Coronary Magnetic Resonance Angiography in Adolescents and Young Adults With Kawasaki Disease

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Background—In patients with Kawasaki disease, serial evaluation of the distribution and size of coronary artery aneurysms (CAAs) is necessary for risk stratification and therapeutic management. Although transthoracic echocardiography is often sufficient for this purpose initially, visualization of the coronary arteries becomes progressively more difficult as children grow. We sought to prospectively compare coronary magnetic resonance angiography (MRA) and x-ray coronary angiography findings in patients with CAA caused by Kawasaki disease.

Methods and Results—Six subjects (age 10 to 25 years) with known CAA from Kawasaki disease underwent coronary MRA using a free-breathing T2-prepared 3D bright blood segmented k-space gradient echo sequence with navigator gating and tracking. All patients underwent x-ray coronary angiography within a median of 75 days (range, 1 to 359 days) of coronary MRA. There was complete agreement between MRA and x-ray angiography in the detection of CAA (n=11), coronary artery stenoses (n=2), and coronary occlusions (n=2). Excellent agreement was found between the 2 techniques for detection of CAA maximal diameter (mean difference=0.4±0.6 mm) and length (mean difference=1.4±1.6 mm). The 2 methods showed very similar results for proximal coronary artery diameter (mean difference=0.2±0.5 mm) and CAA distance from the ostia (mean difference=0.1±1.5 mm).

Conclusion—Free-breathing 3D coronary MRA accurately defines CAA in patients with Kawasaki disease. This technique may provide a non-invasive alternative when transthoracic echocardiography image quality is insufficient, thereby reducing the need for serial x-ray coronary angiography in this patient group. (Circulation. 2002;105:908-911.)

Key Words: Kawasaki disease ■ aneurysm ■ magnetic resonance imaging ■ angiography

Kawasaki disease is an acute vasculitis of unknown etiology that predominantly occurs in young children and produces coronary artery aneurysms (CAAs) in 15% to 25% of untreated cases.1,2 CAAs may rupture, thrombose, or develop stenotic lesions that cause myocardial ischemia. Serial evaluation of the distribution and size of CAAs is necessary for risk stratification and therapeutic management.3,4 Although transthoracic echocardiography is often sufficient for this purpose initially, visualization and characterization of the coronary arteries become progressively more difficult as children grow.4 Serial evaluation with x-ray angiography carries risks associated with its invasive nature and exposure to ionizing radiation, and is more expensive.5 Non-invasive coronary magnetic resonance angiography (MRA) has previously been shown to be useful in the diagnosis of anomalous origin of the coronary arteries,6,7 native coronary artery disease,8,9 and coronary bypass graft patency.10 Reports on the use of current coronary MRA techniques in Kawasaki disease have been limited to 1 or 2 patients, often without comparison to x-ray angiography.11-16 To evaluate the clinical usefulness of coronary MRA in Kawasaki disease, this study prospectively compared coronary MRA and x-ray coronary angiography findings in patients with CAAs.

Methods

Subjects
Subjects meeting the following criteria were included in this study: (1) a diagnosis of Kawasaki disease, (2) known CAA, (3) recent (<1 year) or scheduled x-ray coronary angiography, (4) age >8 years, and (5) no contraindication to MRI. Written informed consent for coronary MRA was obtained from all participants or their legal guardians, and the protocol was approved by the Committee on Clinical Investigation, Beth Israel Deaconess Medical Center. Permission to conduct a medical record and database review was obtained from the Children’s Hospital Committee on Clinical Investigation.

Coronary MRA
Coronary MRA studies were performed on a commercial 1.5T Gyroscan ACS-NT whole body MR system (Philips Medical Systems) equipped with cardiac software (INCA2), a fast gradient
system (23 mT/m, 220 ms rise time), and a cardiac synergy receiver coil. All examinations were performed without sedation and during uncoached free breathing.

The coronary MRA technique has been previously described. Briefly, navigator gating with prospective slice correction is used to compensate for respiratory motion. A flow insensitive T2-prepulse for contrast enhancement is followed by a localized anterior saturation prepulse, the navigator, the spectrally selective fat saturation pulse, and finally a 3D segmented k-space gradient echo sequence (TE=2.4 ms, TR=8.8 ms) with 8 phase encoding steps per cardiac cycle. Data acquisition along the major axis of the artery is performed in mid-diastole. One signal average is performed, and no flow-compensating gradients are used. Twenty slices with a 3-mm thickness (interpolated to 1.5 mm) are acquired with a 360-mm field-of-view and a 512×360 matrix (in-plane voxel size of 0.7×1.0 mm). The scanning protocol was accomplished in approximately 30 minutes.

**X-Ray Coronary Angiography**

All patients were sedated with intravenous morphine and midazolam during catheterization. Multiple selective injections of the right and left coronary system were digitally recorded with biplane fluoroscopy for later review.

**Image Analysis**

X-ray and MRA images were analyzed independently. For coronary MRA, semiautomatic multplanar reformatting of the 3D data was performed on a workstation (EasyVision 4.0, Philips Medical Systems) by an investigator blinded to the x-ray results. X-ray measurements were calibrated to catheter size. Epicardial coronary arteries were assessed for the presence of aneurysms and stenoses. A coronary aneurysm was diagnosed if the internal lumen diameter was ≥4.0 mm, or if the internal diameter of a segment measured at least 1.5 times that of an adjacent segment (Japanese Ministry of Health criteria). A coronary stenosis was defined as diameter narrowing ≥50%. The maximal CAA diameter and length, the maximal diameter of the proximal coronary arteries, and the distance from the coronary ostia to the CAA were recorded.

**Statistical Analysis**

Data are expressed as mean±SD. Bland-Altman analysis and a two-tailed paired t test were applied to assess agreement between measurements with coronary MRA and x-ray coronary angiography. A P value ≤0.05 was considered significant.

**Results**

Six subjects (age 10 to 25 years, weight 30 to 63 kg, 4 males) met inclusion criteria and all completed MRA and x-ray angiography without complications. MRA was performed at a median of 12.7 years (range 5.5 to 23.3) after the diagnosis of Kawasaki disease. The median time between MRA and x-ray angiography was 75 days (range 1 to 359 days).

Representative coronary MRA and x-ray angiography images are shown in Figure 1. MRA and x-ray angiography diagnoses of CAA (n=11) agreed completely. The CAAs were located in the proximal right (RCA; n=4), left main (LM; n=1), left anterior descending (LAD; n=4), and left circumflex (LCX; n=2) coronary arteries. On MRA, the mean continuously visualized length of coronary artery was 42±17 mm for the combined LM and LAD, 27±9 mm for the LCX, and 91±35 mm for the RCA. Because of motion artifacts, one normal RCA could not be visualized by MRA and a distal CAA in the LCX was demonstrated, but image quality was not sufficient for quantitative measurement. For the remaining CAAs, maximal diameters by MRA and x-ray angiography agreed closely (Figure 2A) and were not significant different (P=NS). Maximal CAA lengths were also similar (Figure 2B), although MRA measurements were slightly larger than x-ray angiography measurements (14.6±4.2 mm versus 13.3±3.8 mm, P=0.03). Both coronary MRA and x-ray angiography demonstrated occlusions of the proximal LAD and distal RCA in 1 subject and stenosis of the LAD in 2 subjects. No other stenotic lesions were identified with either technique. Maximal proximal coronary artery diameters determined agreed closely (Figure 2C) and were not significantly different (P=NS). Finally, the distances from the coronary ostia to the CAA were comparable (Figure 2D) and not significantly different (P=NS), indicating that the same CAAs were identified with both techniques.

**Discussion**

This study prospectively evaluated the ability of coronary MRA to detect and measure CAAs in Kawasaki disease using x-ray coronary angiography as the reference standard. MRA accurately diagnosed all 11 CAAs with dimensions that agreed well with x-ray angiography. In addition, MRA detected the 2 coronary occlusions and 2 coronary stenoses present on x-ray angiography. To our knowledge, this study is the largest reported series of patients with Kawasaki disease to be evaluated using current coronary MRA techniques and one of very few to systematically compare findings to x-ray angiography.

In the United States, Kawasaki disease is the most common cause of acquired heart disease in childhood. Although administration of intravenous gamma globulin reduces the incidence of CAA, coronary abnormalities may still develop as the result of treatment failures or late diagnosis. CAA size
often changes over time and is positively correlated with the risk of coronary thrombosis and of development of stenosis and myocardial ischemia.\textsuperscript{1,2} As a result, serial assessment of aneurysm size is important for determining the need for antithrombotic therapy and the intensity of follow-up.\textsuperscript{3}

As children grow, their coronary arteries often cannot be adequately visualized by transthoracic echocardiography. For those patients who might otherwise require serial catheterizations, coronary MRA may be a useful noninvasive alternative for detecting and monitoring CAAs. Moreover, emerging MRI techniques to visualize the vessel wall, rather than simply the lumen as in x-ray angiography, may yield information on the transformation from CAA to stenosis.\textsuperscript{11,22} Combined with the established ability of MRA to visualize aneurysms in other systemic arteries, MRA has the potential to play a central role in the follow-up of patients with Kawasaki disease.

Limitations
The number of subjects in this study is small, all subjects had known CAA, and serial data are not yet available. This study compared measurements derived from a projectional imaging technique (x-ray angiography) to those from reformatted three-dimensional image data (MRA). There may be inherent small measurement discrepancies between these techniques, particularly for tortuous vessels. Detection and measurement of distal coronary artery lesions using current coronary MRA techniques may be limited.

Conclusions
In patients with a history of Kawasaki disease, coronary MRA can be used for CAA detection and measurement. Such an approach may provide a non-invasive alternative when transthoracic echocardiography image quality is insufficient, thereby reducing the need for x-ray angiography in this population.

Acknowledgments
Dr Greil was supported by grants No. 1751/1–1 and No. 1751/1–2 from the Deutsche Forschungsgemeinschaft, Bonn, Germany. Dr Newburger is supported in part by the Kobren Fund. Dr Manning is an established investigator of the American Heart Association (9740003N), Dallas, Tex.

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_Circulation_. 2002;105:908-911
doi: 10.1161/hc0802.105563
_Circulation_ is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
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Print ISSN: 0009-7322. Online ISSN: 1524-4539

The online version of this article, along with updated information and services, is located on the World Wide Web at:
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