

## MRI Assessment of Atrial Septal Defects in Adults

**Xiuling Qi<sup>1</sup>**, Naeem Merchant<sup>2</sup>, Fiona Walker<sup>2</sup>, Gary D. Webb<sup>2</sup>, Peter McLaughlin<sup>2</sup>, Jeffrey Stainsby<sup>1</sup>, Graham Wright<sup>1</sup>

<sup>1</sup>Sunnybrook and Women's College Health Sciences Centre, University of Toronto, 2075 Bayview Ave., Toronto, Canada; <sup>2</sup>University Health Network, University of Toronto, Toronto, Canada;

### Introduction

Atrial septal defects (ASD) are one of the most common congenital cardiac defects with incidence ranging from 6-14% of all congenital heart disease. The left to right shunt in these patients results from the differences in end diastolic pressures between the left and right atria. The factors affecting the amount of shunting across the ASD can be complex but most likely relate to the size of the ASD and the relative compliance of the atria. Patients with ASD's will tend to develop symptoms of LV failure. Atrial arrhythmias especially atrial fibrillation are also common in ASD patients. All of these complications lead to an increase in the morbidity and mortality of patients with ASD's. The presence, therefore, of an ASD can be considered an indication for closure. Historically ASD closure has been performed through open heart surgery, by either suturing the defect, or by closing the ASD by the insertion of a synthetic patch. More recently, ASD closure devices have been developed to close the ASD in a minimally invasive fashion. Careful evaluation of the ASD prior to placement of the device is critical to a successful outcome of ASD closure. Currently this pre-procedural work-up consists primarily of a transesophageal echocardiogram, and right sided cardiac catheterization.

Magnetic resonance imaging (MRI) is a useful tool for the noninvasive diagnosis of congenital heart disease (CHD), and MRI evaluation of atrial septal defects (ASD) has been focused on blood flow ratio of the pulmonary and systemic circulation (Qp/Qs) (1), defect diameter (2, 3) by conventional methods, and, more recently, blood oxygenation step-ups on the right side of the heart (4). To date, these measures have been acquired separately in isolated studies. There is a need for a more comprehensive assessment for use in interpreting ASD physiology. In association with this, the volume of the trans-septal shunt flow and ASD size measured by real-time, as well as phase contrast cine MRI has a potential role. The purpose of this study was to explore the new noninvasive MRI techniques for assessing the oxygen saturation in left and right sides of the heart, pulmonary to system flow ratio (Qp/Qs) intracardiac shunt flow and ASD size compared to the gold standard of cardiac catheterization and transesophageal echocardiography.

### Methods

#### MRI study:

Nine adult patients (age from 21 to 69 years old, 1 male and 8 female) were studied using a 1.5 T GE Signa (GE Medical Systems, Milwaukee, WI). Patients were placed in a supine position with a 5 inch surface coil over the heart. Peripheral gating was performed and respiratory motion compensated using a respiratory bellows placed at the level of the diaphragm. Fast gradient echo localizers were obtained to identify the position of the superior vena cava (SVC), inferior vena cava (IVC), Aorta (AO), and main pulmonary artery (MPA).

1) Blood oxygen saturation measurements: T2-weighted images were acquired in an axial plane to estimate the blood oxygen saturation (O2%) in SVC and MPA via an in vitro T2-O2% calibration (4). Step-up values were calculated by the oxygen level in MPA minus the oxygen level in SVC. Invasive blood oxygen saturation measurements were obtained by cardiac catheterization in the MPA, SVC and were compared to O2% measured by MRI (T2) study before the closure procedure.

2) Flow measurements: Using MR phase contrast techniques flows (ml/min, 20 heart beats, FOV 24 cm, 1x2 mm in plane resolution, 10 mm slice thickness) were calculated in the AO and MPA. From these the Qp/Qs and Qp-Qs were calculated. In addition, cine phase contrast images were acquired perpendicular to the ASD in order to directly measure trans-septal shunt flow.

3) Size of septum defect: Defect diameters were studied using real-time MRI (10 frames/sec. 2mm in plane resolution, 5 mm slice thickness) (5) and phase contrast cine MRI (same as above) to determine the size of ASD. Images both parallel and perpendicular to the ASD were recorded, and the maximum defect diameter was

measured. These were compared with ASD measurements from the patients' clinical trans-esophageal echo (TEE).

### Results

1) Blood oxygen saturation measurements: Our data suggested that the step-up (O2% in MPA -SVC) measured by MRI is strongly correlated with measurements from cardiac catheterization (R=0.874, p=0.023).

2) Flow measurements: Shunt flow measurement by direct phase contrast imaging through the ASD, and by estimating Qp-Qs correlated well (R=0.909; p=0.002). Qp/Qs also showed a weak correlation with the step-up measured by MRI (R=0.662, P=0.052).

3) Size of septum defect: Septum defect size measured by real-time MRI was correlated well with both Qp-Qs (R=0.813, P=0.008) and shunt flow volume (R=0.796, P=0.018). The defect size measured by TEE was also compared with real-time MRI results, and demonstrated a highly significant correlation (R=0.903, p=0.005). Moreover, the defect size measured by cine MRI was positively related to real-time MRI (R=0.915, P=0.002) and TEE (R=0.821, P=0.045) results.

### Discussion

The results demonstrate that MR oximetry is reliable compared to the cardiac catheterization results. Qp-Qs was closely correlated to shunt flow, indicating that the phase contrast cine MRI flow measurements are consistent. However, the step-up oxygen saturation was only weakly related to Qp/Qs (p=0.052). This may be associated with the presence of biphasic shunt flow through the septal defect. In adult CHD patients, there is greater potential for higher pressure in right side of the heart, resulting in shunt flow back to the left side during the diastolic phase.

The size of the septum defect measured by real-time and cine MRI were highly related to the transesophageal echocardiography. Interestingly, MRI measurements of the ASD size are about 10% higher by real-time and 30% higher by cine than the TEE measurements. Based on measurements during intervention, TEE typically underestimates defect size by about 10%. Real-time MRI may provide a more accurate measure of shunt size than cine MRI. With cine MRI data is acquired over 20 heart cycles yielding potential blur due to variable motion effects. Also, scan plane localization with cine is less accurate than real-time interactive localization and visualization at 10 frames/second. If the plane is off the septum then size (measured by extended high flow region) may be expended.

Taken together, MRI is useful for evaluating the ASD not only by oxygen saturation and blood flow on AO, MPA, trans-septal shunt studies, but also by real-time and cine MRI defect size measurements. Obviously, combining several MRI methods together could provide a more complete ASD assessment. Noninvasive conventional MRI and real-time MRI could become a practical routine diagnostic method and provide guidance for the treatment for ASD patients.

### References

1. Hundley WG, Li HF, Lange RA, Pfeifer DP, Meshack BM, Willard JE, Landau C, Willett D, Hillis LD, Peshock RM. Assessment of left-to right intracardiac shunting by velocity-encoded, phase-difference magnetic resonance imaging. *Circulation*. 1995;91:2955-2960.
2. Holmvang G, Palacios IF, Vlahakes GJ, Dinsmore RE, Miller SW, Libberthson RR, Block PC, Ballen B, Brady TJ, Kantor HL. Imaging and sizing of atrial septal defects by magnetic resonance. *Circulation*. 1995;92:3473-3480.
3. Holmvang G. A magnetic resonance imaging method for evaluating atrial septal defects. *Journal of Cardiovascular Magnetic Resonance* 1999;1(1):59-64.
4. Kim G et al., *Proc. ISMRM* 42, 1998.
5. A. Kerr, *MRM*, 38, P:355, 1997.