JOURNAL OF CARDIOVASCULAR MAGNETIC RESONANCE®
Vol. 6, No. 1, pp. 281–307, 2004

# Poster Abstracts: Congenital Heart Disease

## 400. Magnetic Resonance Coronary Angiography and Myocardial Viability Imaging in Children with Arterial Switch Operation for Transposition of the Great Arteries

Andrew M. Taylor, MD, MRCP, FRCR,[1] Steven Dymarkowski, MD, PhD,[2] Pascal Hamaekers,[2] Reza Razavi, MBBS, MRCP,[3] Marc Gewillig, MD, PhD,[4] Willem Daenen, MD, PhD,[5] Luc Mertens, MD, PhD,[4] Jan Bogaert, MD, PhD.[2] [1]*Cardiac Unit, Institute of Child Health and Great Ormond Street Hospital, London, United Kingdom,* [2]*Department of Radiology, Gasthuisberg University Hospital, Leuven, Belgium,* [3]*Cardiac MR Research Group, Division of Imaging Sciences, Guy's Hospital, King's College London, London, United Kingdom,* [4]*Department of Pediatric Cardiology, Gasthuisberg University Hospital, Leuven, Belgium,* [5]*Department of Cardiac Surgery, Gasthuisberg University Hospital, Leuven, Belgium.*

*Introduction:* In older subjects who have undergone the arterial switch operation for transposition of the great arteries, there remains concern about the development of late coronary artery complications. Coronary investigations tend to be restricted to those patients who have evidence of myocardial ischaemia clinically or on ECG, though several studies have demonstrated coronary abnormalities in asymptomatic individuals. Due to issues related to radiation exposure, screening of this group of subjects with x-ray coronary angiography is not feasible. Magnetic resonance (MR) coronary angiography has been demonstrated to be excellent for defining anomalous coronary arteries in adults and adolescents, and may provide an alternative non-invasive method for imaging coronary changes in subjects following the arterial switch operation.

*Purpose:* 1) To demonstrate the usefulness of MR coronary angiography for direct visualization of the coronary ostia and their proximal course, and 2) to assess the extent of unsuspected myocardial damage with late-enhancement MR viability imaging in the above group of patients.

*Methods:* Sixteen subjects with arterial switch operation for transposition of the great arteries participated in the study (age, $10.8 \pm 1.3$ years; range 8.7 to 14.1 years; 11 male, 5 female). Fifteen of the arterial switch operations were performed by a single surgeon (WD). Age at operation was $13.1 \pm 7.6$ days; range 3 to 31 days. The study was approved by the Local Research Ethics Committee. All parents/guardians gave informed consent. All subjects were asymptomatic at the time of MR imaging. Fifteen subjects were imaged whilst awake, and a single subject was imaged under general anaesthesia. All images were obtained with a 1.5 T Intera MR scanner (Philips Medical Systems, Best, the Netherlands). Free breathing navigator-echo MR coronary angiography of the right and left coronary arteries (3D balanced-turbo-field echo: TR 5.7 ms, TE 2.8 ms flip angle 110°, SLT 3.0 mm, matrix $218 \times 256$), short axis and long axis late-enhancement MR viability images (3D T1-weighted turbo-field-echo: TR 4.5 ms, TE 1.3 ms, flip angle 15°, SLT 10 mm, matrix $128 \times 256$, TI 200–300 ms), and global ventricular function and regional wall motion (balanced-turbo-field echo: TR 3.8 ms, TE 1.9 ms, flip angle 60°, SLT 7 mm, matrix $160 \times 256$) were assessed.

*Results:* In all subjects, the proximal course of the coronary arteries was visualized. There were 13 normal arrangements and 3 coronary anomalies. No coronary artery stenoses were seen. In 56% of awake patients diagnostic MR coronary images were acquired of both



DOI: 10.1081/JCMR-120028317
1097-6647 (Print); 1532-429X (Online)

coronary arteries (80% of right coronary arteries); this figure rose to 89% in subjects older than 11 years. In 3 subjects, non-diagnostic images of both coronary arteries were acquired, though MR coronary angiography was completed in all 3 subjects. These subjects were the youngest, 2nd and 5th youngest within the awake group (8.6, 9.1, 10.1 years). Good quality diagnostic images were acquired in the anesthetized subject (8 years) (Figure 1).

Two subendocardial viability defects were detected, corresponding to known compromise of the artery supplying that territory. No unexpected areas of myocardial damage were visualised.

Global left and right ventricular function were preserved (right and left ventricular ejection fraction were $68 \pm 7\%$ and $70 \pm 5\%$, respectively) with no regional wall abnormalities detected.

*Conclusions:* We have demonstrated that diagnostic MR coronary angiography can be performed in most subjects with arterial switch operation for transposition of the great arteries (above 11 years). Though image quality was generally non-diagnostic in the younger children (below 9 years), we have demonstrated that diagnostic images can be acquired under general anesthesia with intermittent suspended ventilation. Furthermore, we have demonstrated that there were no unexpected areas of myocardial infarction, suggesting that patients surviving to this age did not have asymptomatic episodes of myocardial damage at the time of operation.

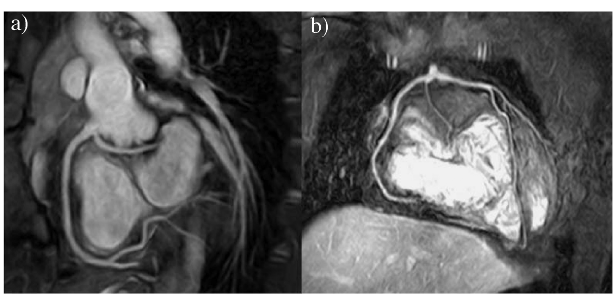



***Figure 1.*** Maximum intensity projection images reconstructed from the 3D MR coronary angiograms using Pride Workstation and Soap Bubble software (both, Philips Medical Systems, Best, the Netherlands). a) Oblique sagittal view demonstrating an anomalous origin of the left circumflex from the RCA. b) Coronal view demonstrating an anomalous accessory left anterior descending artery (on right of image) arising from the same ostia as the RCA (to left of image). No ostial stenoses or proximal coronary artery kinking are seen.

## 401. Diagnosis of Patent Foramen Ovale Using Contrast-Enhanced Dynamic MRI—First Results Compared with TEE

Oliver K. Mohrs, MD,[1] Christine Rubel, MD,[1] Damir Erkapic,[1] Bernd Nowak, MD,[1] Thomas Schulze,[2] Rainer Schraeder, MD,[1] Andrea Reinhart,[1] Katja Hoffmann,[1] Ute Kampwerth,[1] W. Andreas Fach, MD,[1] Thomas Voigtlaender, MD.[1] [1]*Department of MRI, Cardiovascular Center Bethanien, Frankfurt/Main, Germany,* [2]*Section of MRI, Medical Solutions, Siemens AG, Erlangen, Germany.*

*Introduction:* As patent foramen ovale (PFO) is known as a cause of cerebral stroke or transient ischemic attack due to paradoxical embolism, diagnosis and treatment are required to prevent further cerebral events.

*Purpose*: Aim of this study was to evaluate the feasibility of contrast-enhanced Magnetic resonance Imaging (ceMRI) to detect PFO.

*Methods:* We studied 12 patients (4 female, mean age $50 \pm 13$) with PFO diagnosed by transesophageal echocardiography (TEE). A contrast-enhanced (Gd-DTPA), dynamic examination (SR-TrueFISP-sequence) was performed during Valsalva maneuver at 1.5 Tesla. Beside visual analysis signal-intensity-curves over time were measured in left atrium (LA) and pulmonary vein (PV) to proof the diagnosis in a quantitative manner.

*Results:* CeMRI showed in all cases an early contrast enhancement in LA due to contrast flow through PFO. In cases of a huge PFO (more than 20 bubbles in TEE) a bright enhancement in the entire LA and in the cases of small PFO only a slight enhancement near the atrial septum occured. Signal-to-time curves showed two signal-peaks in LA compared to base line signal. The first peak (mean 195% of the base line signal, min.: 112%, max.: 378%) appeared earlier (11 seconds) to the single signal-peak in PV (mean 537%, min.: 188%, max.: 1078%). A second signal-peak in LA followed (mean 558%, min.: 253%, max.: 1086%). The mean interval between the two signal peaks in LA was 11 seconds during which the signal decreased (mean 125%, min.: 96%, max.: 219%).

*Conclusions:* This study demonstrates that dynamic ceMRI has the potential of a new method to detect PFO non-invasively . Beside visual detection the early peak in LA signal-time-curves enables reliable diagnosis. Also, a differentiation between enhancement due to PFO and contrast enhancement from pulmonary veins is possible.

## 402. Biventricular Diastolic Response to Dobutamine Stress in Patients with Pulmonary Regurgitation (PR) After Repair of Tetralogy of Fallot (TOF) Using Cardiac Magnetic Resonance Imaging (CMR)

W.J.B.W. van den Berg,[1] P.A. Wielopolski,[2] P.M.T. Pattynama,[2] F.J. Meijboom,[3] A.J. Bogers,[4] M. Witsenburg,[1] W.A. Helbing.[1] [1]*Paediatric cardiology, Erasmus Medical Centre, location Sophia Children's hospital, Rotterdam, Netherlands,* [2]*Radiology, Erasmus Medical Centre, location Dijkzigt, Rotterdam, Netherlands,* [3]*Cardiology, Erasmus Medical Centre, location Dijkzigt, Rotterdam, Netherlands,* [4]*Thoracical Surgery, Erasmus Medical Centre, location Dijkzigt, Rotterdam, Netherlands.*

*Introduction:* Systolic and diastolic biventricular dysfunction are known problems after repair of TOF. CMR combined with physical stress has been used to study both systolic and diastolic response to exercise. Assessment of diastolic changes using physical stress has not been successful. Pharmacological stress with an inotropic drug may be a good alternative creating less motion artefacts. With PR, diastolic filling of the right ventricle (RV) occurs through two valve orifices. CMR provides a unique tool to quantify valvular flow. Postprocessing of flow data allows 2 independent orifice flow measurements to be combined into one ventricular filling curve.

*Purpose:* To determine biventricular diastolic functional indices in rest and during dobutamine stress using Phase Velocity encoded Cine (PVC) MR flow measurements.

*Methods:* 17 patients operated for TOF (mean age 17.2 ± 4.9 years, range 7.4 to 23.2 years, mean age at repair 1.0 ± 0.7 years) underwent CMR at rest, and during low dose dobutamine stress (maximum dose 7.5 $\gamma$). A GE 1.5T Signa CV/i scanner and torso array coil were used. Flow measurements in the tricuspid and pulmonary valve plane were performed using a PVC MR technique (TR = 6.2–6.8 ms/TE = 3.2–3.6 ms/$\alpha$ = 20°/SL = 6 mm/FOV 28–34 cm) during breathholds in end-expiration. Pulmonary and tricuspid time-volume flow curves were derived from these data using CV Flow software. The finding of end-diastolic forward flow (EDFF) in the main pulmonary artery corresponds with restrictive ventricular function. RV time-volume change curves were reconstructed by summation of both curves, assuming changes in RV volume are equal to the sum of flow entering and leaving these two valve planes. Indices of RV diastolic function were derived from the RV time-volume change curve. If MR examination time permitted, the same measurements were performed in the left heart. Indices of LV diastolic function were derived according to the same principles (n = 14).

*Results:* No serious adverse effects of dobutamine were seen. Heart rate (/min) changed from 75 ± 12 at rest to 89 ± 18 during stress ($p < 0.01$). Time-volume change curves showed EDFF in the main pulmonary artery in n = 13 in rest and n = 14 during stress. EDFF (%) at rest measured 6.2 ± 5.9 versus 5.4 ± 4.3 with stress (n.s.) (Table 1).

*Conclusions:* In patients with PR, in whom RV filling occurs through two valve orifices, CMR offers a unique tool to study ventricular filling characteristics. Compared to physical stress protocols, a pharmacological stress protocol requires less motor skills from participants and restricts artefacts related to patient motion. This last method allows diastolic biventricular functional measurements during stress. Both RV and LV diastolic function are abnormal after TOF repair at young age. Changes with stress are compatible with

***Table 1.*** Biventricular diastolic indices.

| RV indices | Rest | Stress | P-value | LV indices | Rest | Stress | P-value |
|---|---|---|---|---|---|---|---|
| PEFR(ml/s) | 439 ± 160 | 502 ± 193 | < 0.01 | PEFR(ml/s) | 425 ± 118 | 504 ± 143 | < 0.001 |
| PAFR(ml/s) | 271 ± 158 | 394 ± 187 | < 0.01 | PAFR(ml/s) | 133 ± 59 | 192 ± 99 | < 0.01 |
| ttPEFR(ms) | 108 ± 22 | 88 ± 18 | < 0.05 | ttPEFR(ms) | 123 ± 17 | 110 ± 23 | 0.07 |
| ttPAFR(ms) | 60 ± 30 | 62 ± 28 | n.s. | ttPAFR(ms) | 88 ± 48 | 65 ± 25 | < 0.05 |
| AFF(%) | 23 ± 11 | 30 ± 13 | 0.08 | AFF(%) | 17 ± 10 | 15 ± 7 | n.s. |
| FF(%) | 46 ± 13 | 43 ± 11 | n.s. | FF(%) | 60 ± 17 | 60 ± 18 | n.s. |
| dt(ms) | 244 ± 52 | 293 ± 81 | n.s. | dt(ms) | 133 ± 22 | 146 ± 50 | n.s. |

Abbreviations: PEFR = peak early filling rate; PAFR = peak atrial filling rate; ttPEFR = time to PEFR; ttPAFR = time to PAFR; AFF = atrial filling fraction; FF = filling fraction during first one-third of diastole; dt = decelleration time.



Marcel Dekker, Inc.
270 Madison Avenue, New York, New York 10016

abnormal ventricular relaxation. In over 70% of patiens EDFF was present, confirming RV diastolic restrictive function abnormalities. Restrictive diastolic dysfunction did not increase with stress.

## 403. Breath Holding or Non Breath Holding? The Effect of Respiration on the Volumetric Quantification of the Ventricles in Children with Congenital Heart Disease

Emanuela R. Valsangiacomo Büchel, MD,[1] Luciano Molinari, PhD,[2] Urs Bauersfeld, MD.[1] [1]*Pediatric Cardiology, University Children's Hospital, Zurich, Switzerland,* [2]*Biostatistics, University Children's Hospital, Zurich, Switzerland.*

*Introduction:* Motion artefacts caused by respiration are a well-known problem in cardiac magnetic resonance imaging (MRI). Therefore image acquisition during a single breath hold is generally recommended. However in some cases, particularly in non-compliant or sedated patients, breath holding may fail. The situation in which cardiac MRI images need to be acquired during free breathing occurs more frequently in small children.

*Purposes:* We sought to evaluate the effect of respiration not only on the quality of the images but also on the quantitative measurements performed by cardiac MRI. We therefore compared volumetric measurements of the ventricles when the images were acquired by using steady state free precession (SSFP) during a single breath hold (BH) and during free breathing (NBH).

*Methods:* The study was performed in 19 children with congenital heart disease, age 10.7±4 years, weight 32±13.6 kg, undergoing cardiac MRI for clinical evaluation. Five examinations were performed in general anaesthesia. Images for measurement of the ventricular volume were planned as a multisection stack of images dividing the ventricles in 10 to 12 contiguous slices in a short axis parallel to the plane of the atrioventricular valves.

The same stack of images was acquired with SSFP sequences performed first during BH and immediately after during NBH. The same parameters were used for both acquisitions, except for the number of excitations that were doubled for the acquisitions during NBH. Volumetric data analysis was performed off-line by using a MASS software package (MEDIS, Leiden, Netherlands), by tracing manually the endocardial contours of each ventricle in the end-systolic and in the end-diastolic phase. The right ventricular end-diastolic (RVEDV) and end-systolic volume (RVESV), the right ventricular ejection fraction (RVEF), the left ventricular end-diastolic (LVEDV) and end-systolic volume (LVESV) and the left ventricular ejection fraction (LVEF) were so obtained. Additionally both the image quality and the degree of partial volume effect were judged for each image stack acquired during BH and NBH.

*Results:* A total of 76 ventricular volumes, 38 acquired during BH and 38 during NBH, were calculated for the right and the left ventricle, respectively. A significant decrease in image quality and a more pronounced partial volume effect were observed in the NBH images.

The quantitative results, including mean values and degree of agreement are summarised in Table 1. A significant systematic error was observed. Volumes calculated from the NBH images were consistently larger than volumes measured from the BH images. Considering the limits of agreement found, the potential error by acquiring the images during NBH ranged from 15% for the LVEF to 30% for the LVESV.

*Conclusions:* A significant risk of error for measurement of the ventricular volumes and contractility is present when images are acquired during free breathing. As the range of error is larger than the usually tolerated 5 to 10% for clinical measurements, we strongly advise to acquire images serving for quantitative measurements during breath hold. If this is not possible, the results obtained should be considered

***Table 1.*** Quantitative results.

| | Mean BH | Mean NBH | Mean difference | Limits of agreement |
|---|---|---|---|---|
| RVEDV (ml) | 155.4±62.5 | 160±73 | −4.7 | −51.7/+42.3 |
| RVESV (ml) | 82.3±41 | 88.8±43.6 | −6.4 | −30.6/+17.7 |
| RVEF (%) | 47.8±8.7 | 49.2±8.2 | −1.4 | −17/+14 |
| LVEDV (ml) | 79.4±23.7 | 84.4±30.8 | −5 | −28.3/+18.3 |
| LVESV (ml) | 33.5±9.5 | 37.4±13.5 | −3.9 | −16.2/+8.5 |
| LVEF (%) | 56.7±7 | 55.1±6.2 | +1.5 | −7.7/+10.8 |

as indicative (semi-quantitative) and not be used for critical clinical decisions.

## 404. Feasibility of Velocity-Encoded Cine MR Imaging to Measure Changes in Collateral Blood Flow After Stenting of Aortic Coarctation

Sandra Pujadas, MD,[1] Gautham P. Reddy, MD,[1] Oliver Weber, PhD,[1] Christopher Tan, MD,[2] Philip Moore, MD,[2] Charles B. Higgins, MD.[1] [1]*Department of Radiology, University of California San Francisco, San Francisco, CA, USA,* [2]*Division of Pediatric Cardiology, University of California San Francisco, San Francisco, CA, USA.*

*Introduction:* Velocity-encoded cine magnetic resonance (MR) imaging has been recognized as a method for assessing hemodynamic significance coarctation of the aorta by quantifiying collateral flow. The presence of collateral flow is a clear indication of hemodynamic restriction of flow through the coarctation site. This information has been used for diagnostic purposes. However, there are no studies that have assessed the use of early alterations of collateral flow for documenting effectiveness of coarctation treatment.

*Purpose:* The purpose of this study was to assess the feasibility of using velocity-encoded cine MR imaging to measure the change in collateral blood flow immediately after stenting of aortic coarctation.

*Methods:* We enrolled seven patients (4 females, 3 males; mean age 17 y.o, age range 12–27 y.o) with coarctation of the aorta. All of these patients had previously undergone operative repair of the coarctation and had clinical signs and/or symptoms of re-stenosis.

The following MR imaging sequences were obtained before stent placement:

1. Black blood: single shot, Sense 2, 256 matrix, TSE factor (42), TE = 42 ms, TR = 2 heart beats, flip angle = 50, dual-inversion black-blood pulse.
2. Velocity-encoded cine MR imaging (quantitative flow) at two sites in the descending aorta (just distal to the coarctation and at the level of the diaphragm): TE = 4.8 ms, TR = 7.7 ms, 16 heart phases, 3 NSA, velocity encoding 400 cm/s.
3. Gadolinium-enhanced 3D MR angiography. Matrix 400, 25 slices at 3.4 mm (interpolated to 50 slices at 1.7 mm), partial echo, flip angle 40, spatial resolution $0.5 \times 1.76$ mm, TE= 1.44 ms, TR = 5.1 ms, breathhold. Gd-DTPA 0.2 mmol/kg at 2 ml/sec, timed with use of bolus tracking sequence.

Patients then underwent x-ray angiography and treatment of the coarctation with balloon angioplasty and stenting (2910 Cordis Genesis stainless steel balloon-expandable stent). Early after stent placement, patients underwent black blood and velocity-encoded cine MR imaging, as described above.

The velocity-encoded cine MR imaging sequences were analyzed on an off-line workstation (Philips EasyVision) to determine aortic blood flow. Collateral flow was calculated as distal aortic flow minus proximal flow. The collateral flow percentage was obtained by dividing collateral flow by proximal aortic flow and multiplying by 100.

The collateral flow and collateral flow percentage before and after stent placement were compared.

*Results:* All patients had substantial collateral flow percentage before stenting. Before stenting: mean proximal aortic flow = $44 \pm 3.6$ ml/sec; mean distal flow = $54 \pm 3.3$ ml/sec; collateral flow = $10 \pm 1.7$ ml/sec; collateral flow percentage = $24 \pm 5.1\%$.

After stent placement there was reduction of approximately 50% in collateral flow percentage in all of them. After stenting: mean proximal aortic flow = $60 \pm 8.2$ ml/sec; mean distal flow = $61 \pm 7.9$ ml/sec; collateral flow = $1 \pm 1.3$ ml/sec; collateral flow percentage = $4 \pm 2.4\%$.

*Conclusions:* Velocity-encoded cine MR imaging can be used to measure changes in collateral circulation after stent treatment of coarctation of the aorta. A possible application of this technique is the assessment of the success of stenting.

## 405. Is Invasive Oxymetry the Gold Standard in the Assessment of the Pulmonary-to-Systemic Flow Ratio (Qp/Qs)? An MRI Study

Pierluigi Festa,[1] Lamia Ait-Ali,[2] Alfredo Giuseppe Cerillo,[3] Francesca Amoretti.[4] [1]*Pediatric Cardiology and MRI lab., Ospedale Pasquinucci, CNR, Massa-Pisa, Italy,* [2]*Pediatric Cardiology, Ospedale Pasquinucci, Massa, Italy,* [3]*Pediatric Cardiac Surgery, Ospedale Pasquinucci, Massa, Italy,* [4]*Radiology, Ospedale Pasquinucci, Massa, Italy.*

*Introduction:* The Qp/Qs is a crucial parameter in the management of patients with congenital heart disease, which has been traditionally assessed by invasive oxymetry during cardiac catheterisation. PVC-MRI is a powerful non-invasive technique to measure and analyse blood flow, and has been employed in the measurement of the Qp/Qs.

*Purpose:* To assess the accuracy of MRI in evaluation of the Qp/Qs in comparison with oxymetry.

*Methods:* The QP/QS ratio was measured in 21 patients with ASD or partial anomalous pulmonary venous connection by cardiac catheterisation and PVC-MRI, by measuring the through-plane flow in pulmonary artery and aorta. In 12 of them and in 4 additional patients not scheduled for cardiac catheterisation, the Qp/Qs was also calculated by right and left ventricular stroke volume ratio (RVSV/LVSV), by MRI (FIESTA). A GE CV/Signa 1.5 T machine was used.

*Results:* Linear regression analysis showed a high correlation between PVC-MRI and oxymetric calculation of the Qp/Qs ($y=1.064+0.381*X$; $R^2=0.728$; $P<0.0001$) . However, a systematic underestimation of the Qp/Qs was observed with PVC-MRI compared to oxymetry, mainly in patients with large shunts. Furthermore, a very good correlation between the Qp/Qs calculated by PVC-MRI and volumetric MRI method was observed ($y=-0.129+1.155*X$; $R^2=0.0846$; $P<0.0001$).

*Conclusions:* PVC-MRI is a valid tool in the measurement of the Qp/Qs. The discrepancy that we observed between PVC-MRI and oxymetry in the presence of large left to right shunts is consistent with the previous observation that estimate of shunt magnitude by oximetry may be somewhat imprecise in patients with a high Qp/Qs. The accuracy of PVC-MRI in analysing Qp/Qs is also confirmed by the measurement of the Qp/Qs by RVSV/LVSV (volumetric method) that strictly correlates with PVC-MRI.

## 406. MRI Evaluation of Right Heart Remodeling After Percutaneous Atrial Septal Defect (ASD) Closure

Hong Huang, MD,[1] Naeem Merchant, MD,[1] Peter McLaughlin, MD,[2] Graham Wright, PhD.[3] [1]*Joint Department of Medical Imaging, University Health Network and Mount Sinai Hopital, Toronto, ON, Canada,* [2]*Department of Cardiology, University Health Network and Toronto General Hospital, Toronto, ON, Canada,* [3]*Department of Medical Biophysics, University of Toronto, Sunnybrook and Women's College Health Sciences Centre, Toronto, ON, Canada.*

*Introduction:* Atrial Septal Defect (ASD) is an important congenital cardiac defect, which is commonly diagnosed in adulthood, and accounts for 10% of all congenital heart disease. ASDs can cause volume overload of the right atrium/ventricle (RA/RV) with the potential for subsequent development of late complications, such as pulmonary hypertension, stroke, atrial arrhythmias and heart failure. Patients receive symptomatic relief and prevention of progression of right heart dysfunction with ASD closure. Transcatheter device closure has been found to be effective and safe in occluding ASDs. Echocardiography (TEE) and cardiac catheterization can confirm closure of the ASD; however, a precise measure of the impact of the closure on RA/RV size, volume and function can best be done with MRI.

*Purpose:* The purpose of this study is to evaluate the effect of Percutaneous Atrial Septal Defect (ASD) Closure on RA/RV size and function using MRI.

*Method and Materials:* Twenty patients between the ages of 20 and 72 (11 female and 9 male) with ASD defects underwent an MRI study prior to and 3 months after percutaneous closure using the Amplatzer atrial septal occluder. MRI techniques on a 1.5 T GE Signa CV/I system were used. Patients were placed in a supine position with a cardiac coil. MRI studies included Axial Fiesta images (TR 4, TE 1.3, Flip 45, matrix $128 \times 256$, NEX 1, 8-mm slices thickness and FOV 26). As no normal ranges of RA volumes are available in the literature, twenty normal age-and sex-matched subjects were also studied to obtain normal ranges for RA/RV volumes. End systolic and end diastolic slice were identified and manual regions of

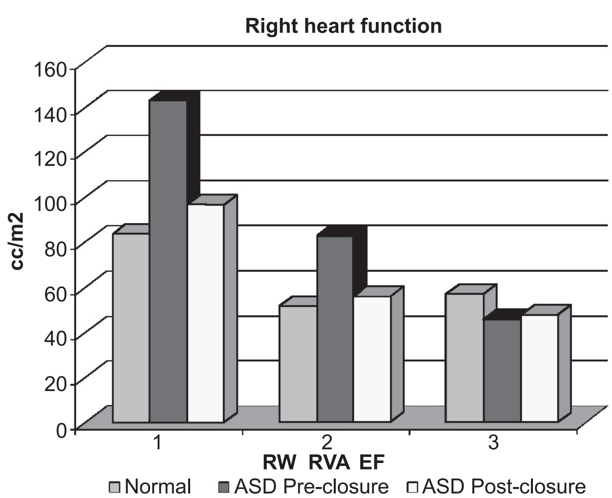



***Figure 1.*** Comparison right heart function between normal, pre and post ASD closure. (*View this art in color at www.dekker.com.*)

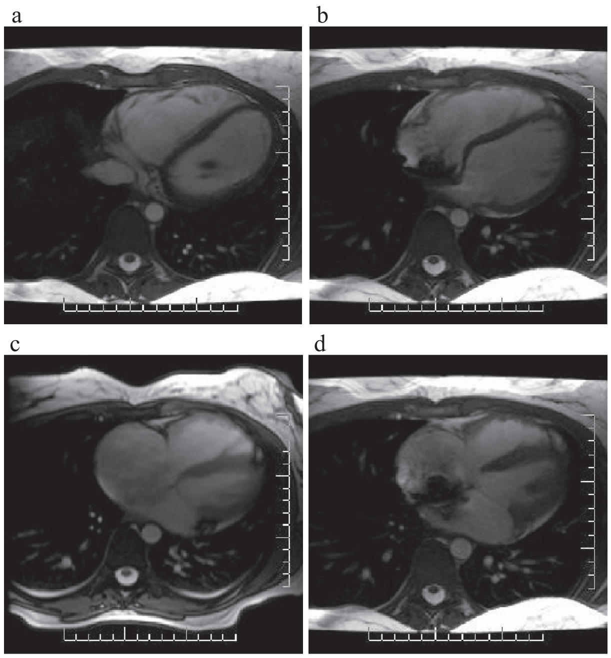



*Figure 2.* a. End diastolic ASD pre-closure. b. End diastolic ASD post-closure. c. End systolic ASD pre-closure. d. End systolic ASD post-closure.

interest were drawn in the RA/RV in normal and ASD patients prior to and three months post ASD closure. Volumes were normalized to body surface area.

*Results:* The average volume of the RV in pre-closure ASD patients was 143 ml/m2 (84 ml/m2 in the normal group). This decreased to 97 ml/m2 post closure. ($p<0.001$). RA volumes also decreased markedly from, 83 ml/m2 (52 ml/m2 in the normal group) to near normal at 54.5 ml/m2 ($p<0.001$). RV ejection fraction (RVEF) from pre-closure to post-closure did not change significantly: 46% pre-closure (57% in the normal group) to 48% post closure (Figures 1 and 2).

*Conclusion:* ASD closure results in measurable RA/RV remodeling with a significant decrease of RA/RV volume. Long-term follow-up to evaluate the clinical implications of these changes is needed.

## REFERENCES

Hijazi, Z. M., Hellenbrand, W. E. (1992). The right ventricle in congenital heart disease. *Cardiol. Clin.* 10:91–102.

Kort, H. W., Balzer, D. T., Johnson, M. C. (2001). Resolution of right heart enlargement after closure of secundum atrial septal defect with transcatheter technique. *J. Am. Coll. Cardiol.* 38:1528–1532.

Veldtman, G. R., Razack, V., Siu, S., et al. (2001). Eight ventricular form and function after percutaneous atrial septal defect device closure. *J. Am. Coll. Cardiol.* 37:2108–2113.

## 407. Magnetic Resonance Imaging for Hypoplastic Left Heart Syndrome Following the Norwood Stage 1 Operation

Andrew M. Taylor, MD, MRCP, FRCR, Vivek Muthurangu, BSc, MBChB, MRCPCH, Sanjeet R. Hegde, MBBS, MRCPCH, Marc E. Miquel, PhD, Derek L. G. Hill, PhD, Reza Razavi, MBBS, MRCP, MRCPCH. *Cardiac MR Research Group, Division of Imaging, Guy's Hospital, King's College London, London, United Kingdom.*

*Introduction:* Hypoplastic left heart syndrome (HLHS) constitutes a spectrum of congenital heart disease in which there is hypoplasia or atresia of the left heart components and ascending aorta. Untreated, HLHS is almost universally fatal, with over 90% of neonates dying within the first 90 days of life. There are three management options available for HLHS neonates: Cardiac transplantation, palliation with the Norwood procedure, and compassionate care. In the USA and UK, the Norwood procedure has become the preferred treatment option.

*Purpose:* To demonstrate that cardiac magnetic resonance (MR) can provide a comprehensive anatomical and functional assessment of HLHS following the stage 1 Norwood operation, which can be used to establish patient suitability for procedure to the stage 2 (bi-directional Glenn) operation.

*Methods:* We have performed cardiac MR in 30 infants under general anaesthesia following the Norwood stage 1 operation. Informed consent was obtained for all subjects. Imaging was performed on a 1.5 T Intera MR scanner (Phillips Medical Systems, Best, the Netherlands). Axial balanced fast-field-echo volume images of the heart and great vessels (TR 3 ms, TE 1.5 ms, flip angle 45°, matrix $256 \times 160$, resolution $1.3 \times 1.3 \times 1.3$ mm), 'black-blood' turbo spin echo images through the innominate to right pulmonary artery (RPA) shunt, native/neo-aorta anastomosis and aortic arch (TR 800 ms, TE 80 ms, flip angle 90°, echo train length 25, slice thickness 6 mm, number of signal averages 3, matrix 256 × 256), short axis balanced fast-field-echo cine images of the heart to assess right ventricular volumes and function (TR 3.4 ms, TE 1.7 ms, flip angle 50°, slice thickness 6 mm, phases 20, matrix 192 × 256), phase contrast velocity flow mapping through the ventricular inlet and outlet valves (fast-field-echo: TR 5 ms, TE 3 ms, slice thickness 8 mm, matrix 192 × 256), and 3D gadolinium contrast-enhanced MR angiography images of the great vessels (fast-field-echo: TR 4.7 ms, TE 1.5 ms, flip angle 40°, slice thickness 1.4 mm, matrix 240 × 512) were acquired. The MR findings were compared with the operative findings.

*Results:* One patient was referred for cardiac transplantation (ejection fraction 17%). Twenty-nine patients were referred for the stage 2 operation. In these 29 patients the following anatomical findings were demonstrates by cardiac MR and confirmed at surgery: Patency of the native/neo-aorta anastomosis, patency of the innominate to RPA shunt, pulmonary artery anatomy, vena caval anatomy and aortic arch anatomy. Eight patients required additional aortic arch surgery to stenosis at the neo-aorta/descending aorta anastomosis that were visualised on MR. Bilateral superior vena cavas were seen in 4 patients. Single ventricle ejection fraction was 52 ± 14% (excluding the patient referred for transplantation) (Fig. 1).

*Conclusion:* Cardiac MR can provide anatomical and functional information for optimal surgical planning of both the stage 2 operation and any necessary stage 1 revisions, and help guide medical treatment. In our own practice, cardiac MR obviates the need for x-ray cardiac catheterisation in this group of patients.

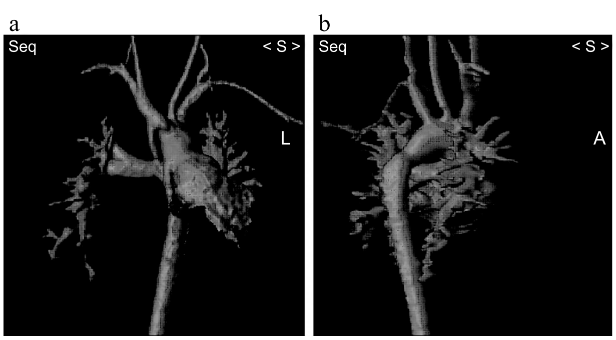



***Figure 1.*** 3D gradolinium contrast-enhanced MR angiogram of HLHS following Norwood stage 1 operation, a) Anterior view showing widely patent native/ neo-aorta anastomosis and innominate to RPA shunt, b) Lateral view showing mild narrowing at the neo-aorta/ descending aorta anastomosis (no surgical revision required).

## 408. Regional Differences in Right Ventricular Systolic Function following Infundibulotomy as Determined by cine-Magnetic Resonance Imaging

Irene D. Lytrivi, MD,[1] H. Helen Ko, BS, RDCS,[1] Shubhika Srivastava, MD,[1] Karen Norton, MD,[2] Wyman Lai, MD, MPH,[1] Jeffery Goldman, MD,[2] James C. Nielsen, MD.[1] [1]*Pediatric Cardiology, Mount Sinai School of Medicine, New York, NY, USA,* [2]*Department of Radiology, Mount Sinai School of Medicine, New York, NY, USA.*

*Introduction:* Evaluation of right ventricular (RV) volumes and ejection fraction (EF) by cine-MRI is the accepted reference standard. Significant differences between the two distinct components of the RV, the sinus and the infundibulum, have been demonstrated in normal subjects with regard to their contribution to stroke volume and ejection fraction. Limited quantitative data, however, is available about regional differences in systolic function in subjects following RV outflow tract (RVOT) surgery.

*Purpose:* Our aim was to examine the relative size and contribution of the RV sinus and infundibulum to global RV size and systolic function in subjects after surgical procedures involving the RVOT (infundibulotomy).

*Methods:* Cine-MRI data from a single institution were reviewed retrospectively for two groups: status-post RVOT surgery (n = 20) and controls (n = 14). Subjects who fulfilled the following criteria were included for the RVOT surgery group: 1) Prior surgery on the RVOT; 2) Biventricular repair. For the control group: 1) No history of surgical procedure involving the RV; 2) No significant tricuspid or pulmonary valve stenosis or regurgitation; 3) No branch pulmonary artery stenosis or pulmonary hypertension; 4) No atrial or ventricular septal defects. Global and regional RV end-diastolic volumes (EDV) and end-systolic volumes were determined by analyzing images from cine MRI utilizing steady-state free precession pulse sequences. The infundibulum was defined as the segment of the RV that extends between the proximal os infundibulum and the pulmonary valve. The proximal os infundibulum is a muscular ring comprised of the septal band, moderator band, anterior papillary muscle group of the tricuspid valve and the parietal band. The boundary between the sinus and the infundibulum was traced so that the parietal, moderator and septal bands were included in the infundibulum. EDV was indexed to body surface area raised to the 1.4 power ($BSA^{1.4}$). All values are reported as mean ± standard deviation

***Table 1.*** Regional right ventricular size and systolic function.

| | Age (years) | Infundibular EF (%) | Sinus EF (%) | Global EF (%) | Infundibular EDVi (ml/BSA$^{1.4}$) | Sinus EDVi (ml/BSA$^{1.4}$) | Global EDVi (ml/BSA$^{1.4}$) |
|---|---|---|---|---|---|---|---|
| RVOT Surgery (n=20) | 16.7±10.8 | 28±11.4 | 54±6.8 | 48±5.7 | 26±14 | 79±17 | 107±27 |
| Controls (n=14) | 16.0±6.5 | 56±12.5 | 57±6.5 | 57±7.3 | 19±5 | 48±9 | 67±13 |
| p value | NS | <0.01 | NS | <0.01 | 0.05 | <0.01 | <0.01 |

and variables were compared using the two-tailed t-test.

*Results:* Global and infundibular EF differed between the two groups ($p<0.01$), however sinus EF did not ($p=0.28$). Indexed global, sinus and infundibular end-diastolic volumes (EDVi) differed between the two groups ($p<0.01$, $<0.01$ and $=0.05$, respectively). See Table 1.

*Conclusions:* Despite significant decrease in the regional infundibular EF in subjects following RVOT surgery, the regional sinus systolic function as quantified by EF is preserved. In addition, our data suggest that, following RVOT surgery, the RV sinus appears to enlarge to a greater degree than the infundibulum. Segmenting the RV into its component parts and measuring regional size and function may provide variables that correlate with clinically important outcomes.

## 409. Validation and Application of Single Breath-Hold Cine Cardiac MR for Ventricular Function Assessment in Children with Congenital Heart Disease

Andrew M. Taylor, MD,[1] Steven Dymarkowski, MD, PhD,[2] Kristof De Meerleer, MD,[2] Pascal Hamaekers,[2] Marc Gewillig, MD, PhD,[3] Luc Mertens, MD, PhD,[3] Jan Bogaert, MD, PhD.[2] [1]*Cardiac Unit, Institute of Child Health and Great Ormond Street Hospital, London, United Kingdom,* [2]*Department of Radiology, Gasthuisberg University Hospital, Leuven, Belgium,* [3]*Department of Pediatric Cardiology, Gasthuisberg University Hospital, Leuven, Belgium.*

*Introduction:* Cardiac MR can provide accurate quantitative ventricular volumes, mass and function, and is now regarded as the in vivo 'gold-standard' for measuring these parameters in adults. In general, this data is acquired during multiple breath-holds. However, for young children who are scanned without a general anaesthetic, breath-holding is problematic. Firstly, breath-hold instructions may not be fully understood; secondly, breath-holds may not be maintained; and thirdly when a breath-hold is performed on multiple occasions the same breath-hold position may not be achieved. Acquisition of the entire data set in a single breath-hold would be useful, as it would restrict the number of breath-holds required to a minimum and limit the effects of image mis-registration between multiple breath-holds.

*Purpose:* To validate the accuracy of ventricular volume measurements using a single breath-hold real-time steady sate free precession (SSFP) cine MR method in comparison with a more conventional multiple breath-hold SSFP method, and demonstrate its application during adenosine stress imaging in children with congenital heart disease.

*Methods:* Twenty-eight subjects with congenital heart disease were studied (mean age 12.4 ± 2.3 years [range 8.8–16.8], 16 males, 17 congenital aortic stenosis, 11 transposition of the great arteries with arterial switch operation). All studies were performed in accordance with the guidelines of the hospital committee on medical ethics. Informed consent was obtained from all patients or their guardians. All images were obtained with a 1.5T Intera MR scanner (Philips Medical Systems, Best, the Netherlands). Short-axis images were acquired from the base of the heart to the apex, encompassing the entirety of both ventricles with both a conventional 2D balanced-turbo-field-echo sequence acquired over multiple breath-holds (TR—3.8 ms, TE—1.9 ms, flip-angle—60°, slice thickness—7 mm, matrix—160 × 256, phases—30) and a single breath-hold 2D balanced-turbo-field-echo sequence (TR—2.8 ms, TE—1.4 ms, flip-angle—60°, slice thickness—10 mm, matrix—122 × 256, phases—20). Two independent observers performed the ventricular volume, mass and function analysis. Correlation coefficients and Bland Altman analysis were used to compare the two methods of measuring ventricular volumes.

Paired Student t-test was performed to compare data measured at rest and during adenosine stress.

*Results:* There was good agreement between the multiple breath-hold and single breath-hold methods for measurement of end-diastolic volume (EDV) (r=0.95 and 0.96) and end-systolic volume (r=0.76 and 0.90) for the right (RV) and left ventricles (LV) respectively, and the left ventricular mass (r=0.97). There was small systematic overestimate of the volume measurements by the single breath-hold method (mean bias 5–10%) and a corresponding underestimate of the LV mass (mean bias −4.6%). This led to a reduced ejection fraction calculation (mean bias −3%), but no significant bias in the cardiac output calculation.

In two patients who could not breath-hold appropriately, the multiple breath-hold technique images were uninterruptible, whilst the single breath-hold images (not actually acquired during breath-holding) were of good quality and useable for cardiac function analysis.

Adenosine was administered safely to all subjects with no major side effects. During adenosine stress there was no change in the RV and LV EDV, but a significant increase in the heart rate ($p<0.001$) and a significant reduction in the ESV ($p=0.03$). This led to a significant increase in the SV ($p=0.004$), EF ($p=0.004$) and cardiac output (mean increase of $1.5\pm1.0$ L/min [range 0.1–2.9], $p<0.001$, see Figure 1).

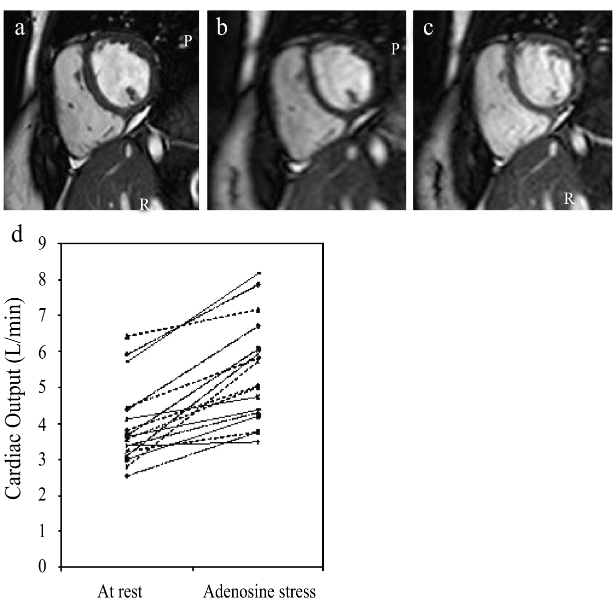



*Figure 1.* Mid-ventricular short axis cuts in a single subject. a) multiple breath-hold method at rest, b) single breath-hold method at rest and c) single breath-hold method acquired during adenosine stress. d) Change in cardiac output for each of the subjects who underwent stress imaging with adenosine. In all subjects there was an increase in cardiac output.

*Conclusion:* Single breath-hold SSFP cine imaging is robust and accurate in assessing cardiac function in children with congenital heart disease. The main advantage is that an uncooperative child need only perform one good quality breath-hold to acquire the data or, in the worse case scenario, no breath-hold, without significant degradation of the image quality. An application of this method is the assessment of cardiac function during stress.

## 410. Right Ventricular Function of Patients with Transposition of the Great Arteries

Hallgeir Tveiten, MD,[1] Stig F. Samnøy, PhD,[1] Erling Andersen, PhD,[1] Gottfried Greve, MD, PhD,[2] Gunnar Norgård, MD, PhD,[2] Terje H. Larsen, MD, PhD.[1] [1]*Department of Radiology, Haukeland University Hospital, Bergen, Norway,* [2]*Department of Pediatrics, Haukeland University Hospital, Bergen, Norway.*

*Introduction:* Transposition of the great arteries (TGA) is a serious congenital heart disease that has to be surgically corrected. The condition is characterized by the change in position of the ascending aorta and the pulmonary artery in which the ascending aorta arises from the right ventricle whereas the pulmonary artery arises from the left ventricle. A shunt between these circulatory systems is required in order to bring oxygenated blood to the body.

*Purpose:* The current surgical method of choice is to restore the anatomical position of the ascending aorta and the pulmonary artery, respectively. The previous surgical approach was the atrial switch procedure (Senning technique). Conducting oxygenated blood of the pulmonary veins to the right ventricle and the caval blood to the left ventricle, the right ventricle maintains to be the systemic ventricle in these patients. The consequence of sustained increased right ventricular workload is myocardial hypertrophy and in some cases development of tricuspidal regurgitation, arrythmia and right ventricular failure. A life long follow-up of these patients is necessary, and MRI may contribute to provide information of the heart morphology and right ventricular function.

*Methods:* 12 TGA patients operated with the Senning technique and 8 healthy volunteers were

***Table 1.*** Velocities and blood flow in the pulmonary artery and ascending aorta.

| Velocities and blood flow | | Patients (n=11) | SD | Controls (n=8) | SD |
|---|---|---|---|---|---|
| Maximal velocity of the pulmonary artery | cm/s | 97.2 (69.4–152.9) | 25.1 | 49.6 (47.8–83.4) | 22.3 |
| Maximal velocity of the ascending aorta | cm/s | 100.5 (73.6–142.7) | 19.8 | 116.6 (87.3–157.0) | 21.8 |
| Mean velocity of the pulmonary artery | cm/s | 17.6 (9.6–24.2) | 5.2 | 12.5 (9.8–17.6) | 3.2 |
| Mean velocity of the ascending aorta | cm/s | 21.4 (10.8–46.9) | 9.5 | 23.6 (18.9–32.3) | 4.5 |
| Blood flow of the pulmonary artery | ml/s | 112.0 (66.9–190.3) | 40.9 | 91.8 (51.9–122.7) | 22.3 |
| Blood flow of the ascending aorta | ml/s | 105.7 (63.9–156.8) | 31.1 | 135.0 (77.4–269.9) | 57.5 |

examined by MRI. The patient group consisted of 7 girls and 5 boys (mean age=13.4 years, range 9–20 years). The control group consisted of 4 boys and 4 girls (mean age=19.5 years, range 9–27 years). The images obtained from 1 patient was not of sufficient quality and was eliminated. 2D FLASH velocity-encoded measurements were obtained by a 1.5 T Siemens Magnetom Vision Plus magnet, and a standard Siemens flow program was applied.

*Results:* The maximal and mean velocities of the pulmonary artery were consistent with that found in the ascending aorta of the Senning operated patients. Correspondingly, the blood flow of the pulmonary artery and ascending aorta was comparable (Table 1). The measurements obtained from the controls showed a less consistency concerning both velocities and blood flow between the pulmonary artery and ascending aorta (Table 1).

Although the right ventricle of the Senning operated patients showed considerable wall thickening and increased performance as indicated by the velocity measurements, the delayed contraction of the right ventricle compared to the left ventricle was still present, and was comparable to that seen in the control group (Figures 1 and 2).

*Conclusions:* MRI provides important information of the right ventricle of Senning operated patients and should be implemented in the follow-up examination of these patients. The flow-weighted acquisitions should be meticulously positioned in an orthogonal plane to the blood flow. In this study the velocity and blood flow measurements of the pulmonary artery of the

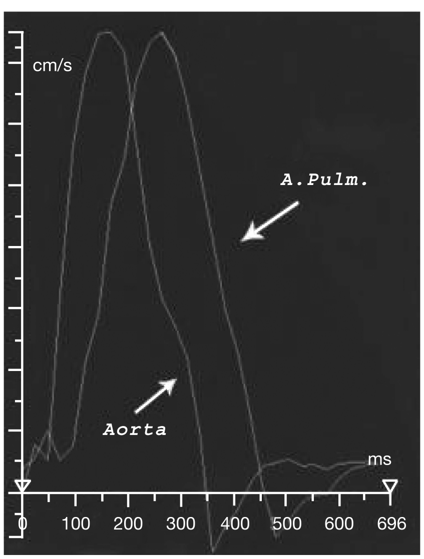



***Figure 1.*** The peak velocity of the pulmonary artery and ascending aorta, respectively, obtained from a control.

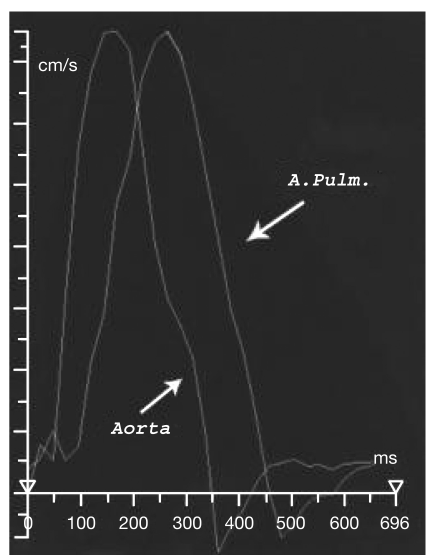



***Figure 2.*** The peak velocity of the pulmonary artery (arising from the left ventricle) and the ascending aorta (arising from the right ventricle), respectively, of a Senning operated patient.



Marcel Dekker, Inc.
270 Madison Avenue, New York, New York 10016

controls were apparently underestimated, whereas the consistency of the measurements of the pulmonary artery and ascending aorta of the TGA patients were considerable better. Probably this was a result of altered position of the pulmonary artery in TGA patients making it easier to achieve adequate slice positions. Interestingly, it was shown that contractile features of the right ventricle are maintained in these patients even though it functions as the systemic ventricle. This may be associated with the long-term development of right ventricular dysfunction that appears in some patients.

### 411. The Use of Contrast-Enhanced MR Angiography for Planning Interventional Catheterization

Emanuela R. Valsangiacomo Büchel, MD, Stefano DiBernardo, MD, Urs Bauersfeld, MD, Felix Berger, MD. *Pediatric Cardiology, University Children's Hospital, Zurich, Switzerland.*

*Introduction:* Interventional catheterization is being increasingly used for relief of residual lesions in congenital heart disease. Exact anatomical imaging is crucial in the planning of an intervention. This can be provided non-invasively and without radiation by contrast-enhanced MR angiography (CEMRA).

*Purpose:* To evaluate the accuracy of the measurements of the vessels obtained by CEMRA in comparison to those obtained by conventional X-ray angiography (CXA).

*Methods:* Two experienced observers, a MRI specialist and an angiocardiographer, blinded to each other retrospectively measured the diameters of aorta and pulmonary arteries on the CEMRA and CXA images. Particular care was taken in choosing the images in the same angulation and in measuring the vessels in the same location, corresponding to the aortic root, ascending aorta, transverse aortic arch, isthmus segment, proximal thoracic aorta and the origin of the pulmonary arteries and their peripheral segment. The measures obtained were compared by Pearson correlation and by calculating the limits of agreement.

*Results:* Twenty-one children with congenital heart disease, mean age $5.6 \pm 5.2$ years, weight $21.1 \pm 18.4$ kg, underwent CEMRA and catheterization for assessment or treatment of a residual lesion. The time interval between the CEMRA and the CXA examination was $2.6 \pm 2.3$ months. A total of 98 measurements, 37 of the aorta and 61 of the pulmonary arteries were performed on the images obtained by each technique. The correlation between CEMRA and CXA measurements was excellent, $r = 0.97$, $p < 0.0001$. The mean difference between the two techniques was $0.018 \pm 1.1$ mm; the limits of agreement were $-2.14$ and $+2.18$ mm. Similar agreement was found for measures of the aorta ($r = 0.97$, mean difference $0.20 \pm 1.08$ mm, limits of agreement $-2.3/+1.9$) and of the pulmonary arteries ($r = 0.97$, mean difference $0.048 \pm 0.89$ mm, limits of agreement $-1.7/+1.8$).

*Conclusions:* CEMRA provide accurate quantitative anatomical information, which highly agrees with CXA data, and can therefore be used for planning interventional catheterization.

### 412. The Spectrum of Aortic Arch Anomalies in Patients with a 22q11.2 Deletion by Cardiac Magnetic Resonance Imaging

Tiffanie R. Johnson, MD,[1] Donna M. McDonald-McGinn, MS,[2] Elaine H. Zackai, MD,[2] Elizabeth Goldmuntz, MD,[2] Mark A. Fogel, MD.[2] [1]*Pediatric Cardiology, Riley Hospital for Children, Indiana University, Indianapolis, IN, USA,* [2]*Cardiology, Children's Hospital of Philadelphia, Philadelphia, PA, USA.*

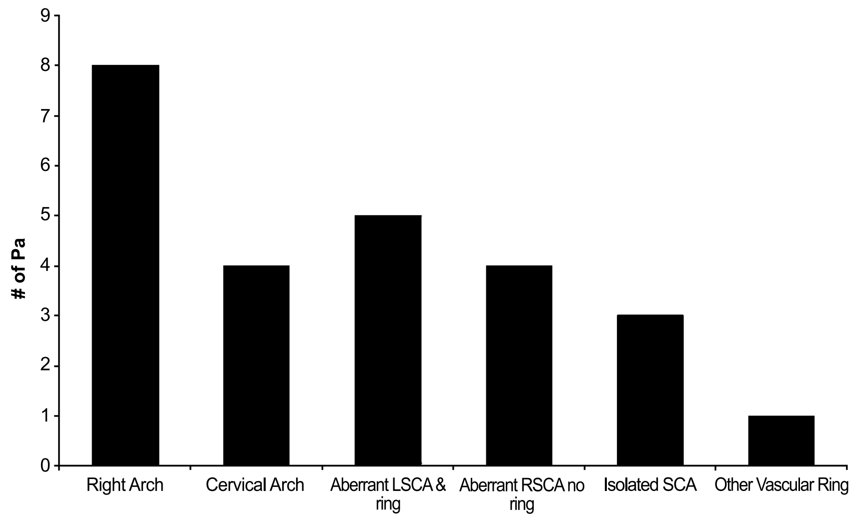
*Introduction:* Aortic arch anomalies are a common finding in the 22q11.2 deletion syndrome but are not always immediately appreciated or easily diagnosed. MRI has proven to be a useful tool to detail complex aortic arch anatomy.

*Purpose and Methods:* This study reviews aortic arch anomalies diagnosed by MRI in a single center for patients (pts) with a 22q11.2 deletion and demonstrates the wide variety of complex aortic arch anomalies that can only be accurately defined by MRI as compared to echo. Records of pts with a 22q11.2 deletion referred for cardiac evaluation were reviewed. From May 1999 to August 2003, 16 pts underwent cardiac MRI, after echocardiography, to clarify aortic arch anatomy. Cardiac anatomy was imaged using steady state free precession, HASTE dark blood sequences and gadolinium for 3D reconstruction.

*Results:* Of 67 pts seen for cardiac evaluation, 16 (23.9%) were referred for MRI due to uncertainty of diagnosis regarding aortic arch anatomy by echocardiography. All MRI findings were abnormal (Figure 1). In 15/16 cases, MRI was better able to delineate the anatomy where echo had failed. Three pts underwent



Marcel Dekker, Inc.
270 Madison Avenue, New York, New York 10016




([1]Some patients had multiple diagnoses. Abbreviations: LSCA=left subclavian artery, RSCA=right subclavian artery, SCA=subclavian artery)

***Figure 1.***

surgical repair of a vascular ring diagnosed by MRI. The three pts with an isolated subclavian artery need future monitoring for symptoms of ''steal'' phenomena from the vertebral artery.

*Conclusions:* Cardiac MRI demonstrates a wide variety of aortic arch anomalies in pts with a 22q11.2 deletion. Even in pts with normal intracardiac anatomy, there should be a high index of suspicion for aortic arch anomalies. When aortic arch anatomy proves difficult to define by echocardiography or is thought to be abnormal, MRI is the imaging modality of choice.

## 413. Isolated Non-compaction Cardiomyopathy. Magnetic Resonance Imaging Compared with (Contrast)Echocardiography

Robert J. M. van Geuns,[1] Lotte de Laat, MD,[1] Timo Baks, MD,[1] Folkert J. ten Cate, MD,[1] Piotr A. Wielopolski, PhD,[2] Pim J. de Feyter, MD.[1] [1]*Cardiology, Erasmus MC, Rotterdam, Netherlands,* [2]*Radiology, Erasmus MC, Rotterdam, Netherlands.*

*Introduction:* Isolated Ventricular Non-compaction Cardiomyopathy (IVNC) is a recently established diagnosis for which the criteria are not defined yet. Both MRI and echocardiography have been used for the diagnosis. A comparison between both techniques has never been performed.

*Purpose:* To investigate the relation between MRI and Echocardiography diagnosis of IVNC.

*Methods:* Seven patients suspected for non-compaction cardiomyopathy were investigated with echocardiography and MRI. The MRI protocol consisted a cine-Fiesta sequence (TR 3.4 ms, TE 1.3 ms, Flip angle 45, 8 shots, matrix $160 \times 128$, FoV 320 mm, slice thickness 8 mm) in 2-chamber, 4-chamber and short axis orientation using a 1.5 T MRI system (GE, Signa CV/i, Milwaukee, WI).

Two-dimensional echocardiography (2DE) was performed in standard orientations using a modern ultrasound system (Philips, Sonos 5500; Andover, MA). For contrast echocardiography (CE) a commercially available contrast agent (Sonovue, Barcco, Italy) was injected in an antecubetal vein.

Regional prevalence of non-compaction was registrated for all techniques and non-compacted and compacted layers were measured.

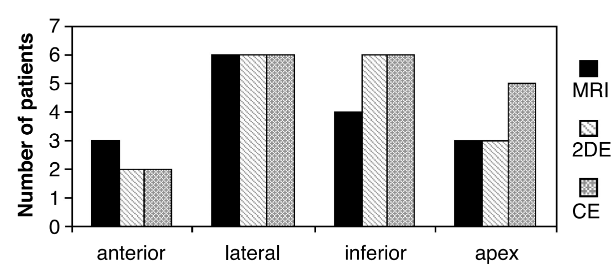



***Figure 1.***

*Figure 2.*

*Results:* All 7 patients completed the protocol without complications and with sufficient image quality for analysis. A very close correlation between all three techniques for regional involvement of the left ventricle was seen. (Figure 1). Involvement of the apex was more frequently established with contrast echocardiography compared to MRI and 2D-echo. Mean non-compacted layer thickness in MRI, 2DE and CE were 15.0 ± 2.8 mm, 14.1 ± 3.3 mm and 14.4 ± 2.8 mm respectively, while compacted layer thickness was 5.7 ± 0.9 mm, 6.3 ± 1.0 mm and 5.4 ± 5.4 mm respectively. Using a Student T-test these differences were not significant. The mean ratio between non-compacted and compacted layers was less in 2DE compared to MRI ($p = 0.06$) and CE ($p = 0.04$) (Figure 2).

*Conclusions:* MRI and echocardiography show a high correlation in the diagnosis of IVNC. In echocardiography contrast agents may be necessary for a reliable differentiation between the compacted and the non-compacted necessary for an accurate measurement of the ratio.

## 414. Pulmonary Perfusion Defects Detected by Time Resolved MRA in Patients with Adult Congenital Heart Disease

Jeffrey Goldman, MD,[1] James Nielson,[2] Emil Cohen,[1] Wyman Lai,[2] Richard Golinko.[2] [1]*Radiology, Mount Sinai Medical Center, New York, NY, USA,* [2]*Pediatric Cardiology, Mount Sinai Medical Center, New York, NY, USA.*

*Introduction:* Time resolved MRA of the chest enables us to evaluate lung perfusion as well as to directly visualize vascular shunts in congenital heart disease.

*Purpose:* The goal of this study was to determine the clinical utility of analyzing pulmonary blood volume and velocity maps as well as arterial venous transit time measurements from our time resolved MRA dataset.

*Methods:* 18 patients with a history of adult congenital heart disease underwent time resolved MRA on a 1.5T GE scanner. MRA was performed after the injection of 20cc's of IV Gd-DTPA. Time resolved MRA was performed of the chest using a 3D spoiled gradient echo sequence with the following parameters: TR = 2.4, TE = 1.7, $128 \times 64$ matrix, slice thickness 1.2 cm, 0.5NEX, acquisition time 1.9 seconds. Pulmonary blood volume and maximum slope parametric maps were calculated using software on an AW 4.0. Arterial venous transit time measurements were calculated in all patients from the signal intensity/time uptake curves for the pulmonary artery, left atrium and aorta. Peak uptake was determined for the right pulmonary artery, left atrium and aorta.

*Results:* The average pulmonary artery to left atrial transit time in normal volunteers was 5.6 seconds with a standard deviation of 1 second. 5/18 (23%) of the patients in our study with adult congenital heart disease had pulmonary artery to left atrial transit times less than 4 seconds. All five of these patients had a left to right cardio-pulmonary shunt. 6/18 (30%) of patients had mismatched pulmonary volume and pulmonary velocity maps. In two cases this was secondary to congenital partial anomalous pulmonary venous return. In three cases mismatch between blood volume and velocity mapping was secondary to iatrogenic shunts created by surgery. Three cases had a Glenn procedure (SVC to right pulmonary artery shunt) causing earlier filling of the right from the left lung which was filled later by the left pulmonary artery. One patient had a left aorto-pulmonary artery shunt causing delayed filling of the left lung. All five of these cases had normal pulmonary blood volume mapping but abnormal maximum slope images due to delayed filling of one lung. A six case presented with little right lung perfusion with normal filling of the main pulmonary artery due to outflow obstruction caused by compression of the pulmonary vein.

*Conclusion:* In addition to detecting right to left cardiac shunts, time resolved MRA of the chest revealed abnormal pulmonary perfusion in patients with anomalous pulmonary vasculature, patients' status post iatrogenic shunts created by surgery of the pulmonary vasculature and a patient with compression of the right pulmonary veins. Pulmonary perfusion imaging is a useful adjunct to evaluation of patients with congenital heart disease.

## 415. Gadolinium Cardiovascular Magnetic Resonance Detection of Myocardial Fibrosis in Adult Patients After Surgery for Tetralogy of Fallot

Sonya V. Babu-Narayan, BSc, MRCP,[1] Philip J. Kilner, MD, PhD,[2] James C. C. Moon, MB, BS, MRCP,[2] Dudley J. Pennell, MD, FRCP, FESC,[2] Michael A. Gatzoulis, MD, PhD, FESC, FACC.[1] [1]*Cardiovascular Magnetic Resonance and Adult Congenital Heart Unit, Royal Brompton Hospital, London, United Kingdom,* [2]*Cardiovascular Magnetic Resonance Unit, Royal Brompton Hospital, London, United Kingdom.*

*Introduction:* The population of adults with congenital heart disease is growing thanks to the merits of paediatric cardiac surgery. A late complication is ventricular dysfunction which contributes significantly to morbidity and mortality. Cardiovascular magnetic resonance (CMR) imaging with late gadolinium detects myocardial fibrosis after infarction. CMR has an advantage in imaging the congenitally abnormal right ventricle clearly. Gadolinium enhanced CMR can be used to detect myocardial infarction or fibrosis. We extended this technique to study the right ventricle (RV) after operated tetralogy of Fallot.

*Purpose:* We hypothesised that myocardial hyperenhancement would be present in adults after surgery for tetralogy of Fallot (TOF) implicating infarction or fibrosis to have a role in ventricular pathogenesis in these patients.

*Methods:* 55 consecutive patients (38 male, mean age 33±12, range 13 to 66 years) with operated TOF referred for CMR were studied with steady state free precession cine and corresponding late gadolinium segmented flash inversion recovery imaging. 53 patients had undergone repair and 2 patients had undergone Brock operation only.

*Results:* 54/55 (98%) had evidence of surgical scarring. Hyperenhancement was seen in the free wall of the right ventricular outflow tract (RVOT) in 48/55 secondary to surgical resection or patching. Both Brock patients (subpulmonary resection only) had such scarring. Hyperenhancement was seen in the area of the VSD patch in 42/53 repaired patients. Focal apical hyperenhancement consistent with apical vent (drain) insertion at the time of surgery was seen in 30/55 patients.

Of note, 17/55 (31%) patients had additional hyperenhancement within the trabeculated RV myocardium, unexplained by surgery directly. Such patients with hyperenhancement additional to surgical scarring were older (38±9 versus 31±13, p<0.03) and there was no significant difference in age at repair.

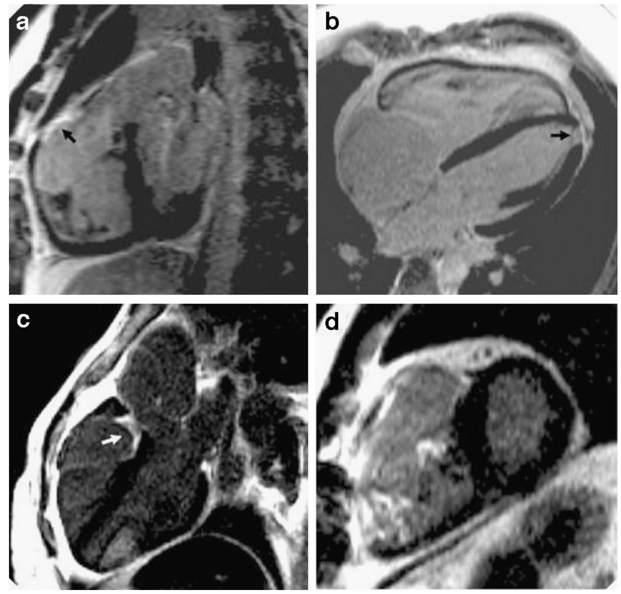


*Figure 1.*

3/55 (5%) of patients had unexpected infarction of the left ventricle (LV). These patients were older than those without evidence of LV infarction (47±6 versus 33±12, p<0.03), had a longer time elapsed since repair (35±3 versus 25±8, p<0.015) but were also older at time of repair (12±3 versus 7±6, p<0.003) (Figure 1).

*Conclusions:* Gadolinium enhancement CMR as a technique can be extended to the congenitally abnormal subpulmonary RV. Surgical scarring is common. A sub-group of patients have hyperenhancement unrelated to direct surgical scarring which may be a clue in understanding late ventricular pathophysiology in these patients.

## 416. Cardiovascular Magnetic Resonance Morphological and Functional Evaluation in Patients with Right Ventricular By-Pass Surgery

Horacio J. Di Nunzio, MD, AFACC,[1] Cesar Viegas, MD,[2] Eleonora Doglia.[3] [1]*Cardiovascular Imaging Department, Fundacion Cientifica del Sur, University of Buenos Aires., Argentina,* [2]*Pediatric Cardiology, R. Gutierrez Children´s Hospital, Buenos Aires., Argentina,* [3]*Cardiovascular Imaging, Fundacion Cientifica del Sur, Buenos Aires, Argentina.*

*Purpose:* Some older patients with complex congenital heart diseases that receive surgical correction and have to be evaluated postoperatively, do have technical window limitations for echo and require other non invasive techniques. We reviewed retrospectively our Cardiovascular Magnetic Resonance studies (CMR) in a subgroup of patients with these complex congenital heart diseases that where operated with different techniques of right ventricular anasthomosis.

*Methods:* From a total of 1665 Cardiovascular Magnetic Resonance studies (CMR), 1205 where performed in patients (p) with congenital heart diseases over a period of 6 years. From these, 77 studies where performed in 60 patients (29 female, 31 male) with varied and complex congenital heart diseases that where operated with different types of right ventricular by-pass surgery (RVS). Average age at study time: 13,5 years old (1–29). All patients had complete clinical non invasive evaluation, including transthoracic echocardiography prior to the CMR study. Some older patients had limited post-operative diagnosis because of acoustic limitations.

*Results:* According to the surgical procedure, we defined 6 groups of patients.

*Group I:* (8 CMR) with Glenn anasthomosis (termino-terminal cavopulmonary anasthomosis).
*Grupo II:* (34 CMR) with bi-directional Glenn anasthomosis (termino-lateral cavopulmonary anasthomosis).
*Grupo III:* (22 CMR) with atriopulmonary anasthomosis.
*Grupo IV:* (11 CMR) with extracardiac conduit plus bi-directional anasthomosis (total cavo-pulmonary connection).
*Grupo V:* (1 CMR) with ''one and a half ventricle repair technique.''
*Grupo VI:* (1 CMR) with Kawashima technique.

Magnetic resonance imaging was performed with a 1.5 T Picker EDGE System (Philips Medical Systems) using prospective ECG triggering. Conventional protocol studies for congenital heart diseases where applied, using multislice T1-T2 spin-echo, single slice cine-gradient echo and cine-phase contrast flow velocity, time of flight and contrast enhanced 3D angiography sequences, that allowed us to analyze the anatomical and functional status in all cases. Patients younger than 7 years old received anesthesia with Sevorane®.

The assessment included: identification of the native congenital heart disease, size of the anasthomotic vessels, orifices and conduits, flow direction and existence of turbulent jets, thrombus formation, pulmonary vein compression, central pulmonary artery system growth, right atrium size, functionality of the by-pass, presence or absence of decompressing venous collaterals, pericardial effusion and existence of other surgical complications (pulmonary artery angulations, aneurysm and seudoaneurysm formation, etc).

In 2 CMR (from a same patient) a diagnosis of criss-cross heart not recognized previously was made. The size of the anasthomotic orifice was considered satisfactory in all patients. 7 CMR detected thrombus formation (6 in the right atrium and 1 in the main pulmonary artery). 2CMR from group III had right pulmonary vein displacement and compression. The central pulmonary arterial growth was considered normal in all patients (McGoon>1.8; Nakata>200 $mm^2/m^2$). Pericardial effusion was present in 16 CMR (moderate or severe in 3). Right atrial dilation with non laminar and slow flow was present in 22 CMR from Group III (7 moderate and 5 severe). By-pass loss of functionality was considered in 8 CMR (from Groups I and II), due to the presence of abnormal decompressing venous collaterals connecting both, superior and inferior, vena cava territories (Fig. 1).

*Conclusions:* CMR helped to define the native congenital heart disease in one case and to obtain accurate evaluation of the postoperative anatomical status and complications in all patients, especially in older patients where transthoracic echocardiography evaluation was limited by unsatisfactory acoustic window. CMR proved to be a very useful and reliable diagnostic technique in assessing the morphological and functional status of patients with complex congenital heart diseases that where treated with right ventricular by-pass surgery.

***Figure 1.***

## 417. MR Imaging of Complex (Type II) Pulmonary Artery (PA) Sling

Beverley Newman. *Radiology, Children's Hospital of Pittsburgh, Pittsburgh, PA, USA.*

*Introduction:* Type II PA sling is characterized by a low anomalous left PA arising from the right PA in association with tracheobronchial anomalies.

*Purpose:* Evaluate and compare MRI with other imaging methods in assessing the range of vascular and pulmonary anomalies in the Type II sling.

*Materials andMethods:* Five infants (4 male, 1 female) age one day to six months with unexplained respiratory distress underwent MR imaging. All had plain chest radiographs, echocardiography and bronchoscopy; angiography (3), chest CT (2), barium swallow (2) and high KV airway fluoroscopy (1).

*Results:* On chest radiographs there was poor visualization of the trachea (5) and a low T shaped carina (4). One child had bilateral hyperinflation; right lung abnormality was present in 4 cases, absence (1), atelectasis/pneumonia (2), hypoplasia/atelectasis and question scimitar vein (1). All five had MR delineation of an LPA sling passing between trachea and esophagus (partial to left lower lobe only in one baby), the LPA anomaly was recognized by ultrasound prior to MR in one case. All had low carina, long segment distal tracheal narrowing with right bridging bronchus in 4 (left bronchus only in 1). Two had a separate right upper lobe bronchus above the carina. Additional areas of tracheal narrowing (2); aberrant subclavian artery and anterior crossing aortic arch respectively. Other anomalies: absent right lung and distal RPA (1), aberrant right subclavian artery (1), scimitar syndrome with hypoplastic right lung, small RPA, right anomalous pulmonary venous return to IVC, horseshoe lung and pulmonary sequestration (1). Cardiac anomalies on ultrasound included VSD (2), patent ductus (1), Tetralogy of Fallot (1), cardiac dextroposition with absent RPA (1). Bronchoscopy was initially interpreted as normal in two children with severe tracheal compression described in one. Tracheal stenosis was confirmed bronchoscopically in 4 (post MR). Angiography (3) confirmed MR and ultrasound cardiovascular findings without adding significant additional information. CT (2) with poor vascular opacification in small infants, was unhelpful or misleading. Barium swallow (2) did not demonstrate the sling; high KV fluoroscopy (1) confirmed tracheal stenosis.

The sling LPA was surgically addressed in 4 infants (not in child with right lung agenesis); 3 required tracheal resection, all have survived.

*Conclusions:*

1. Type II LPA sling vascular and tracheobronchial malformations are characteristic with some variations, interrelationships are best defined with high quality MR imaging.
2. There are some suggestive plain chest radiographic findings.
3. Other imaging modalities provided incomplete information.
4. A variety of complex additional cardiopulmonary abnormalities can accompany the Type II sling, defined by MR (extracardiac) and echo (intracardiac).
5. Long segment tracheal stenosis is a key feature that requires surgical repair in many but not all cases.

## 418. Progression of Ascending Aortic Dilatation in Congenital Bicuspid Aortic Valve Patients: Assessment by Serial MRI

Benjamin Atkeson,[1] Gian Novaro,[2] Brian Griffin,[1] Richard White.[1] [1]*Cleveland Clinic Foundation, Cleveland, OH, USA,* [2]*Cleveland Clinic Foundation, Weston, FL, USA.*

*Introduction:* Congenital bicuspid aortic valve (BAV) patients have an associated aortopathy, with ascending aortic dilatation and increased risk of dissection. Data is limited regarding the rates of dilatation in these patients and, when available, is provided by serial echocardiographic imaging.

*Methods:* We identified consecutive adult patients with a diagnosis of BAV, who underwent serial magnetic resonance imaging (MRI) of the aorta,

***Table 1.***

| | All patients (n=66) | Aortic stenosis (N=12) | Aortic insufficiency (n=25) | Normal valve (N=22) |
|---|---|---|---|---|
| Baseline aorta diameter at sinuses | 43 mm | 42 mm | 45 mm | 43 mm |
| Average total change (mm) | 1.9 mm | 1.8 mm | 2.7 mm | 1 mm |
| Annualized rate of change (mm/yr) | .8 mm/yr | .8 mm/yr | 1.2 mm/yr | .4 mm/yr |



Marcel Dekker, Inc.
270 Madison Avenue, New York, New York 10016

at least 12 months apart. Patients with prior aortic valve surgery were excluded. Demographic and echocardiographic data, including beta blocker use was obtained by chart review. Aortic measurements were made at the level of the sinuses and mid-ascending aorta.

*Results:* 66 BAV patients were identified (80% male; mean age 53 yrs). Mean follow-up was 32 months (range 12–96). The mean annualized increase in aortic dilatation was .8 mm/yr. Those with aortic regurgitation showed increased rates of dilatation compared to those with normal and stenotic BAV(p=.05). No association was noted between beta blocker use and rates of dilatation (Table 1).

*Conclusions:* BAV patients have aortic dilatation, irrespective of valve dysfunction. In this cohort BAV patients assessed by MRI, the average rates of ascending aortic dilatation was 0.8 mm/yr, similar to prior reports. Those with aortic regurgitation appear to have greater rates of progression, and may require closer serial follow-up.

## 419. Magnetic Resonance Imaging in Arrhythmogenic Right Ventricular Dyplasia/Cardiomyopathy (ARVD/C)

Kata Petro, MD,[1] Tamas Simor, MD, PhD,[1] Levente Toth, MD,[1] Lajos Papp, MD, DSc,[1] Imre Repa, MD, PhD.[2] [1]*Heart Institute, University of Pécs, Pécs, Hungary,* [2]*Institute of Diagnostics and Oncoradiology, University of Kaposvar, Kaposvar, Hungary.*

*Introduction:* ARVD/C is a condition with fibro-fatty replacement of the right ventricular (RV) myocardium, usually affecting teenagers and young adults. The diagnosis of ARCD/C is based on the McKenna's criteria.

*Purpose:* The aim of our study was to analyze the abnormalities examined by cardiac MRI.

*Methods:* 94 pts were referred to cardiac MRI with the suspicion of ARVD/C, mean age 34.47±17.57 years, 54 male and 40 female. The cardiac MRI examinations were performed at the University of Kaposvar, Institute of Diagnostics and Oncoradiology on a Siemens Vision Plus 1.5 T scanner. With cine imaging (T2 weighted) dimensions of the heart chambers, global and regional function of right and left vetricula, morphology of heart apex and separately RV apex are valued. On T1 weighted images signal intensity increase is assessed caused by lipid infiltration of RV myocardium. The examined pts according to McKenna's criteria were divided into group 1 with non-ARVD/C (53 pts 56.4%), and group 2 with ARVD/C (41 pts 43.6%).

*Results:* The findings are summarized in Table 1.

*Conclusions:* The analyzed major and minor criteria are significantly more frequent in group 2, with exception of regional RV hypokinesia. According to our study the prominent RV trabeculae is characteristic to ARVD/C, while the morphology of the heart apex is not. During our study according to the literature pathognomic sign for ARVD/C was not found.

***Table 1.***

| The analyzed abnormalities | Group 1 (pts) | Group 2 (pts) | |
|---|---|---|---|
| Lipid infiltration | 3 (6%) | 28 (68%) | p<0.01 |
| RV aneurysm | 3 (6%) | 22 (54%) | p<0.01 |
| Reduction of the RV EF | 3 (6%) | 11 (27%) | p<0.01 |
| Dilatation of the RV | 24 (45%) | 28 (68%) | p<0.01 |
| Regional RV hypokinesia | 14 (26%) | 8 (20%) | NS |
| Dilatation of the RV apex | 32 (60%) | 28 (68%) | NS |
| Prominent RV trabeculae | 14 (26%) | 21 (51%) | p<0.01 |
| Heart apex is composed of both chambers | 30 (57%) | 27 (66%) | NS |

## 420. Characterization of Hypertrophic Obstructive and Non-obstructive Cardiomyopathy Using Contrast Agent Enhanced Cardiac MRI

Levente Toth, MD,[1] Tamas Simor, MD, PhD,[1] Reka Faludi,[1] Robert Sepp, MD,[2] Imre Repa, MD, PhD,[1] Lajos Papp, MD, DSc.[1] [1]*Heart Institute, University of Pécs, Pécs, Hungary,* [2]*Department of Medicine, University of Szentgyorgyi, Szeged, Hungary.*

*Introduction:* CM may be accompanied with dynamic outflow tract obstruction resulting HOCM.

*Purpose:* The aim of our study was characterize differences in HCM vs HOCM groups using contrast agent enhanced cardiac MRI.

*Methods:* 1.5 T Siemens Vision plus (Siemens, AG Germany) with a cardiac software package at the Institute of Diagnostics and Oncoradiology (University of Kaposvár) was used for cardiac imaging. ECG gated long axis (4, 3 and 2 chamber view) and consecutive, multiple, no slice gap, 8 mm thick short axis plane MR images covering the entire left ventricle (LV) were acquired. First: gradient-echo cine imaging with an FOV of 450 mm, TE/TR/Flip 4.8 ms/40 ms/20° and $256^2$ image resolution was set for the measurement of global cardiac function. Second: IR prepared segmented K-space TFL sequence was used to study delayed enhancement (DE) after the injection of contrast agent. MASS 5.0 (Medis, NL) was used for the analysis of MR images.

*Results:* 30 pts (13 female, 17 male, mean age of $49 \pm 14$) were studied by whom HCM or HOCM was already diagnosed by echocardiography. SV, CO, EF, PER, PER/EDV were significantly lower ($p<0.05$) in pts with HCM vs. HOCM, but no differences were found in parameters of EDV, ESV, FPR/EDV, LVM and LVM/BSA.

DE pattern in HCM and HOCM was shown in 52.63% (10/19) and 45.45% (5/11) of the pts, respectively (N.S.). HCM and HOCM subgroups with no DE pattern showed no differences. However, HCM with DE pattern compared to HOCM with DE pattern showed decreased systolic and diastolic LV functions ($p<0.05$). Furthermore HOCM pts with DE pattern show better systolic and diastolic function as data compared to the other 3 groups (HCM with and without DE pattern and HOCM without DE pattern) (Table 1).

*Conclusions:* This study shows high incidence of DE phenomenon in both HCM and HOCM groups, indicating high risk for SCD. The occurrence of DE pattern indicates that DE pattern itself is not pathognomic for the differentiation between HCM and HOCM. The analysis of subgroups, however, indicate that HOCM pts with DE pattern have better systolic and diastolic LV function. The latter finding may indicate further benefits of ablation in HOCM patients.

***Table 1.***

| | | HCM | HOCM | |
|---|---|---|---|---|
| EF | (%) | $71.2 \pm 8.8$ | $79.2 \pm 8.3$ | $p<0.01$ |
| PFR | (ml/s) | $324.1 \pm 97.2$ | $427.6 \pm 116.2$ | $p<0.05$ |

## 421. A Web-Based Teaching Resource Utilizing Cardiac MR Images for Understanding Congenital Heart Disease

Marc E. Miquel, PhD, Vivek Muthurangu, MBChB, Rado Andriantsimiavona Rakotonisainana, MSc, Sanjeet Hegde, MBBS, Reza Razavi, MBBS, Stephen Keevil, PhD. *Division of Imaging Sciences, King's College London, London, United Kingdom.*

*Introduction:* Congenital heart disease is often associated with complex morphological and physiological abnormalities. This can overwhelm health professionals who look after patients with congenital heart disease. Until recently the study of post-mortem specimens was considered the most useful method of learning about congenital heart disease. However, the limited availability of specimens, the lack of trained morphologists and ethical considerations have made post-mortem study of congenital heart disease more difficult. In the last 10 years, Magnetic Resonance Imaging (MRI) has established itself as an imaging modality of choice in assessment of congenital heart disease. This technique can provide detailed three-dimensional anatomical information previously only available using post mortem specimens, as well as functional information and two-dimensional imaging.

The aim of our project is to make the wealth of knowledge and information acquired by cardiac MR especially in congenital heart disease available as a teaching aide to medical students and health professionals. To achieve this goal we are developing a web-based teaching database. This website will include images and associated physiological data derived from MRI for normal subject and patients with congenital heart disease and ischaemic heart disease. At the moment we are focussing our efforts on the congenital heart disease section.

*Methods:* Although over 95% of people use a PC/Windows/Internet Explorer combination to access the internet, our aim is to ultimately develop a cross-browser cross-platform product. Consequently, all script included in the website are written in javascript and work on Mac and PC (windows or Linux) in recent versions of the three most common browsers (Windows IE, Netscape and Opera). Furthermore, any image/

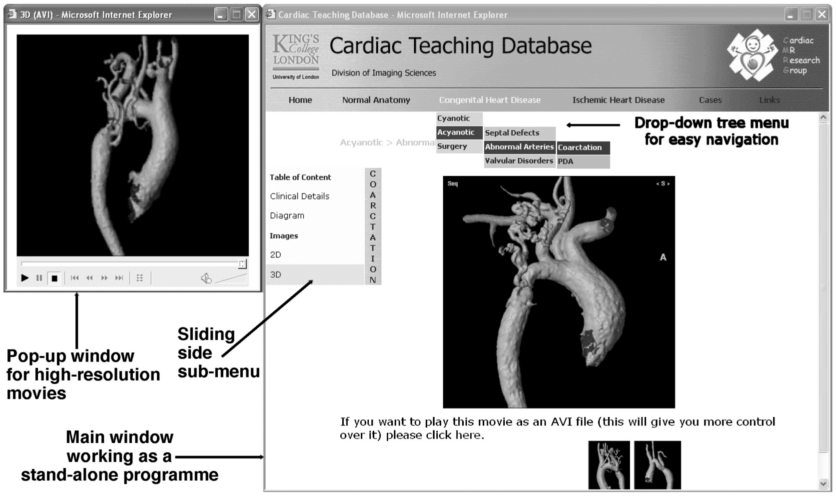



*Figure 1.*

movie included in the site can be viewed directly by those browsers or with the help of a readily and freely available plug-in.

The site was designed to be a stand-alone program (Figure 1). High-resolution 3D movie are open in separate windows (pop-up windows).

To fulfil its teaching ambition simple and logical menu have been created. The top menu has four main categories: normal anatomy, congenital heart disease, ischaemic heart disease and cases. For the congenital heart disease a drop-down three-level tree structure has been designed to allow easy navigation through the information and improve conceptual understanding of the classification of congenital heart disease. The first level is divided in three categories: acyanotic, cyanotic and surgery. For the first two categories, the second levels represent family of disease (e.g. abnormal arteries, valvular disorders…) and the third level gives access to specific pathologies (e.g. tetralogy of Fallot, coarctation…). The surgery category only contains one sub-level containing common cardiovascular procedures (e.g. Fontan, Rastelli). For each disease or surgical procedure a sub-menu on the left of the screen allows the user to navigate between text information, diagrams and relevant MR data and images.

The case category is aimed at post-graduate/continuous teaching. It will present the most complex/interesting imaged in our facilities. For each case the clinical background and relevant images will be provided and the user will be able to fill in an online questionnaire about the case.

*Conclusions:* In its development form this website has already received considerable support and positive feedback from its testers. Once fully developed this website will be a unique opportunity for a students to learn about normal cardiac anatomy, physiology and cardiovascular conditions. It will fill a gap between conventional classroom teaching and patient contact. This teaching database will also be valuable to any established clinician who desires to learn about cardiac MRI. By collaborating with other group we will be able to integrate images and data from other diagnostic modalities.

## 422. Cardiac Magnetic Resonance Imaging Accurately Predicts Findings at Angiography in Patients Undergoing Coarctation Stenting

Isabelle F. Vonder Muhll, MD,[1] Sonya Babu-Narayan, MBBS,[1] Michael Mullen, MD,[2] Raad Mohiaddin, MD, PhD.[1] [1]*Cardiovascular Magnetic Resonance Unit, Royal Brompton Hospital, London, United Kingdom,* [2]*Adult Congenital Heart Programme, Royal Brompton Hospital, London, United Kingdom.*

*Introduction:* Stenting for aortic coarctation (COA) is a viable alternative to surgery. Accurate sizing of the aorta proximal and distal to the COA is essential to avoid dissection (from over-sizing) or embolization (from under-sizing) at the time of intervention.

*Table 1.* Comparison of CMR techniques with XRA in coarctation of the aorta.

| | TrueFISP cine versus XRA | TSE versus XRA | MRA versus XRA | CMR-dP versus XRA-dP |
|---|---|---|---|---|
| R (confidence interval) | 0.89 (0.82±0.94) | 0.85 (0.74±0.91) | 0.90 (0.83±0.94) | 0.95 (0.68–0.99) |
| p value | <0.0001 | <0.0001 | <0.0001 | 0.001 |
| Mean difference (mm) btwn XRA-CMR measurements (confidence interval) | −0.1 (−1.0 to 0.9) | 1.5 (0.5 to 2.5) | 1.0 (0.2 to 1.9) | 20 mmHg (−12 to 29) |

*Purpose:* We sought to determine if aortic measurements by cardiac magnetic resonance imaging prior to COA stenting would accurately predict aortic dimensions by X-ray aortography (XRA).

*Methods:* Consecutive adult patients (n=11, aged 30±12 years) referred for COA stenting were prospective assessed with CMR (Siemens Sonata whole-body 1.5T scanner) using TrueFISP cine sequences, turbo-spin echo (TSE) sequences, three-dimensional gadolinium-enhanced (0.2 mmol/kg IV) magnetic resonance angiography (MRA) and through-plane phase velocity mapping. CMR measurements at 5 standard sites proximal and distal to the COA were compared to XRA. Pressure gradients across the COA estimated noninvasively by velocity mapping and the modified Bernoulli equation (CMR-dP) were compared to peak-to-peak gradients obtained across the coarctation during catheterisation (XRA-dP).

*Results:* Measurements made with CMR and XRA were closely correlated (Table 1) with a mean difference in aortic diameters between CMR and XRA ranging from −0.1 mm with TrueFISP cine imaging to 1.5 mm with TSE imaging (Table 1). TrueFISP cine measurements, taken during systole, had significantly less mean difference from XRA when compared to TSE and MRA, performed in late diastole (p=0.03). With respect to estimates of pressure gradients, a significant correlation was found between CMR-dP and XRA-dP (R=0.95) when patients with very low flow across the COA were excluded; however, CMR over-estimated the gradient by an average of 20±4 mmHg (Table 1). MRA was superior to other CMR techniques and XRA in demonstrating the spatial relationship of the proximal to the distal aorta and the extent of collaterals.

*Conclusions:* In assessing aortic coarctation prior to stenting, TrueFISP cine imaging and contrast-enhanced MRA provide synergistic information on aortic diameters and the spatial arrangement of the coarctation. Since CMR accurately predicts findings by XRA, it has utility in the pre-procedural planning of balloon and stent size prior to intervention.

## 423. Characterization of Regional Function in HCM Using Contrast Agent Enhanced Cardiac MRI

Tamas Simor, MD, PhD, Levente Toth, MD, Reka Faludi, MD, Lajos Papp, MD, DSc, Imre Repa, MD, PhD. *Heart Institute, University of Pécs, Pécs, Hungary.*

*Introduction:* Hypertrophic cardiomyopathy (HCM) is adequately investigated by echocardiography. However, MRI may provide more insight into the pathophysiology of HCM.

*Purpose:* The aim of our study was to demonstrate the advantages of MRI to characterize HCM.

*Methods:* .5 T Siemens Vision plus (Siemens, AG Germany) with a cardiac software package at the Institute of Diagnostics and Oncoradiology (University of Kaposvár) was used for cardiac imaging. ECG gated long axis and consecutive, multiple, no slice gap, 8 mm thick short axis plane MR images covering the entire left ventricle (LV) were acquired to study morphology and cardiac function. First: gradient-echo cine imaging with an FOV of 450 mm, TE/TR/Flip 4.8 ms/40 ms/20° and $256^2$ image resolution was set for the measurement of regional cardiac function (systolic and

***Table 1.***

| WT (mm) | <15 | 15–20 | 20–25 | 25–30 | >30 |
|---|---|---|---|---|---|
| # of segments | 1363 | 264 | 82 | 24 | 1 |
| % of segments | 78.3 | 15.2 | 4.71 | 1.38 | 0.06 |
| % of DE | 2 | 12 | 37 | 58 | 100 |

diastolic wall thickness, thickening in all short-axis slices in six segments each). Second: IR prepared segmented K-space TFL sequence was used to study delayed enhancement (DE) after the injection of contrast agent. MASS 5.0 (Medis, NL) was used for the analysis of MR images.

*Results:* 30 pts (13 female, 17 male, mean age of 49±14) were studied by whom HCM was already diagnosed by echocardiography. DE pattern was shown in 104 out of 1740 segments in 15 out of 30 pts. Data in details shown in Table 1.

End diastolic wall thickness (EDWT) was 19.0±5.1 mm in segments with DE pattern, while EDWT was only 11.5±4.3 mm in the absence of DE pattern. Wall thickening (WT%) of 48.5±38.2% and WT% of 83.2±61.8% was observed in the presence and absence of DE pattern, respectively.

*Conclusions:* The analysis of regional LV function and DE shows a positive correlation between EDWT and extent of DE pattern, and a negative correlation between WT and WT% and WT% and extent of DE pattern.

## 424. Time-Resolved SENSE Contrast Enhanced Magnetic Resonance Angiography of Congenital Cardiovascular Disease with Higher SENSE Factors

Ricardo H. Pignatelli, MD,[1] Taylor Chung, MD,[2] Raja Muthupillai, PhD,[3] Jason Su, DO,[1] Laura K. Diaz, MD,[4] John P. Kovalchin, MD,[1] Giles W. Vick, III.[1]
[1]*Pediatric Cardiology, Baylor College of Medicine, Houston, TX, USA,* [2]*Radiology, Baylor College of Medicine, Houston, TX, USA,* [3]*Philips Medical Systems, Bothell, WA, USA,* [4]*Anesthesiology, Baylor College of Medicine, Houston, TX, USA.*

*Introduction:* Contrast-enhanced gadolinium magnetic resonance angiography has been demonstrated to be a useful tool for the evaluation of congenital cardiovascular disease. Employment of the sensitivity encoding (SENSE) parallel processing acquisition technique can greatly reduce acquisition time for angiographic volumes, thereby improving temporal resolution and reducing artifact induced by respiratory motion. However, many previous implementations of SENSE have been limited to a factor of 2 or less. This study was performed to evaluate the utility of SENSE factors of 3 to 4 in the assessement of congenital cardiovascular disease with contrast-enhanced gadolinium magnetic resonance angiography.

*Purpose:* To evaluate the effect of employing SENSE factors of 3 to 4 in the assessment of congenital cardiovascular disease with contrast enhanced gadolinium magnetic resonance angiography.

*Methods:* All MR studies were performed with a commercial 1.5 T whole body MR system (Gyroscan ACS-NT; Philips Medical Systems, Best, The Netherlands). The system was equipped with Powertrak 6000 gradients (23 mT/m, 220 usec rise time) and four and five element phased array receiver coils. A one minute ungated SENSE reference scan was performed. Multiple sequential volumes were obtained with SENSE factors of 3 or 4 subsequent to intravenous injection of 0.2 mmol/kg of gadolinium chelate. A T1-weighted fast field echo acquisition sequence was employed with typical TR/TE of 4.3/1.3, 35 degree flip angle. Acquisition matrix, field of view, number of partitions, and partition thickness varied widely with patient size and diagnosis and study goals. Typical volume acquisition times ranged from 3 to 6 seconds, but subsecond volume acquistion times could be obtained by limiting spatial resolution. Results from twenty five subjects were studied (age range 1 week–21 years) in this preliminary review. Diagnoses included: pre operative coarctation of the aorta, pre operative tetralogy of Fallot, post operative coarctation of the aorta with aneurysm formation, post operative coarctation of the aorta with recurrent stenosis, post operative tetralogy of Fallot, single ventricle status post Fontan, double aortic arch, right aortic arch with aberrant retroesophageal left subclavian artery, and postoperative transposition of the great arteries.

*Results:* Good quality contrast enhanced magnetic resonance angiograms were obtained in all patients. Volume acquisition times varied with anatomical coverage and matrix resolution required, but were 66% to 50% of the corresponding volume aquisition times that would have been required with a SENSE factor of 2. The shorter volume acquisition times facilitated with the higher SENSE factors were particularly helpful in temporal separation of pulmonary arterial, pulmonary venous, and systemic arterial vessel maximal opacifications. Because volumes could be obtained rapidly, good images were produced without breath holding in many cases. However, when suspension of respirations was performed, necessary breath hold times were substantially reduced. Furthermore, the high SENSE factors facilitated multiple sequential volume acquisitions, therefore obviating the need for a time-consuming and potentially inacurate test-bolus approach. Coverage and spatial resolution could be enhanced with high SENSE factors at a given temporal resolution. Conversely, higher temporal resolution could be achieved with constant coverage and spatial resolution. Volumes obtained with higher SENSE factors did contain more background noise than volumes obtained with a SENSE factor of 2. However, this increased background noise had minimal clinical significance in most cases because of the high intravascular signal produced by contrast enhancement (Fig. 1).

*Conclusion:* Time resolved contrast enhanced magnetic resonance angiography with SENSE factors of 3 to 4 is a very effective technique for evaluation of congenital cardiovascular disease.

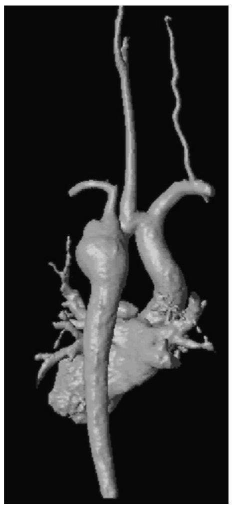


***Figure 1.***

### 425. Effect of Sildenafil on Ventricular Function and Remodelling in Patients with Pulmonary Arterial Hypertension

Sanjay Kumar Prasad, MD,[1] Smith Gillian,[1] Ghada Mikhail,[1] Paula Rogers,[1] Sharmeen Masood,[2] Andrew Elkington,[1] Dudley Pennell,[1] Philip Kilner,[1] Michael Gatzoulis.[3] [1]*CMR Unit, Royal Brompton Hospital, London, United Kingdom,* [2]*CMR Unit, Imperial College, London, United Kingdom,* [3]*Achd, Royal Brompton Hospital, London, United Kingdom.*

*Introduction:* Pulmonary arterial hypertension (PAH) is a progressive disease with a high morbidity and mortality and is associated with right ventricular (RV) dysfunction. Several therapeutic options are available including prostacyclin but are hampered by the mode of administration or expense. Sildenafil promotes vasodilatation in the pulmonary circulation through selective inhibition of phophodiesterase-type 5 and increased nitric oxide production.

*Purpose:* To determine if oral sildenafil can improve RV function and remodelling as measured by CMR determined functional, volumetric and contractile parameters.

*Methods:* Nine patients with PAH were studied (mean age 37±14 yrs; 7 females). Patients underwent initial right heart cardiac catheterisation with vasodilator testing using intravenous sildenafil to ensure no adverse haemodynamic disturbance. They were then commenced on oral sildenafil at 50 mg tds for 3 months. CMR was performed at baseline and after 3 months using a Siemens Sonata 1.5T scanner. All measurements were made by a single blinded experienced operator.

*Results:* At 3 months, there was a significant improvement in RV ejection fraction (29.8±18.8% to 39.8±20.4%; P=0.02). RVEDV and RVESV both showed a non-significant trend towards reduction. (RVEDV 218.3±82.0 mL to 211.8±93.2 mL, P=0.68; RVESV 158.5±95.9 mL to 146.3±85.1 mL, P=0.27). Left ventricular dimensions and function were unchanged. Compared to baseline, there was a marked improvement in septal wall principal strain as determined by HARP tagging at 3 months (0.5±0.25 vs 2.5±1.6 respectively, p=0.0019). Overall, sildenafil was well tolerated by patients but had to be discontinued in 1 patient due to visual disturbance.

*Conclusions:* Oral sildenafil appears to have a beneficial effect on RV function and remodelling in PAH as determined by CMR. This improvement was associated with increased exercise capacity. Sildenafil may have a role as an adjunct to transplantation.

### 426. High Speed Valve Tracking Using 2DFIESTA CINE in Conjunction with Sensitivy Encoding

Thoralf Niendorf,[1] Ralph Noeske,[2] Matthias Friedrich.[3] [1]*Applied Science Laboratory, GE Medical Systems, Brookline, MA, USA,* [2]*GE Medical Systems, Potsdam, Germany,* [3]*Franz-Volhard-Klinik, Charite' Campus Berlin-Buch, Berlin, Germany.*

*Introduction:* High speed imaging of rapidly moving valvular structures is of profound clinical importance for the diagnosis of valvular insufficiency, the assessment of stenotic valves and the detection of congenital deformations of the valves. It requires high temporal resolution, excellent muscle/blood contrast and complete coverage of the cardiac cycle. This makes short TR, steady-state free precession based 2D



Marcel Dekker, Inc.
270 Madison Avenue, New York, New York 10016

CINE techniques an ideal candidate for the visualisation of the artrioventricular valves while parallel imaging strategies can be employed to further boost the temporal resolution (Pruessmann et al., 1999; Sodickson et al., 1997; Weiger et al., 2000).

*Purpose:* This study examines the application of 2D CINE FIESTA imaging (Hoppel et al., 2001; Noeske et al., 2003) in conjunction with the Array Spatial Sensitivity Encoding Technique (ASSET) for the assessment of the valvular function and morphology. ASSET is used for parallel imaging purposes in order 1) to reduce the temporal resolution down to 10.5 ms for each cardiac phase and 2) to minimize motion sensitivity without increasing the total acquisition time compared to the conventional approach.

*Methods:* Studies were conducted on a 1.5 Tesla whole body system (GE Medical Systems, Milwaukee, Wisconsin, USA) using a 4-element and 8-element cardiac phased array coil (GE Medical Systems, Milwaukee, Wisconsin, USA). For calibration of the relative coil sensitivity a low spatial resolution gradient echo sequence was used. 2D CINE FIESTA imaging was performed employing: TE=1.5 ms, TR=3.5 ms, flip angle 45°, FOV=(32–38) cm, slice thickness 8 mm, data matrix size: 256×192, Phase FOV=1.0. For parallel imaging an acceleration factor of 2–4 was used. For the data acquisition 3–6 views per segment where used, resulting in a temporal resolution of (10.5–21) ms and a breath-hold time of 16 heartbeats. For the reconstruction variable view sharing was applied, resulting in an effective temporal resolution of 5 ms (200 phases per cardiac cycle). Four chamber long axis (LA) views were acquired for the assessment of the valvular function (Figure 1).

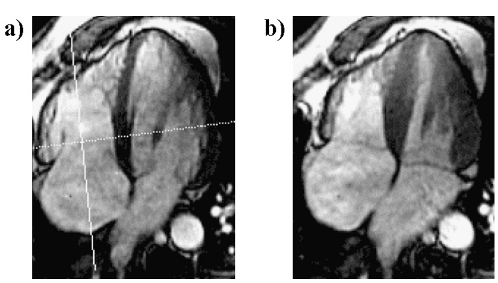



***Figure 1.*** Four chamber view at mid diastole (a) and at end systole (b), acquired with 2D FIESTA ASSET using a high temporal resolution of 20 ms (reconstructed with a temporal resolution of 5 ms using a variable view sharing technique). The fast moving structures of the tricuspid and mitral valve are clearly visible. The exact time point of closing and opening of the atrioventricular valves can easily be evaluated because of the temporal resolution.

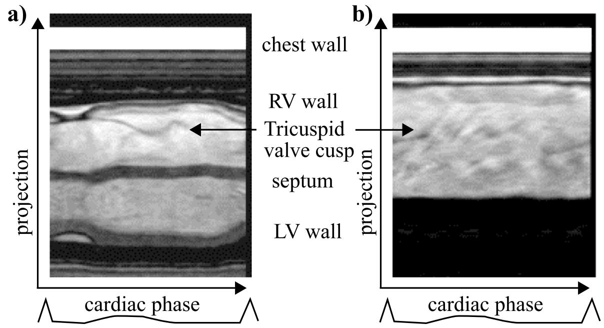



***Figure 2.*** Whole R-R interval time series of one-dimensional projections (left: dotted line in Figure 1, right: solid line in Figure 1) derived from a 2D CINE FIESTA ASSET data set which was reconstructed with a temporal resolution of 5 ms. The trace of the tricuspid valve is marked by the arrows. For guidance the chest wall is also shown.

*Results:* For high speed 2D CINE FIESTA imaging the temporal resolution has been reduced to 10.5 ms by using 3 views per segment in conjunction with the ASSET parallel imaging approach without extending the total acquisition time but maintaining the high spatial resolution of the conventional approach. The exact time of closing and opening of the atrioventricular valves could be determined by using an effective temporal resolution of 5 ms/cardiac phase for the reconstructed images. The image contrast and superb temporal resolution allowed an analysis of the valvular morphology, but also tracking of the fast moving cusps of the artrioventricular valves. The trace of the tricuspid valve derived from one-dimensional projections through the four chamber view revealed a biphasic pattern as illustrated in Figure 2 (left).

*Conclusions:* The ASSET sensitivity encoding technique can be used in combination with 2D CINE FIESTA for tracking the atrioventricular valves. Its greatest potential may be the option to increase the number of cardiac phases without extending acquisition times. The excellent temporal resolution achievable can be used to generate highly accurate time-series curves, which may be useful for the assessment of congenital valvular disease. Further studies are required in order to differentiate the valvular trace function of healthy volunteers from those of patients suffering from valvular malfunctions or deformations.

## REFERENCES

Hoppel, B. E., et al. (2001). *ISMRM Proceedings*. 421.
Noeske, R., et al. (2003). *ISMRM Proceedings*. 1563.

Pruessmann, K. P., et al. (1999). *Magn. Reson. Med.* 42: 952.
Sodickson, D. K., et al. (1997). *Magn. Reson. Med.* 38: 591.
Weiger, M., et al. (2000). *Magn. Reson. Med.* 43:177.

## 427. Interdisciplinary Approach to Complex Congenital Heart Disease in Adults

Jens Bremerich, MD,[1] Andreas Hoffmann, MD,[2] Sabine Haller, MD,[1] Georg Bongartz, MD,[1] Peter Buser, MD.[2]
[1]*Radiology, University Hospital, Basel, Switzerland,*
[2]*Cardiology, University Hospital, Basel, Switzerland.*

*Introduction:* Patients with complex congenital heart disease benefit from improvements in diagnosis and therapy with enhanced life expectancy and quality. Early detection of complications, however, require monitoring tools that are reliable and easy to apply. Magnetic resonance imaging can provide a lot of precious information regarding morphology, function and tissue composition and thus can play a major role in the management of such patients. Moreover, the noninvasive nature and absence of ionizing radiation are ideal for close monitoring with repeated imaging studies in this population of young adults.

*Purpose:* To illustrate the impact of Magnetic Resonance Imaging on patient management in adult congenital heart disease.

*Methods:* Fourteen patients with Truncus Arteriosus Communis (n=2), Fallot Tetralogy (n=8), Pulmonary Artery Stenosis (n=3), and Single Ventricle (n=1) were followed in close cooperation between the departments of radiology, cardiology, and cardiothoracic surgery. MRI was conducted on a 1.5 Tesla Magnetom Symphony (Siemens, Erlangen, Germany) with Quantum gradients and phased array body coil. Sequences used in all studies were Fast Imaging with Steady State Precession (TrueFisp, axial), T1 weighted Turbo Spin Echo (T1w-TSE; short and horizontal short axis), and Cine TrueFisp (horizontal long and short axis). Optional sequences were contrast enhanced angiography (MRA) with high temporal or spatial resolution, phase contrast MRA for flow quantification, and Half Fourier Acquisition Single Shot Turbo Spin Echo (HASTE) for further tissue characterisation. Among the other diagnostic and therapeutic modalities were echocardiography, interventional cardiology, and scintigraphy.

*Results:* Magnetic Resonance Imaging provided valuable information and had an impact on management in all patients. One patient with Truncus Arteriosus Communis Type IV (pulmonary atresia) who was previously treated with Potts anastomosis showed stenosis of the anastomosis and hypoperfusion of the left lung on time resolved contrast enhanced MRA. Stenosis was sucessfully treated by angioplasty with substantial gain in life quality. One patient with pulmonary artery stenosis underwent surgical repair with a composite homograft. This homograft, however, was complicated by restenosis requiring surgical repair. Two more patients were treated by surgical repair. The other patients are currently under medical treatment, cardiac morphology and function are monitored by MRI and echocardiography.

*Conclusion:* Cardiac MR is an excellent tool for imaging of morphology and function with high spatial and temporal resolution. These unique features together with its nonivasive nature and the absence of ionizing radiation are particulary helpful in young adults who require monitoring with repeated studies. These selected cases illustrate the impact of MRI on inderdisciplinary management of adult congenital heart disease.

## 428. Myocardial Fibrosis Patterns Correlate with Adverse Right Ventricular Morphology and Function in Patients with Repaired Conotruncal Heart Defects

Anne Marie Valente, MD, Salim F. Idriss, MD, PhD, Peter Cawley, MD, John Heitner, MD, Igor Klem, MD, Joseph Kay, MD, Michele Parker, RN, J. Rene Herlong, MD, Raymond Kim, MD. *Duke University Medical Center, Durham, NC, USA.*

*Introduction:* Repair of tetralogy of Fallot (TOF) and transposition of the great arteries (TGA), the most common conotruncal congenital heart defects, often results in right ventricular (RV) volume and/or pressure overload. RV failure often ensues over time. Myocardial fibrosis (MF) may be an important correlate of RV dysfunction and adverse RV remodeling. Delayed contrast enhancement cardiac MRI (DEMRI) is known to be a sensitive technique for determining the presence, location and extent of myocardial fibrosis in vivo.

*Purpose:* The purpose of this study was to correlate the presence, location and extent of MF on DEMRI with RV volumes and function, as well as QRS duration in patients with repaired TOF or TGA.

*Methods:* Twenty seven patients with TOF or TGA were prospectively identified and underwent cine and DEMRI (1.5T Magnetom Sonata, Siemens Medical). Measurements of RV morphology and function were assessed on the cine images. QRS duration was measured from the standard electrocardiogram. The presence, location and extent of hyperenhancement (HE) were assessed on the delayed enhancement (DE) images.

*Results:* All patients, regardless of RV size and function, had evidence of some MF as determined by the presence of HE. However, there was a predilection of MF for specific locations. In particular, the junction of the RV freewall with the interventricular septum was commonly involved (100% at the inferior septal junction, 56% at the anterior septal junction). Six patients (22%) had direct involvement of the right ventricular free wall.

The extent of HE correlated with RVEDV and RVESV ($p<0.01$). There was a trend towards significance between extent of HE and RVEF ($p=0.11$, $r=-0.31$) and QRS duration ($p=0.05$, $r=0.39$). In addition, QRS duration correlated with RVEDV, RVESV, and RVEF ($p<0.05$, all).

*Conclusions:* Patients with repaired conotruncal congenital heart defects such as TOF and TGA have areas of myocardial fibrosis that are located remote from sites of direct surgical intervention. The concentration of myocardial fibrosis in these unexpected locations remains to be explained. The extent of fibrosis in these patients and QRS duration correlates with adverse right ventricular morphology and function. Future investigations of the relationship between right ventricular fibrosis characteristics and outcomes in this patient population are necessary.

## 429. Magnetic Resonance Assessment of Percutaneous Pulmonary Valve-Stent Implantation

Reza Razavi, MBBS,[1] Vivek Muthurangu, MBChB (hons),[1] Andrew Taylor, MD,[1] Hegde Sanjeet, MBBS,[1] Phillipe Bonhoeffer, MD.[2] [1]*Division of Imaging, King's College London, London, United Kingdom,* [2]*Paediatric cardiology, Institute of Child Health, London, United Kingdom.*

*Introduction:* Patients who have had surgery to their right ventricular outflow tract or pulmonary valve or who have pulmonary homografts may develop pulmonary incompetence with or without associated pulmonary stenosis. This often leads to progressive right ventricular dysfunction which may necessitate pulmonary valve replacement. Currently open pulmonary valve replacement, requiring cardiopulmonary by-pass, is the preferred method. However, there are significant risks attached to cardiopulmonary bypass (i.e. cerebrovascular accident) and open surgery. A new technique involving trans-catheter implantation of a bovine valve-stent in the pulmonary position has been developed. Although this technique is significantly less invasive than the traditional approach, it is important to demonstrate its clinical effectiveness before it can become a mainstream tool in the management of pulmonary incompetence. MR can accurately quantify pulmonary incompetence and right ventricular function. In addition MR imaging is particularly useful in planning such interventions.

*Purpose:* To assess the effectiveness of MR, in planning trans-catheter implantation of bovine valve stents and to assess changes in ventricular function and pulmonary incompetence post procedure.

*Methods:* In 10 patients undergoing pulmonary valve-stent implantation, right ventricular function and pulmonary incompetence were assessed pre and post (within 1 week) procedure. The MR protocol included a 3D Steady State Free Procession (SSFP) volume, a series of SSFP cine images (short axis stack, four chamber, right ventricular outflow tract), and phase contrast through plane of the pulmonary artery. Pre procedure gadolinium enhanced 3D angiography was used to image the pulmonary vasculature, to assess suitability for trans-catheter valve stent implantation. Post procedure the valve-stent was imaged using a black blood turbo spin echo sequence to assess patentcy.

End diastolic volume, and ejection fraction were used to assess right ventricular function and pulmonary regurgitation was quantified pre and post procedure. All values are expressed as medians (inter-quartile range), $p<0.05$ was taken as significant.

*Results:* The minimum diameter of the pulmonary valve/homograft/conduit was between 7 mm–20 mm. All patient who were predicated to have suitable size (20 mm or less) and anatomy went on to cardiac catheterisation and successful valve-stent implantation. There was significant reduction in the regurgitation fraction (RF) of the pulmonary valve in all patients. The median RF pre procedure was 27.5% (17%–31.5%) and post procedure was 2% (0%–7.5%). In all patients valve-stents position was optimal and there was no residual narrowing on black blood imaging.

There was no significant change in right ventricular volume indices and ejection fraction. The median pre procedure end diastolic volume was 130 mls (91–

182 mls) and the median right ventricular volume post procedure was 115 mls (82–165 mls). Ejection fraction pre procedure was 52% (48%–68%) and post procedure was 57% (47%–63%).

*Conclusion:* We have demonstrated the efficacy of using MR to assess suitability for and planning of pulmonary valve-stent procedures. The ability to accurately visualize the 3 dimensional anatomy of the right ventricular outflow tract is particularly useful in sizing of pulmonary valve stents, and is a marked improvement over angiographic methods. Post procedure MR is useful in demonstrating valve stent patentcy (using black blood imaging) and valve competence. Early results show a marked reduction in pulmonary regurgitation but no change in right ventricular volume indices or ejection fraction. However, the initial follow up scan was done within a week of stent implantation. We plan to scan this group of patients 6 months after stent implantation which we believe is adequate time for ventricular recovery. We hope this will demonstrate the beneficial effects of this procedure on right ventricular function.