Analysis of Aortopulmonary Window Using Cardiac Magnetic Resonance Imaging

James Wong, MA, MB BChir, MRCPCH; Sujeev Mathur, MBBS, MRCPCH; Daniel Giese, PhD; Kuberan Pushparajah, BMBS; Tobias Schaeffter, PhD; Reza Razavi, MD; Gerald F. Greil, MD

A 1-day-old infant was referred to our pediatric cardiology service with tachypnea and differential saturations of 95% in the right arm and 85% in the left arm and lower limbs. Echocardiography showed a small patent foramen ovale with the presence of an aortopulmonary window. There was difficulty visualizing the aortic arch and distal pulmonary arteries, and therefore magnetic resonance imaging (MRI) of the great arteries was performed.

A contrast agent–enhanced MR angiogram and a 4-dimensional flow MRI sequence (velocity encoding, 250 cm/s; field of view, 180x180x77.5 mm; voxel size, 2.25x2.3x2.5 mm; repetition time/echo time = 3.8/2.4; 20 phases; flip angle, 5°; SENSE 3 [2 in the phase-encoding direction and 1.5 in the slice-encoding direction]; respiratory self-gating for motion correction)1 were used to demonstrate anatomy and flow patterns within the great arteries and provide quantitative assessment of hemodynamics with the use of a commercial 1.5-T MRI scanner (Achieva; Philips Healthcare, Best, Netherlands).

The use of contrast-enhanced MRI provides detailed 3-dimensional anatomic information of the great vessels within a single breath hold. This patient was found to have an interrupted aortic arch between the left common carotid artery and the left subclavian artery and an aortopulmonary window.2 Conventional 2-dimensional phase-encoded contrast flows provide information from a prespecified plane. However, abnormal flow patterns due to shunting of blood can be missed while the patient is being scanned. Four-dimensional flow MRI can bridge this gap and obtain qualitative and quantitative data within a single data set, allowing retrospective flow analysis in any plane.3 In this subject, a complete qualitative (Figure and Movie I in the online-only Data Supplement) and quantitative (Table) assessment of anatomy and flow was achieved in 15 minutes. Analysis was performed with the use of proprietary software (GT Flow).

Despite the presence of blood shunting across the aortopulmonary window (Table), the high pulmonary vascular resistance seen in newborns contributes to the balance in flow between the lungs (Qp) and systemic circulation (Qs) in this patient (Qp:Qs = 1). A fall in pulmonary vascular resistance, which typically occurs during the first few weeks of life, would increase pulmonary blood flow, leading to congestive heart failure. Furthermore, because no ventricular septal defect is present, the flow through the proximal aorta and

Figure. Three-dimensional magnetic resonance angiogram reconstruction of heart and great vessels with 4-dimensional flow sequence overlay.
main pulmonary artery demonstrates balanced ventricular stroke volumes, making this suitable for a biventricular repair. On the basis of these MRI findings, a decision was made to perform early corrective surgery. This was successfully performed on day 3 of life.

Thus far, the clinical use of 4-dimensional flow sequences has been limited by the duration of the MRI sequence and the amount of data that needs to be processed and displayed. This is now overcome with the use of novel MRI technology and postprocessing methods. Improved and simplified diagnosis and preoperative assessment of complex congenital heart disease with MRI will now be possible.

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Disclosures
None.

References

Table: Quantitative Analysis of the 4D Flow Dataset

<table>
<thead>
<tr>
<th></th>
<th>Aorta</th>
<th>MPA</th>
<th>RPA</th>
<th>LPA</th>
<th>Ascending Aorta</th>
<th>Ductal Arch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forward flow (mls)</td>
<td>6.4</td>
<td>8.5</td>
<td>4.2</td>
<td>2.2</td>
<td>3.2</td>
<td>5.5</td>
</tr>
<tr>
<td>Backward flow (mls)</td>
<td>0.4</td>
<td>0.7</td>
<td>0.1</td>
<td>0.2</td>
<td>0.1</td>
<td>0.7</td>
</tr>
<tr>
<td>Stroke volume (mls)</td>
<td>6.0</td>
<td>7.8</td>
<td>4.1</td>
<td>2.0</td>
<td>3.1</td>
<td>4.8</td>
</tr>
<tr>
<td>Cardiac output</td>
<td>13.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pulmonary flow (mls)</td>
<td>6.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Systemic flow (mls)</td>
<td>7.9</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Stroke volumes (mls) of each vessel calculated from the 4D flow sequence. The stroke volume of the proximal aorta and main pulmonary artery (MPA) make up the cardiac output. Because no ventricular septal defect was present, both ventricles created sufficient stroke volumes for biventricular repair. The stroke volume into the right pulmonary artery (RPA), left pulmonary artery (LPA), distal ascending aorta, and ductal arch result in a similar volume compared to the cardiac output. Flow across the aorto-pulmonary window is predominantly left to right. The ratio of pulmonary to systemic blood flow (Qp:Qs) is approximately equal, being in line with a stable newborn without congestive heart failure.
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