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Poster Abstracts: Clinical MRI— Congenital Heart Disease

304. Delayed Myocardial Enhancement in Hypertrophic Obstructive Cardiomyopathy Post-septal Ablation

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Introduction: Septal ablation using intravascular ethanol is a percutaneous therapy for hypertrophic obstructive cardiomyopathy (HOCM) that causes myocardial necrosis from cytotoxic injury. Delayed myocardial enhancement on MR imaging is hypothesized to correlate with areas of irreversible myocardial damage and has been reproducibly demonstrated in regions of infarct secondary to coronary artery disease.

Purpose: We sought to study myocardial enhancement characteristics in HOCM post-ethanol ablation using varying delay times.

Methods: Consecutive patients with HOCM treated with ethanol ablation underwent MR imaging as a component of follow-up assessment. Short axis oblique images of the left ventricle were obtained using an IR prepared fast gradient echo pulse sequence. All images for each patient were obtained with the same time-to-inversion (TI) of 200 ms. Images were obtained at 10 and 20 minutes post-intravenous injection of 40 ccs of gadolinium. Regions of interest were placed in ablated and normal myocardium to calculate signal intensities.

Results: 8 patients (mean age 53, 4M) were studied with MR imaging at a mean of 56 (range 13–109) weeks post ablation procedure. Mean (+ SD) changes in signal intensity of ablated septal myocardium vs. normal myocardium expressed as a percentage of normal at 10 and 20 minutes were 665% + 258 and 547% + 160 respectively. Statistically significant increases in signal in ablated myocardium were observed at 10 ($p < 0.01$) and 20 minutes ($p < 0.01$). No statistically significant difference was observed between 10 and 20 minutes.

Conclusion: Myocardium ablated with ethanol in patients with HOCM shows a statistically significant increase in signal intensity at 10 and 20 minutes post-gadolinium administration. No statistically significant difference in enhancement is seen between 10 and 20 minutes of delay suggesting that the shorter delay time may be used to minimize scan duration. The delayed enhancement of ablated myocardium observed in this study is similar to that observed in infarction secondary to coronary artery disease, supporting the hypothesis that delayed enhancement is observed in areas of irreversible myocardial damage. Demonstation of the anatomic extent of septal ablation may be of utility in the clinical management of these patients.

305. Impaired Regional Myocardial Perfusion in Patients with Hypertrophic Cardiomyopathy

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Introduction: In hypertrophic cardiomyopathy (HCM) the myocardial perfusion patterns as a determinant of congestive symptoms and sudden cardiac death are not well understood.

Purpose: It has been difficult to quantify the severity and extent of myocardial blood flow in HCM. We hypothesized that MR first-pass perfusion imaging allows a precise quantitative assessment of the regional blood flow distribution in HCM pts.

Methods: Magnetic resonance (MR) first pass perfusion imaging was performed in 16 HCM pts (38 ± 15 yrs) and 13 volunteers (34 ± 0.8 yrs). Quantitative Rest-Stress (Adenosine 140 ug/kg/min) MR perfusion and cine imaging was performed with a 1.5T MR-Scanner (Sonata/Siemens) injecting a gadolinium-DTPA bolus (0.03 mmol/kg). Myocardial rest-stress flow and the Perfusion Reserve (MPR = hyperemic over

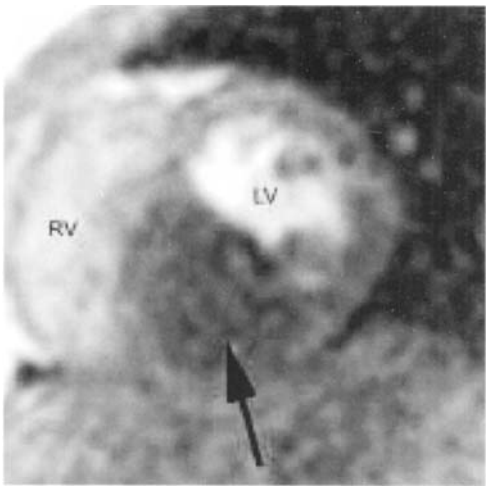

Figure 1. Dilatation of the pulmonary artery with a Gd filled balloon.

resting myocardial flow) were calculated in 8 ventricluar regions (2–4 slices/pt) in all pts without left ventricular outflow tract obstruction. The perfusion and cine images were anatomically matched and segmental wall thickness and signal intensity curves for flow calculation were generated in identical segments.The perfusion and cine images were anatomically matched and segmental wall thickness and signal intensity curves were generated in identical segments. Blood flow was derived from SI curves with a Fermi-model of constrained deconvolution. 3D models of regional perfusion and wall parameters were constructed.

Results: Results: In HCM, there is a significantly reduced myocardial flow at rest and stress in hypertrophied (>15 mm) segments (HS) compared to normal volunteers as well as non-hypertrophied segments (<12 mm) in the same pts.

Conclusion: In HCM, MR-perfusion imaging showed evidence of regional myocardial ischemia (as reduced MP and MPR). This suggest that ischemia in HCM may be due to remodeling of the microvasculature most prominent in hypertrophied as compared to non-hypertrophied segments.

306. Left Ventricular Mass Regression Assessed by MR Imaging in Hypertrophic Obstructive Cardiomyopathy Post-septal Ablation

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Introduction: Left ventricular (LV) mass regression is an important anatomic outcome of septal ablation therapy in hypertrophic

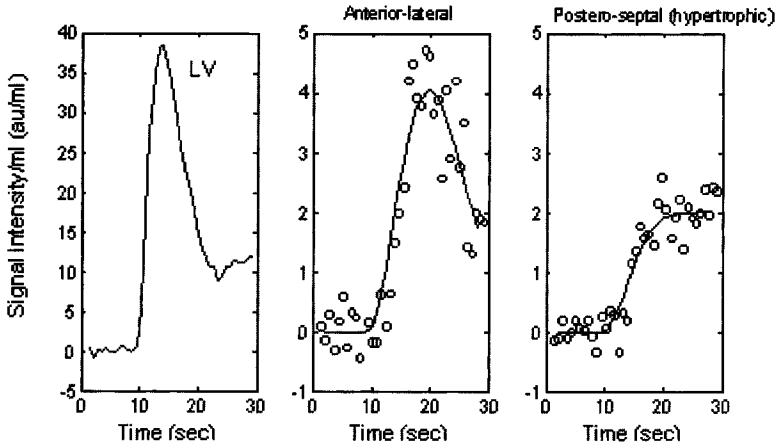

Figure 2. Perfusion in HCM.

Table 1

	Segments	Rest MP	Stress MP	MPR
Hypertrophic	(n = 50)	0.63 ± 0.16	1.64 ± 0.1	2.6 ± 0.72
Non-hypertrophic	(n = 11)	0.98 ± 0.4	—	—
normal volunteers	(n = 52)	0.86 ± 0.31	3.39 ± 1.12	4.15 ± 1.54
P		<0.05	<0.01	<0.01

obstructive cardiomyopathy (HOCM). Change in LV mass offers insight into ventricular remodelling post-procedure. Although echocardiography has been used to study LV mass regression post-ablation, MR has been shown to be a more precise and accurate technique for the assessment of LV mass.

Purpose: We sought to study LV mass regression post-septal ablation using MR imaging.

Methods: Consecutive patients were studied with MR imaging prior to ablation and at approximately 4 months post-procedure. Short axis oblique images of the left ventricle were obtained using fast gradient echo cine imaging. Image analysis was performed in a blinded manner by one reader (NM). End-diastolic (ED) and end-systolic (ES) phases were identified. For each slice location from apex to base, manual segmentation was performed to define the inner and outer contours of the LV. The interventricular septum was included as part of the LV. Using the MASS analysis program (General Electric Company), LV mass at ED was calculated. Additionally, calculation of end-diastolic volume (EDV), end-systolic volume (ESV), and ejection fraction (EF) were obtained.

Results: 8 patients (mean age 56, 3M) were studied at baseline and at a mean of 16 weeks (range 13–19) post-ablation procedure. Baseline mean (±SD) LV mass was 265 g ± 57. Post-ablation, mean LV mass was 198 g ± 50 for a mean reduction of 25%. This was statistically significant ($p < 0.01$). No statistically significant difference was observed for EDV, ESV, or EF.

Conclusion: MR assessment of LV mass post-septal ablation demonstrates a statistically significant regression of approximately 25% at 4 months, indicating that important anatomic change in the left ventricle occurs within a relatively short time period. Ablation did not result in a significant change in LV volumes or function during the follow-up period.

307. Are Left and Right Pulmonary Artery Mechanics Similar? A Cine MRI Study

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Introduction: Understanding pulmonary arterial mechanics is important for the advancement of surgical management of various forms of congenital heart disease such as tetralogy of Fallot and the Fontan procedure.

Purpose: Our purpose was to investigate normal pulmonary arterial mechanics in children, hoping to use this information to improve surgical reconstruction.

Methods: We performed cross-sectional cine MRI of the right (RPA) and left pulmonary arteries (LPA) in 11 normal children who were undergoing MRI for other reasons. The distensibility of the cross-sectional area, supero-inferior plane and its orthogonal plane were measured along with the motion of the center of mass.

Results: Although no significant difference in cross-sectional area distensibility between RPA and LPA was noted, the LPA was significantly more distensible than the RPA in the supero-inferior dimension (.35 ± .12 vs. .27 ± .12, P = .03). In addition, maximum distension in the LPA supero-inferior dimension occurred earlier than in its orthogonal plane (25 ± 12% vs. 35 ± 17% of the cardiac cycle, P = .03). Furthermore, the rate of change of the LPA's supero-inferior expansion was nearly twice the rate of expansion in its orthogonal plane (.008 ± .004 sec^{-1} vs. .004 ± .001 sec^{-1}, P = .007). The LPA center of mass was also displaced maximally in significantly less time than that of the RPA (27.8 ± 13.3% vs. 43.6 ± 15.2%, P = .02).

Conclusion: Significant differences exist in LPA and RPA arterial mechanics. In addition, the LPA was noted to be anisotropic in its distensibility during systole. These differences suggest the potential use of different therapeutic approaches to surgical pulmonary artery reconstruction to best mimic normal mechanics.

308. Are Right and Left Aortic Wall Mechanics Similar: Insights Utilizing Cine MRI

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Introduction: Aortic wall mechanics are important in determining systemic blood pressure and fluid mechanics. Improving aortic surgical reconstruction, in part, depends upon understanding these properties.

Purpose: The purpose of this study is to gain insight into aortic wall mechanics in children. In specific, to determine the impact of aortic arch geometry on aortic wall mechanics in the hopes of improving surgical arotic reconstruction.

Methods: We performed cine MRI of the ascending (AAo) and descending aorta (DAo) in 24 children (13 with left aortic (LAo) and 11 with right aortic arches (RAo)) without intracardiac lesions who were undergoing MRI for other reasons. We measured maximum distensibility of the aorta in 3 ways: 1) cross-sectional area, 2) antero-posterior (AP) dimension & 3) lateral dimension. The motion of the aortic center of mass was also measured.

Results: Although no significant differences between LAo & RAo were noted in AAo wall mechanics, this was not the case in the DAo. The LAo demonstrated significantly smaller distensibility than the RAo in area and lateral dimension. In addition, the maximum rate of change of the LAo's area & lateral dimension expansion was much smaller than the RAo's along with its center of mass motion (see table on following page). In comparing AAo to DAo in LAo, the AAo center of mass demonstrated greater displacement than the DAo (.029 ± .023 vs .017 ± .017 mm/meter2, P = .004) which took longer occur (47 ± 10% vs 37 ± 11% of the cardiac cycle, P = .01). In the RAo, the distensibility of the DAo was greater than the AAo in area (71 ± 36 vs 51 ± 24% respectively, P < .05) & AP dimension (33 ± 9 vs 23 ± 10%, P = .008).

Conclusion: Wall mechanics in the AAo of LAo and RAo are similar, however, differences exist in DAo wall mechanics between the 2 types of arches. In addition, there are different wall mechanics in the AAo and DAo, depending upon the aortic geometry. This information may lay the groundwork for improved aortic reconstruction.

Table 1

DAo Wall Mechanics

	Area Distensibility (%)	Lateral Distensibility (%)	Rate of Change of Area Distensibility (%/sec)	Rate of Change of Lateral Distensibility (%/sec)	Center of Mass Motion (mm/meter2/sec)
LAo	48 ± 17	20 ± 8	0.8 ± 0.3	0.3 ± 0.1	0.0002 ± 0.0002
RAo	71 ± 36	31 ± 19	1.6 ± 1.1	0.7 ± 0.6	0.0006 ± 0.0006
P value	0.02	<0.05	0.03	0.04	0.006

309. Evaluation of Hemodynamic Data in Patients with Aortic Regurgitation by MRI and Correlation with the Left Ventricular Function

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Introduction: One major problem in the management of patients with aortic regurgitation (AR) is the assessment of the severity of the disease especially in patients with reduced left ventricular function.

Purpose: It was the purpose of the study to evaluate the hemodynamic data of patients with AR and to show the correlation between MRI and the aortic root angiography.

Methods: We investigated 75 patients (55 male, 20 female, age: 58.5 y) with a clinically manifested AR I°-III°. MR cine ventriculaography was performed (Magnetom Vision, 1.5 T, Siemens AG) using a ecg-gated breath-hold multislice Flash 2D sequence with a slice thickness of 8 mm (TR 110 ms, TE 5 ms, VEC 250 cm/s). The invesive determination of the AR was done by the thermodilution method. The patients were divided in a group with regular (EDVI < 100 ml/m2) and impaired (EDVI > 100 ml/m2) left ventricular function.

Results: The results showed a good correlation (p = 0.001) between the aortic regurgitation of both methods. The determination by MRI of the AR is independent of the left ventricular function.

The invasive method shows a greater variablity of the AR in correlation to the angiographic classification in patients with impaired left ventricular function.

Conclusion: The accuracy in quantification of the AR was demonstrated by a significant correlation between both methods.

Especially in patients with impaired left ventricular function, MRI is superior to the aortic root angiography, because the determination of AR is independent of the left ventricular function.

Further studies have to shown, wether MRI can became a reliable place in the management of patients with AR and can optimize the term of the valve replacement.

310. Free Breathing, Time-Resolved, Contrast-Enhanced 3D-MRA (CE-MRA) Using Sensivity Encoding (SENSE) in Pediatric Patients—A Pilot Study

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Introduction: SENSitivity Encoding (SENSE) is a recent technique utilizing phased-array coils to accelerate acquisition speed of a pulse sequence without compromising spatial resolution.

Purpose: To illustrate the initial experience of applying SENSE to thoraco-abdominal CE-MRA in freely breathing pediatric patients.

Methods: Twenty patients (median age: 5 years; range 18 days to 15 years) were imaged on a 1.5 T clinical MR scanner

Table 1

Results

	Angio I°	Angio II°	Angio III°
RF MRI EDVI > 100 ml/m2	12% (5–18)	22% (15–30)	39% (28–57)
RF Thermo EDVI > 100 ml/m2	15% (6–32)	26% (12–45)	43% (17–60)
RF MRI EDVI < 100 ml/m2	14% (13–17)	23% (20–27)	40% (25–43)
RF Thermo EDVI < 100 ml/m2	12% (5–18)	22% (15–30)	39% (20–57)

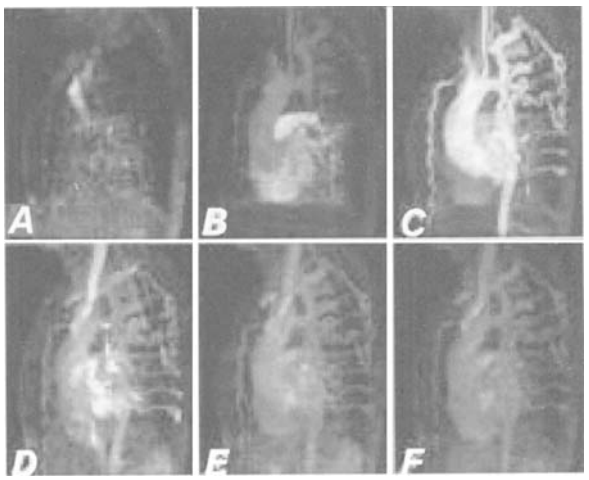

Figure 1. Coarctation.

with standard phased-array body coil using a 3D T1-weighted FFE sequence: TR/TE/flip = 5.1 msec/1.2 msec/40 degrees; 213 × 256 in-plane matrix (average); FOV = 300 to 420 mm; 18 to 25 1.9 to 3.9 mm thick slices acquired (reconstructed as 0.95–1.95 mm thick); SENSE reduction factor of 2 was used accelerate acquisition such that 4 to 8 3D volumes were acquired consecutively at 3.9 to 9.8 seconds per volume. Acquisition and contrast (0.2 mmol/kg of Gadolinium-DTPA) injection were started simultaneously. Qualitative evaluation of the MRA by examining source images and maximum intensity projections and quantitative analysis by computing arterial-to-venous signal ratio (AVR) for each 3D volume were made.

Results: SENSE CE-MRA acquisition and reconstruction were successful in all cases and yielded diagnostic quality MRA's. The 3D volume that had the highest AVR was identified as the peak-arterial volume and the AVR of the temporally adjoining volumes were identified as pre-, and post-arterial volumes. AVR of the pre-, peak-, and post-arterial volumes were 1.0 ± 0.5, 6.55 ± 3.3, and 1.4 ± 0.9 respectively indicating temporal separation of arterial and venous phases. SNR was measured as 38.6 ± 24.4.

Conclusion: To illustrate the initial experience of applying SENSE to thoraco-abdominal CE-MRA in freely breathing pediatric patients.

311. Assessment of Extracardiac Abnormalities in Congenital Heart Disease with Real-Time Color-Flow MRI

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Introduction: Echocardiography is a widely used method for the assessment of congenital heart disease (CHD). However, it is limited in the evaluation of extracardiac structures due to lack of an acoustic window and/or an inability to assess flow in all planes and directions. Conventional MRI methods have been used to address these issues, but phase-contrast methods can be time-consuming and susceptible to artifacts related to respiration and arrhythmias, which are common in these patients. We have developed a real-time interactive color-flow MRI system analogous to color-Doppler echocardiography, which, in contrast to echo, allows complete flexibility of imaging plane, velocity direction, velocity range, and is not limited by acoustic window.

Purpose: To assess the value of a real-time interactive color-flow MRI system in patients with CHD.

Methods: Eleven Patients with a diagnosis of CHD by echocardiography were studied. All patients underwent real-time cardiac MRI evaluation on a 1.5 T MRI system (40 mT/m, 150 T/m/s gradients). A real-time 3-interleave spiral velocity-sensitive color-flow sequence, which does not require breath-holding or cardiac gating, was used (20-cm FOV, 2.8-mm resolution, 18 fps). Standard echo views and additional imaging of the great vessels were interactively prescribed, and images with and without color flow were obtained. The location, direction and timing of flow abnormalities were assessed.

Results: In the 11 patients studied to date, 4 extracardiac flow abnormalities have been imaged by real-time color-flow MRI, in addition to 12 intracardiac findings (predominantly ventricular and atrial septal defects). An aortic coarctation, Blalock–Taussig shunt, Fontan shunt, and occluded left subclavian artery were interactively evaluated from long-and short-axis views using X, Y, and Z axis velocity directions. Anastamotic connections, flow direction, and areas of flow acceleration were documented. These extracardiac findings were more completely evaluated by real-time color-flow MRI than echocardiography.

Conclusion: Real-time color-flow MRI is a promising method for evaluating patients with CHD, particularly in the case of extracardiac abnormalities where echocardiography is more limited.

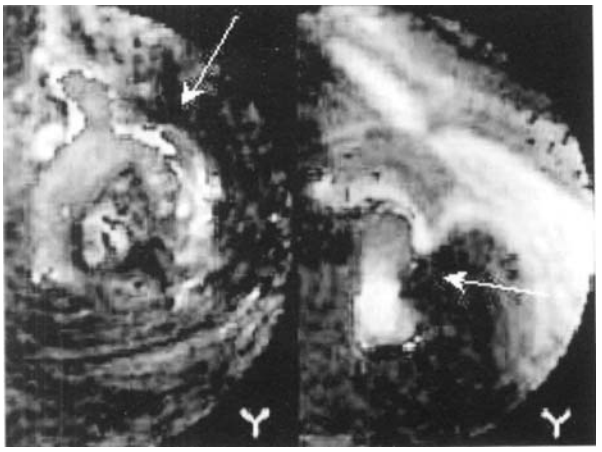

Figure 1. Coronal and axial color-flow MRI of an aortic coarctation (Y velocity direction). No flow is seen to the occluded left subclavian (left arrow); mild flow acceleration is noted in the coarctation (right arrow).

Table 1

Tumor Characteristics

Patient	Tumor	Dimensions (mm)	T1 Tumor/Myocardial Signal Intensity Ratio	T2 Weighted*	Post-Gd Enhancement
1	Fibroma	53 × 55	0.6	Iso-hypointense	Decreased
2	Fibroma	60 × 39	0.9	Iso-hypointense	Decreased
3	Rhabdomyoma	8 × 13	1.4	Iso-hypointense	Decreased
4	Rhabdomyoma*	Multiple	1.4	Iso-hypointense	Decreased
5	Hemangioma	11 × 19	1.6	Hyperintense	N/A
6	Hemangioma	45 × 35	N/A	N/A	Increased
7	Pericardial teratoma	117 × 79	2.1	N/A	N/A
8	Purkinje cell tumor	6 × 11	2.7	N/A	N/A
9	Fatty tumor*	3 × 10	2.5	N/A	N/A
10	Fatty tumor*	3 × 4	1.9	N/A	N/A

*histology not available

312. MRI Signal Characteristics of Cardiac Tumors in Infants and Children

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Introduction: Most childhood cardiac tumors are diagnosed by echocardiography but specific tumor type and extent may not be completely delineated.

Purpose: This study investigates the role of MRI tissue characterization in childhood cardiac tumors.

Methods: MRI, echo, cath, surgical, clinical, and pathology data of 10 pts (age 1 day–11.4 yrs) evaluated by MRI for cardiac tumors were reviewed. T1 standard spin echo (SSE) or fast spin echo (FSE) with double inversion recovery (DIR) were the primary MRI sequences used to assess tumor morphology (n = 10). T2 FSE was used for distinguishing vascular or cystic tumors (n = 5), and post-gadolinium FSE with DIR for assessing tumor vascularity (n = 4). Cine MRI with/without tissue tagging was used for evaluating myocardial motion (n = 8). Triplicate measurements of signal intensities within the tumors and in the adjacent myocardium were performed on T1-weighted images and the average values were expressed as a ratio.

Results: T1 SSE and FSE with DIR clearly identified tumor location and borders in all pts. MRI correctly predicted tumor type in all 7 pts who had a histologic diagnosis available (table 1, above).

Of the 3 pts without histology, 2 presented with arrhythmia and were found by MRI to have fatty tumors (1 septal, 1 right AV groove) and 1 pt had multiple rhabdomyomas. MRI was followed by tumor resection in 5 pts, open biopsy in 2, antiarrhythmic medications in 1, and no treatment in 2.

Conclusion: MRI clearly identifies tumor location and borders, and provides additional information on tumor tissue characteristics that, in this cohort, proved helpful in clinical management.

313. Magnetic Resonance Shows Superior Results in Evaluation of Anomalous Coronary Arteries

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Introduction: X-ray cineangiography has been the imaging modality of choice for assessment of the coronary arteries. However, due to its two dimensional nature it does not reliably delineate the proximal course of anomalous coronary arteries in relation to the aorta or pulmonary artery (PA). This information is often critical to the management of these patients. Preliminary data indicates that coronary magnetic resonance angiography (MRCA) is an effective tool in defining the origin and proximal course of these arteries. We compared the accuracy of MRCA to X-ray angiography or transesophageal echocardiography (TEE) in 16 consecutive patients referred with a diagnosis of anomalous coronary artery.

Methods: Each patient underwent MRCA on a 1.5 T magnet (GE Signa; General Electric Medical Systems, Milwaukee, WI.) After scout images were obtained, axial T1-weighted spin echo sequences were used to determine the location of the aortic root and PA. This was followed by series of cardiac-gated, fat suppressed, segmented fast gradient echo images (TR/TE/Flip Angle = 12/4/20°, slice thickness = 4mm) during breath holding. In addition to axial gradient echo sequences, other sequences were individualized based on the results of the prior images.

Results: After blinded initial review of the results of the MRCA by two independent readers, comparison was made with X-ray angiography or TEE and consensus was reached regarding the exact course of these anomalies. MRCA independently delineated the origin and proximal course of the coronary vessels in all 16 patients. Coronary anomalies diagnosed by MRCA included right sided origin of left coronary artery (n = 7), right sided origin of circumflex artery

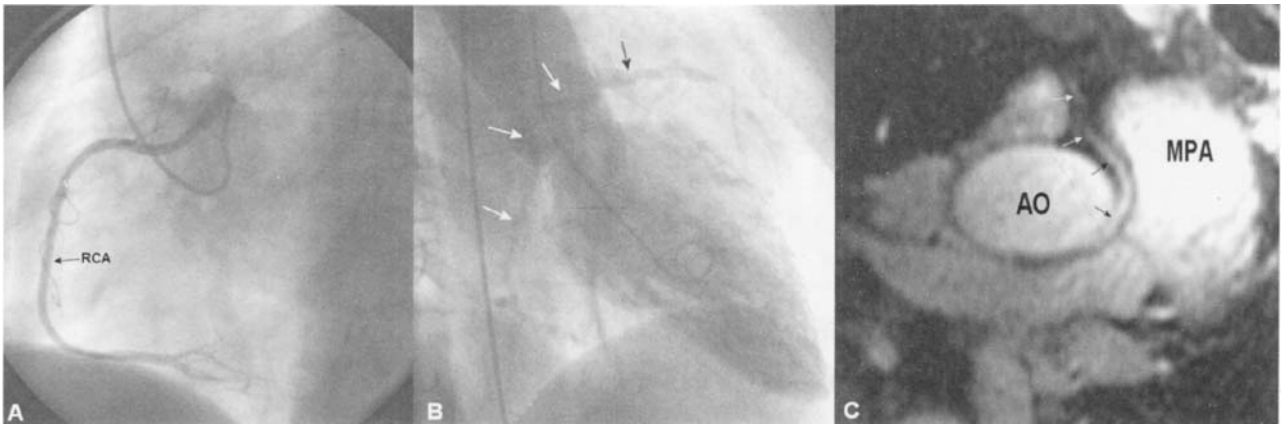

Figure 1.

(n = 2), slight anterior or posterior displacement of left coronary artery (n = 2), left sided origin of right coronary artery (RCA) (n = 3), (Figure 1), anterior displacement of RCA (n = 1), common ostium of left and right coronary artery (n = 1). MRCA was superior to X-ray cineangiography in determining the exact course of the anomalous arteries and had significantly better correlation with the consensus results.

Conclusion: MRCA is a non-invasive and accurate technique for the diagnosis of anomalous coronary arteries. Its three dimensional nature allows for the accurate determination of the course of these vessels in relation to the surrounding structures. In this series, MRCA correctly identified every anomaly. This degree of accuracy qualifies this method as the imaging modality of choice for assessing coronary anomalies.