3d Gadolinium-Enhanced MR Angiography In Congenital Heart Disease: Comparison of High Resolution Recirculation and First-Pass Techniques

James Earls, Bruce Urban, Elise Berman, Charlene Curry, Sherif Tawfik, Steven Shapiro, Bechara Akl, and Lucas Collazo. Department of Radiology, Inova Fairfax Hospital and Fairfax Radiological Consultants, Falls Church, VA. (JE, EB, CC, BU), Department of Pediatric Cardiology (ST, SS) and Cardiothoracic Surgery (BS, LC) Inova Fairfax Hospital, Falls Church, VA

Abstract We optimized parameters of a 3d gadolinium-enhanced MRA protocol for use in children with congenital cardiovascular disease. A 3d-EFGRE sequence was acquired in 18 children (aged 3 days to 3.6 yrs) using a "recirculation" technique (higher matrix, thin slices, full acquisition). This was compared with a "first pass" technique (lower matrix, thicker slices, partial Fourier acquisition) in 18 children (age 2 days to 4.5 yrs). The modified technique had higher resolution but double the acquisition time. The recirculation technique had higher SNR and CNR, and blinded readers found better image quality (p=. 010) and diagnostic confidence (p=. 012).

Introduction. MR imaging is useful for diagnosing congenital anomalies of the heart, aorta, and pulmonary vasculature (1,2). In our practice, we have increasingly relied upon 3d gadolinium-enhanced MR angiography for evaluation of the aorta, pulmonary arteries, pulmonary veins, and surgically placed shunts. However, direct adaptation of the "first-pass" technique used for performing MRA in adults has had some problems. Children have very rapid contrast transit times and accurate timing of the acquisition is difficult; young children are commonly sedated and cannot voluntarily suspend respiration leading to motion artifacts; finally the small field-of-view used for these studies generate noisier images (especially when combined with partial-Fourier acquisitions) than seen with adult MRA's. With these shortfalls in mind, we modified our 3d Gad-MRA protocol to improve resolution, allow for contrast recirculation so that all arteries and veins were simultaneously enhanced, and to increase the number of acquisitions to reduce respiratory artifacts.

Materials and Methods. All patients were imaged on a 1.5 T MR system (Signa LXi, software version 8.0, GE Medical Systems, Milwaukee WI). Eighteen consecutive (10 boys, 8 girls, age 3 days to 3.6 yrs, mean 11 mo. +/- 9.2 mo.) patients underwent 3d gad-enhanced MRA for known or suspected congenital cardiovascular disease using the standard protocol. These studies were compared with those of 18 consecutive patients (12 boys, 6 girls, age 2 days to 4.5 yrs, mean 13 mo. +/- 10.2 mo.) imaged with the revised protocol.

A commercially available enhanced 3-dimensional fast gradient echo (3d EFGRE) sequence was used for both groups. The standard protocol used the following parameters; repetition time (TR) 5.6-7.8 msec, echo time (TE) 1.9-2.6 msec, field of view 18-26 cm, matrix 128 x 256, 2.0-3.0 partition thickness, 24-36 partitions, bandwidth 32-64 kHz, acquisition time 14-23 seconds, number of acquisitions (NEX) 0.5. The modified protocol used the following parameters; TR 5.2-6.8 msec, TE 1.4-2.8 msec, field of view 18-24 cm, matrix 192 x 256, 1.6-2.4 partition thickness, 36-50 partitions, bandwidth 32-64 kHz, acquisition time 30-46 seconds, NEX 1.0. All patients received a hand injected bolus of 0.2 mmol/kg gadolinium-DTPA (Magnavist, Berlex, Wayne NJ) infused at 2.0 cc/sec followed by a 10 cc saline flush at 2 cc/sec.

Images were processed on an Advantage Windows workstation version 4.03 (GE Medical Systems, Milwaukee WI) using volume rendering (VR), maximal intensity projection (MIP), and multiplanar reformation (MPR) algorithms. Quantitative data was acquired by drawing a user defined region of interest over the vessel of interest, as well as a region of air outside the body to determine noise and its standard deviation.

Three blinded reviewers interactively reviewed the post contrast 3d data sets on a workstation. Each was experienced in performing VR, MIPs, and MPRs of gadolinium-enhanced MR angiograms. They determined the presence or absence of 22 separate anatomic section of the aorta, great vessels, pulmonary arteries, and pulmonary veins and scored the image quality (scale 0-5) and their diagnostic confidence (scale 0-5) for determining the presence of pathology in each segment.

Results. All 36 examinations were performed successfully. Congenital anomalies of the aorta (n=16), great vessels (n=9), pulmonary arteries (n=17) and pulmonary veins (n=6) were depicted. Quantitative image analysis revealed that the recirculation method had consistently higher SNR and CNR than the first-pass approach (Table 1). Qualitative blinded reads also determined that the recirculation sequence yielded images with higher image quality and diagnostic confidence (Table 2).

	First Pass	Recirculati	P-value
Aortic SNR	26 +/- 12.3	46 +/- 16.3	.012
Pulm Artery SNR	25 +/- 6.9	33 +/- 11.2	.041
Pulm Veins SNR	16 +/- 10.3	19 +/- 6.3	>.05
Aortic-fat CNR	12 +/- 8.6	35 +/- 12.3	.003
Pulm Artery-fat CNR	24+/- 12.3	31 +/- 8.8	.025
Pulm Veins-fat CNR	12 +/- 7.3	18 +/- 6.9	.009

Table 1. Quantitative data

	First Pass	Recirculati	P-
Aortic Quality	3.8 +/- 1.2	4.3 +/- 0.8	.033
Pulm Artery Quality	3.9 +/- 0.9	4.3 +/- 0.9	>.05
Pulm Veins Quality	3.2 +/- 1.6	3.6 +/- 1.2	>.05
Aorta Diag Confidence	4.2 +/- 1.0	4.7 +/- 0.7	.001
Pulm Art Diag Confidence	4.0 +/- 1.1	4.5 +/- 0.6	.025
Pulm Vein Diag Confidence	3.2 +/- 1.2	3.8 +/- 1.3	.044

Table 2. Qualitative data

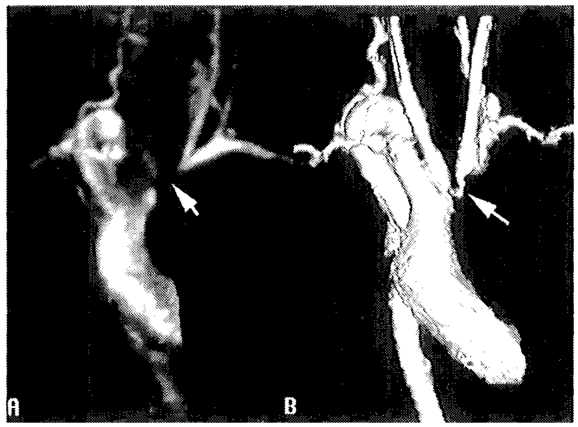

Figure 1. Comparison with first pass (A) and recirculation (B) techniques in 5 mo. old with a right cervical arch and left innominate artery stenosis. The recirculation technique more clearly depicts the morphology of the arch and accurately depicts the left innominate stenosis (arrows), that was over estimated in A.

Discussion. Gadolinium-enhanced 3d MR angiography is a useful tool for evaluating children with congenital cardiovascular disease. Performance of this technique in small children is hindered by motion artifacts, difficulty with timing of contrast enhancement, and image quality issues due to the small fields of view. We modified a standard 3d gadolinium-enhanced MRA protocol to try to correct for each of these issues. Since the children are usually sedated, asleep, or anesthetized they cannot suspend respiration. By increasing the number of acquisitions from 0.5 to 1.0 we double acquisition time, allowing for better enhancement of all structures and boosting the SNR (3). Thinner partitions and larger matrices are used which increased image resolution. The longer acquisition times prevent the acquisition of separate arterial and venous phases: Segmentation of arterial from venous structures is performed interactively on the workstation.

We found the recirculation technique has better quantitative and qualitative results than the first pass method when performing 3d gadolinium-enhanced MRA in patients with congenital heart disease. The improved image quality boosts diagnostic confidence. We have used this modified technique with excellent results in over 80 congenital heart disease patients cases in the last 12 months.

References

1. Hoppe UC, Dederichs B, Deutsch HJ, et al. Radiology 1996 Jun;199(3):669-77
2. Masui T, Katayama M, Kobayashi S, et al J Magn Reson Imaging 2000 Dec;12(6):1034-42
3. Boada FE, Christensen JD, Gillen JS, Thulborn KR. Magn Reson Med 1997 Mar;37(3):470-7