Congenital Heart Disease

Comparison of Magnetic Resonance Imaging and Angiography on the Assessment of Coarctation of the Aorta

Cheng-Hsiang Lien,1,2 Betau Hwang,3 Chui-Mei Tiu,4 Jen-Dar Chen,4 Pi-Chang Lee3 and Chung-Chang Laura Meng1

Background: Coarctation of the aorta (CoA) is encountered in 8% to 10% of all patients with congenital heart defects. In the past, the confirmed diagnosis of CoA relied on angiography, however, this technique uses hazardous radiation, and carries a risk of causing vascular damage at the puncture site, particularly in infants. This study aimed to discover whether magnetic resonance imaging (MRI) was a useful non-invasive tool to estimate the severity of CoA before or after repair.

Methods: Ten children (4 boys and 6 girls), aged from 17 days to 7 years (mean, 1.1 years), 6 who had native CoA and 4 who had re-stenosis after repair, underwent MRI and angiography. The diameters of the aortic arch at the left carotid artery branching (AA), as well as the diameters at the narrowest site on the aorta and descending aorta in the diaphragmatic area (DA), were measured and compared using the above-mentioned 2 methods. Linear correlation coefficients were applied to compare the correlation between MRI and angiography. The relative narrowing of CoA was calculated by using CoA / DA \times 100\% between MRI and angiographic measurement. Narrowing of more than 60\% was thought to induce a significant pressure gradient that called for surgical intervention.

Results: The mean diameters of AA, CoA and DA were, respectively, 6.3 \pm 1.8 \text{mm}, 3.8 \pm 2.0 \text{mm} and 7.2 \pm 1.4 \text{mm} by MRI measurement, and 6.6 \pm 2.7 \text{mm}, 4.0 \pm 2.1 \text{mm} and 7.2 \pm 1.8 \text{mm} by angiography. The mean differences of measured diameters by the 2 methods were AA 1.48 \text{mm} (SD = 1.32 \text{mm}), CoA 0.72 \text{mm} (SD = 0.78 \text{mm}) and DA 0.90 \text{mm} (SD = 0.83 \text{mm}). The linear correlation coefficient (r value) for the diameter of different locations along the aorta as measured by MRI and angiography was 0.662 at AA, 0.868 at CoA and 0.706 at DA. Using this criteria, there was a consistent, relative narrowing calculated by both MRI and angiography.

Conclusion: The mean difference, when taken together with a good linear correlation coefficient of the diameters as measured by MRI and angiography, make this technique acceptable. In addition, MRI proved to be a reliable predictor of the probable severity of coarctation. As a result, we may conclude that MRI is suitable for evaluating the location, size and severity of the coarctation before and after treatment.

Key Words: Coarctation of the aorta • Magnetic resonance imaging • Angiography

INTRODUCTION

Controversies exist over the methods used to diagnose and treat coarctation of the aorta (CoA). Currently, the evaluation and quantification of CoA still relies on angiography. However, this technique requires the use of hazardous radiation and also carries the risk of vascular damage at the puncture site, particularly in infants.
Alternative non-invasive methods such as 2-dimensional echocardiography (2-DE) with simultaneous employment of the Doppler technique have been tried, nevertheless, difficulties have been found in delineating the area of the coarctation.\textsuperscript{2-4} Computerized tomography (CT) was also employed to investigate its effects on CoA.\textsuperscript{5} Magnetic resonance imaging (MRI), a non-invasive approach, can delineate larger vessels, of which tomographic slices can be taken in any projection.\textsuperscript{2} In addition, MRI is a reliable non-invasive investigative method for the diagnosis and semi-quantitative evaluation of CoA particularly when color Doppler ultrasound is not found to be satisfactory.\textsuperscript{6} The purpose of this study was to compare MRI with angiography in an investigation of the severity of narrowing vessels in CoA patients both before and after operations.

**MATERIALS AND METHODS**

**Study patients**

There were ten patients, 4 boys and 6 girls, aged from 17 days to 7 years (mean ± SD, 1.1 ± 2.2 years). Among them, 6 patients had native CoA, and 4 patients had suspected re-coarctation resulting from surgical repair. All 10 patients underwent MRI and angiography examinations.

**MRI**

MRI studies were performed on a 1.5T scanner (General Electric, Milwaukee, WI), with contrast-enhanced 3D time of flight MR angiography on an oblique sagittal plane, with fast SPGR pulse sequence, flip angle 20° TR: 5.2 msec, TE: 1.1 msec, 2.8 mm slice thickness, 256 × 160 or 256 × 192 matrix and 2 NEX (number of excitations). To calm non-cooperating patients, intravenous Dormicum were used. A contrast agent was administered by hand injection at a bolus volume, in sum of 0.2-0.4 cc contrast medium/kg, at the fastest rate. Acquisition time, which ranged from 30 to 50 seconds, depended on the slice number, which was in turn assigned according to the patient’s body size. The total time taken for each exam was about 30-50 minutes.

**Angiography**

All 10 patients underwent routine biplane aortography. The aorta was imaged in a straight frontal and lateral projection. End-diastolic aortic diameters were also measured. For all measurements, a known catheter size was used for calibration. The angiographic sampling rate was 100 frames/s. Measurements were performed on the most clearly imaged projection taken of the aortic section.

**Diameter measurements**

MRI and angiography were applied to measure diameters of the aortic arch at the origin of the left carotid artery branch (AA), narrowest site (CoA) and descending aorta (DA) in the diaphragmatic area (Figure 1). The
findings and measurements of the aorta captured by MRI and angiography were compared using the following statistical methods.

Statistics
Mean differences were determined between MRI and angiographic measurements of aortic diameters. The aortic diameters measured by angiography and MRI were also compared by calculating linear correlation coefficients. Relative narrowing was calculated for angiographic and MRI recordings by using the equation: CoA/DA × 100%.

RESULTS

The diameters of AA, CoA and DA measured by MRI and angiography are listed in Table 1. The mean diameters measured by MRI were 6.3 ± 1.8 mm for AA, 3.8 ± 2.0 mm for CoA and 7.2 ± 1.4 mm for DA. The mean diameters measured by angiography were 6.6 ± 2.7 mm for AA, 4.0 ± 2.1 mm for CoA and 7.2 ± 1.8 mm for DA. The mean differences of the diameters measured by MRI and angiography were 1.48 mm (SD = 1.32 mm) for AA, 0.72 mm (SD = 0.78 mm) for CoA and 0.90 mm (SD = 0.83 mm) for DA. The linear correlation coefficient value (r value) of MRI and angiographic measurement was 0.662 for AA (p value 0.0011) (Figure 2), 0.868 for CoA (p value 0.0225) (Figure 3) and 0.706 for DA (p value 0.0371) (Figure 4). There were 4 patients for whom the respective findings of CoA/DA × 100% conducted by angiography were smaller than 40%, and in their cases a narrowing of more than 60% existed. In addition, their MRI find-

![Figure 2. The linear correlation coefficient value (r value) of MRI and angiographic measurement was 0.662 for AA.](image)

![Figure 3. The linear correlation coefficient value (r value) of MRI and angiographic measurement was 0.868 for CoA.](image)

<table>
<thead>
<tr>
<th>Patients no.</th>
<th>AA MRI (mm) / Angio (mm)</th>
<th>CoA MRI (mm) / Angio (mm)</th>
<th>DA MRI (mm) / Angio (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6.6 / 6.0</td>
<td>2.5 / 1.6</td>
<td>6.6 / 6.0</td>
</tr>
<tr>
<td>2</td>
<td>5.0 / 5.0</td>
<td>2.5 / 2.2</td>
<td>7.5 / 7.3</td>
</tr>
<tr>
<td>3</td>
<td>6.2 / 5.0</td>
<td>3.3 / 3.3</td>
<td>6.2 / 5.0</td>
</tr>
<tr>
<td>4</td>
<td>8.5 / 12.5</td>
<td>5.7 / 6.6</td>
<td>8.0 / 8.3</td>
</tr>
<tr>
<td>5</td>
<td>4.2 / 4.5</td>
<td>2.1 / 2.0</td>
<td>5.7 / 5.4</td>
</tr>
<tr>
<td>6</td>
<td>8.0 / 5.0</td>
<td>8.0 / 6.6</td>
<td>8.4 / 6.6</td>
</tr>
<tr>
<td>7</td>
<td>5.0 / 6.2</td>
<td>3.7 / 4.5</td>
<td>6.6 / 7.5</td>
</tr>
<tr>
<td>8</td>
<td>3.5 / 4.4</td>
<td>1.4 / 1.5</td>
<td>5.7 / 6.2</td>
</tr>
<tr>
<td>9</td>
<td>8.3 / 7.5</td>
<td>4.8 / 5.0</td>
<td>10.4 / 10.0</td>
</tr>
<tr>
<td>10</td>
<td>7.2 / 10.0</td>
<td>4.1 / 6.6</td>
<td>7.2 / 10.0</td>
</tr>
<tr>
<td>Mean ± SD mm</td>
<td>6.3 ± 1.8 / 6.6 ± 2.7</td>
<td>3.8 ± 2.0 / 4.0 ± 2.1</td>
<td>7.2 ± 1.4 / 7.2 ± 1.8</td>
</tr>
</tbody>
</table>

AA = Diameters of the aortic arch at the origin of the left carotid artery branch; Angio = Angiography; CoA = Diameters of the narrowest site of the aorta; DA = Diameters of the descending aorta in the diaphragmatic area; MRI = Magnetic resonance imaging.

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DISCUSSION

CoA accounts for between 8% and 10% of all cases of congenital heart defects. Several diagnostic methods, including angiography, 2-DE and MRI were applied to the diagnosis of CoA following a physical examination. Although each method had its pros and cons, for instance, 2-DE was an effective method in grading a discrete stenosis, but it was unable to image the aortic isthmus of some older children and adults with satisfactory quality.8,9 Among these diagnostic methods, MRI provided the highest definition imaging of the cardiovascular structure and its relationship to adjacent structures. It should also be noted that it is a non-invasive approach, which not only reduces exposure to radiation but also lowers the risks of cardiovascular damage. Still, angiography is considered the gold standard for the diagnosis of CoA, despite the fact that angiography may cause radiation exposure, arrhythmia and the risk of cardiovascular damage.10

Our results revealed that there was an acceptable mean difference between the diameters measured by MRI and angiography. The mean difference was similar to those given in previous reports.7 A good linear correlation between the diameters measured by MRI and angiography on aortic diameter was also found, and the figures proved similar to those given in previous reports.2,3,10 The severity of coarctation is expressed as a percentage of the narrowest lumen compared to the diameter of descending aorta in the diaphragmatic area (CoA/DA × 100%). A previous report indicated that a narrowing of more than 60% was thought to induce a significant pressure gradient and therefore should be viewed as a possible trigger for surgical intervention.7,9 In this study, the MRI findings on 4 out of 10 patients showed the narrowest diameter of coarctation on each of these 4 patients, of which the descending parts in the diaphragmatic area were measured at more than 60%. The MRI findings were consistent with the angiographic measurements.

It can be concluded from this study that MRI is a non-invasive method suitable for replacing angiography in some patients with CoA, especially for those patients who are at higher risk for complications or damage related to angiography. MRI may also be applied as a reliable method for the primary post-operative evaluation of CoA. However, several diagnoses and interventions, such as the assessment of left ventricular function, the assessment of pulmonary artery pressure and resistance, or balloon angioplasty, still have to be conducted by angiography. As such, MRI may be considered as a complementary tool for evaluation, not as a complete replacement for angiography.

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REFERENCES

比較核磁共振影像及血管攝影對主動脈弓縮窄之評估

連振祥1,2 黃碧桃3 刁翠美4 陳振德4 李必昌1 孟春昌1
台北市 台北榮民總醫院 兒童醫學部1 放射線部4
台北市立陽明醫院小兒科2
台北市 國立陽明大學3

背景  主動脈弓縮窄的發生率佔所有先天性心臟疾病的百分之八至十。以往，主動脈弓縮窄的確定診斷端賴心臟血管攝影術。然而，此技術使用幅射線且有可能引起血管傷害之危険，特別是在對嬰幼兒的使用上。此研究之目的乃在探討核磁共振影像 (MRI) 是否可作為評估主動脈弓縮窄術前術後严重影响的有用且非侵犯性工具。

方法  總計有 10 名病童 (四位男童和六位女童)，其年齡分布為 17 天至七歲 (平均為 1.1 歲)。其中有六位病童為先天性主動脈弓縮窄及四位病童為術後復發縮窄，分別進行 MRI 和心臟血管攝影檢查。分別以 MRI 及心臟血管攝影術測量及比較在左頸動脈分支之主動脈弓 (AA)，主動脈最狹窄處 (CoA)及橫膈膜處之下降主動脈 (DA) 之直徑。利用統計得出 MRI 及心臟血管攝影所測得之直徑，且以 CoA / DA × 100% 計算分別以 MRI 及心臟血管攝影所測得之相對主動脈弓縮窄。

結果  以 MRI 測得之 AA，CoA 及 DA 的平均直徑為 6.3 ± 1.88 公釐，3.8 ± 2.0 公釐，及 7.2 ± 1.8 公釐。利用心臟血管攝影所測得之數值則為 6.6 ± 2.7 公釐，4.0 ± 2.1 公釐及 7.2 ± 1.8 公釐。此二種方法所測得之平均差在 AA 為 1.48 公釐 (SD = 1.32 公釐)，CoA 為 0.72 公釐 (SD = 0.78 公釐)，DA 則為 0.90 公釐 (SD = 0.83 公釐)。以 MRI 及心臟血管攝影所測得之主動脈各位置之直徑其線性相關係數 (r 值) 在 AA 為 0.662，CoA 為 0.868 和 DA 為 0.706。相對主動脈弓縮窄超過 60%者被認為會引發有意義之壓力差且應以手術治療之。依此標準，發現以 MRI 及心臟血管攝影所測得之相對主動脈弓縮窄是一致的。

結論  以 MRI 及心臟血管攝影所測得之直徑顯示有可接受的平均差及好的線性相關係數。此外，MRI 就狹窄之嚴重度的評估提供了一可信賴的而與心臟血管攝影一致的結果。是故，可認定 MRI 適於評估主動脈弓縮窄術前術後狹窄之位置、大小及嚴重度。

關鍵詞：主動脈弓縮窄、核磁共振影像、心臟血管攝影。