Neonatal Congenital Heart Disease: Initial Results with High Resolution Contrast Enhanced MR Angiography at 3.0 Tesla

J. M. Moriarty[1], K. Nael[1], G. Satou[2], P. Renella[2], P. Abbona[1], and J. P. Finn[1]
[1]Radiology, UCLA Medical Center, Los Angeles, California, United States, [2]Pediatric Cardiology, UCLA Medical Center, Los Angeles, California, United States

Background and Purpose:
Neonates with complex congenital heart disease (CCHD) frequently have associated vascular anomalies requiring detailed and urgent vascular imaging. While echocardiography is an excellent first-line technique for characterization of cardiac anomalies, it is limited for evaluation of extra-cardiac vascular anatomy. Whereas contrast enhanced MR angiography (CEMRA) would be an attractive non-invasive option, the spatial resolution requirements for imaging tiny target vessels in neonates have so far precluded its use in this patient population. CEMRA at 3.0T has been shown to be a powerful technique in adults, but to our knowledge, has not previously been reported in children. The purpose of our study, therefore, was to explore the potential of high resolution CEMRA at 3.0T in neonates with suspected congenital vascular anomalies.

Materials and Methods:
11 consecutive neonates (mean age 10.6 days, range 1-28 days; mean weight 2.7kg, range 1.6kg-4.2kg) underwent high resolution CEMRA at 3.0T. There were 6 males and 5 females), with a variety of primary diagnoses. (Table 1). Patients were monitored either neonatal intensive care unit (NICU) staff (6 patients) or by dedicated pediatric anesthesiologists (5pts). CEMRA was performed under controlled apnea using a 32-channel 3.0T system (Magnetom TIM Trio; Siemens Medical Solutions) with a maximum gradient amplitude of 45 mT/m and a maximum slew rate of 200 $(mT·m−1)$/msec along each physical axis. The coils used for signal reception were either a 12-channel head-neck coil (4 patients) or a 15-channel adult knee coil (7 patients). Gadolinium (Gd) contrast delivery was calculated based on a total dose of 0.2 mmol /kg (0.4 ml /kg), infused over approximately 66% of the image acquisition time. Parallel imaging (GRAPPA) factors of 4-6 were used, generating 0.7 x 0.5 x 0.6 mm voxels in an acquisition time of 17-22 seconds (depending on patient size).

Images were scored for quality and the presence of artifacts independently by two observers using a four point scale where a score of 0 indicated poor (nondiagnostic) image quality; a score of 1, fair image quality, with reservations about diagnostic content; a score of 2, good image quality, with confidence in diagnostic content; and a score of 3, excellent image quality, with very high confidence in diagnostic content. Artifacts were also rated on a four-point scale; 0 = no artifact; 1 = mild artifact, not interfering with diagnostic confidence; 2 = moderate artifact, degrading diagnostic confidence; 3 = severe artifact, resulting in nondiagnostic images. The high-resolution CEMRA series were evaluated to identify pulmonary arterial and venous anatomy, with consensus between readers for definitive final diagnosis. Consensus was also used to determine the order of pulmonary arterial branch which could be confidently evaluated.

Extra-pulmonary vascular anatomy was divided into 12 sections for image quality assessment on MPR images including internal carotid arteries, vertebral arteries, subclavian arteries, aortic arch, renal arteries, iliac arteries, iliac veins, IVC, portal vein, SVC, subclavian veins and internal jugular veins. Each section was then graded using a 4-point scale (0, Vessel not visualized; 1, vessel poorly visualized such that only gross features (size, patency) are assessable; 2, vessel moderately well visualized with good definition of the vessel wall and lumen; 3, vessel very well visualized with excellent definition of vessel wall and lumen). Ancillary vascular findings in these territories were recorded.

Results:
The MR angiographic data sets had mean image quality scores of 2.7 (range: 2-3), for observer 1 and 2.5 (range 2-3) for observer 2. Mean artifact grading scores of 1 (range: 0-2), for observer 1 and 1 (range: 0-2) for observer 2. No significant difference was evident between the two observers for scoring image quality and artifact (p=0.9 using wilcoxon test), and there was good interobserver agreement between the two observers for image quality score and artifact (k = 0.66, 95% CI: 0.26-0.81).

The pulmonary arteries were confidently visualized to fifth order branches in 1 patient, fourth order branches in 7 patients, third order branches in 2 patients and second order branches in 1 patient.

In the majority of cases (73%), high resolution CEMRA allowed simultaneous comprehensive evaluation of multiple arterial and venous territories from the skull base to the groin. Indeed, out of 132 evaluated segments, 111 (84%) were graded as the vessel "very well visualized with excellent definition of vessel wall and lumen." Ancillary findings were identified in 8 /11 cases (73%). Some ancillary findings such as a hypoplastic aortic arch or left sided SVC were known about having been previously identified on echo, however others such a hypoplastic left vertebral artery arising directly from the arch of the aorta were new diagnoses.

Pulmonary arterial abnormalities were diagnosed in 6 patients and pulmonary venous anomalies in 3 patients. Correlation was made with open surgical findings in 7 cases, confirming the CEMRA diagnoses with no discrepancy between the operative and imaging conclusions. In 3 patients who did not have surgery, the CEMRA findings were used to support a decision not to intervene.

Direct origin of the right pulmonary artery from the common ventricle (arrow) in a 1 day old neonate with DORV and heterotaxy.. Note the simultaneous evaluation of multiple vascular beds.

Discussion and Conclusion:
The results of our study suggest that high resolution CEMRA at 3.0T is extremely promising in neonatal CCHD and, in combination with echocardiography, may often provide comprehensive information for treatment planning. With appropriate use of physiological motion compensation, parallel imaging and coil configuration, voxel volumes less than 0.5 mm3 are routinely achievable.