StatView 4.5 software.

**Results**

Age and weight were slightly smaller in the failure group than in the success group, though these differences were not statistically significant. There was no significant difference in the type of ductus (Table 1). Minimal D, the loop diameter, and the loop diameter and number were larger in the failure group. The loop diameter and number/minimal D appeared slightly smaller in the failure group, although the loop diameter/minimal D was comparable between the 2 groups (Table 1, Fig 1). Stretched D and SI were larger in the failure group. The loop diameter/stretched D was slightly smaller in the failure group and the loop diameter and number/stretched D was significantly smaller in this group (Table 1, Fig 2). Of the loop diameter/minimal D, the loop diameter and number/minimal D, the loop diameter/stretched D, and the loop diameter and number/stretched D, only the p-value of the loop diameter and number/stretched D was statistically significant. In the failure group, the loop diameter/stretched D, and the loop diameter and number/stretched D was less than 1.8 and 7.0, respectively.

**Discussion**

Several factors may determine the outcome of coil occlusion of a PDA, including the age and weight of the patient, the minimal diameter of the ductus, type of ductus, size of coils, and the technical skill of the interventionist. Three major coil types are currently used for PDA occlusion; that is, Gianturco coil\[6–9,11\] detachable PDA coil\[10,12,13\] and Duct-Occlud pfm\[10,14\] Technical modifications have also been reported for safe and effective deployment\[15–18\]. Although there is no prospective controlled study on how the type of coil or technical differences influence the outcome, short or medium term results so far reported are comparable\[10,19\]. Only the minimal diameter and ductus type are recognized as definitive predictive outcome factors. In Japan, including the hospital of Sapporo Medical University, detachable PDA coils are widely used for duct occlusion\[10\]. We retrospectively investigated the influence of stretched diameter of the ductus on the outcome of coil occlusion in a single center.

Among 25 cases initial coil deployment failed in only 3 cases. Of these, in 2 cases success was achieved with a second coil deployment. Consequently we successfully deployed coils in 24/25 (96%) cases. This high success rate limits our comparison between the success and failure groups. Although age and patient weight slightly influenced the initial deployment, we believe these are not crucial factors as long as they are in the age range of the present study group. Minimal D, the loop diameter, and the loop diameter and number were larger in the failure group. Although the loop diameter and number/minimal D was slightly smaller in the failure group, the loop diameter/ minimal D was comparable in both groups. These data indicate that coils failed to remain fixed in the ductus in the failure group, despite the use of larger loop coils with the loop diameter/minimal D comparable to the success group. We conclude that choosing a larger loop simply on the basis of minimal D might not guarantee safe initial deployment. The smaller loop diameter and number/minimal D in the failure group suggests that not only the loop size but also the number of loops should be large compared with the minimal D. Stretched D and SI were significantly larger in the failure group. Both the p-value of the loop diameter/ stretched D, and the loop diameter and number/stretched D were smaller than that of the loop diameter/minimal D, and loop diameter and number/minimal D, respectively. This implies that the stretched D may be a more reliable predictor of coil size than the minimal D for successful initial deployment of coils. As only the loop diameter and number/stretched D had a significant p-value, we conclude that, for successful deployment, the best way to determine the size of coils is to take both the loop diameter of the coil and the number of loops into consideration based on the stretched D.

In a previous study, we reported that the narrowest segment of the ductus could be stretched up to about twice its angiographic minimal diameter. Our recommendation, to allow for stretching, was that the sum of the loop diameters for initial deployment should be twice to 3 times, and the sum of loop diameters of total coils needed to be 3–4 times the minimal diameter of the ductus. Judging from the fact that in the present failure group the loop diameter/ stretched D, and the loop diameter and number/stretched D was less than 1.8 and 7.0, respectively, the sum of the loop diameters, and the sum of the product of the loop diameter and the number of the loops should be around 1.8 and 7.0 times, respectively, the stretched D for the safe initial deployment.

**Study Limitation**

As mentioned earlier, the small number in the failure group may limit comparisons. The retrospective uncontrolled nature of this study may be another drawback. The smallest diameter of the coil used in this study was 5 mm, although the success group included several ductuses with a minimal D of around 1 mm. Consequently the loop diameter/minimal D, the loop diameter/stretched D, the loop diameter and number/minimal D, and the loop diameter and number/stretched D may have been overestimated. However, we believe these numbers in the failure group are significant, as all ductuses in that group had a minimal D ≥2 mm.

**Acknowledgment**

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References
