

# Combined Respiratory and Cardiac Triggered MRA of Congenital Heart Disease with a Blood Pool Contrast Agent

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**INTRODUCTION:** Pediatric cardiovascular MRI is challenged by motion artifacts from cardiac pulsation and respiration. Respiration is managed by suspended respiration, either voluntary for a nonsedated cooperative patient, or under general anesthesia, usually requiring a deeper level of anesthesia than otherwise needed [1]. Cardiac motion is managed through EKG synchronization. However, EKG triggering for MRA is relatively impractical due to the marked lengthening of data acquisition beyond the vascular phase of enhancement. Gadofosveset trisodium reversibly binds to albumin to prolong blood pool residence [2]. Initial work on this agent for cardiac imaging focused on adults [3-6] with promising results. More recently, pediatric use focused on enhancing balanced steady state imaging [7]. This work develops a combined respiratory and cardiac triggered SPGR sequence, assessing its efficacy in pediatric congenital heart MRI when combined with gadofosveset. This reflects an “off-label” use.

**METHODS:** *Sequence:* An SPGR sequence was modified to enable combined cardiac and respiratory triggering, and fractional acceleration to enable fine tuning of scan time. Parameters were flip angle of 20°, BW 62.5 kHz, frequency/phase matrix 300-384, FOV 20-35 cm, slice thickness 1-2.2 mm.

*Subjects and MRI protocol:* 23 consecutive patients referred for pediatric heart disease on a 1.5T GE Signa HDxt who received gadofosveset were recruited with IRB approval and informed consent/assent. Patients underwent conventional SPGR MRA with or without suspended respiration based on each patient’s clinical condition and imaging goals. Also, a free-breathing cardiac and respiratory triggered SPGR sequence was acquired. Data acquisition window was set between 30% and 50% of cardiac cycle based on heart rate. Acceleration factors were increased for triggered imaging in two cases to keep scans under five minutes.

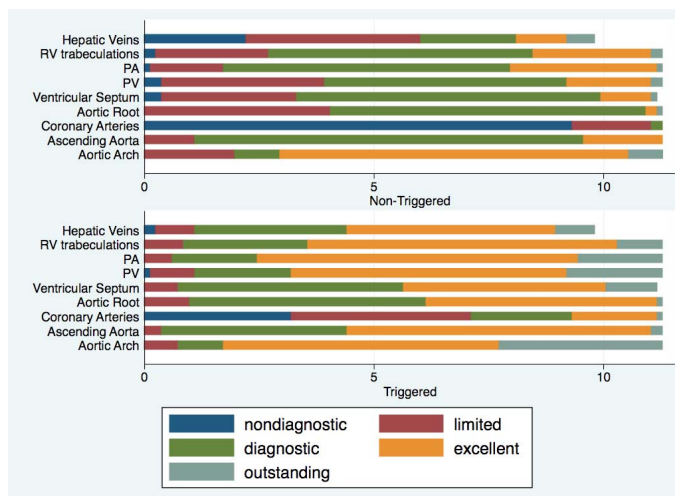
*Image evaluation:* Triggered and non-triggered images were presented in randomized blinded order to two readers, each with more than 10 years dedicated experience in pediatric cardiovascular imaging. Images could be reformatted in interactive fashion into coronal, axial, and sagittal planes (Osirix). Images were reviewed twice in separate sessions two weeks apart. Anatomic structures on both triggered and non-triggered images were graded on a five point scale, with well-defined criteria for each point on the scale and for each anatomic structure. Also, anatomic structures as well as the overall degree of cardiac ghosting artifacts on triggered and non-triggered images were compared directly against each other, again in blinded fashion, on a five point scale.

*Statistical analysis:* To test the null hypothesis that there is no significant difference between triggered and non-triggered gradings for each anatomic structure, a Wilcoxon matched-pairs rank sum test was employed. To test the null hypothesis that triggered images are not improved over non-triggered images when directly compared, a binomial test was performed. A significance level of 0.05 was used. Linearly weighted kappa values assessed inter- and intra-observer agreement.

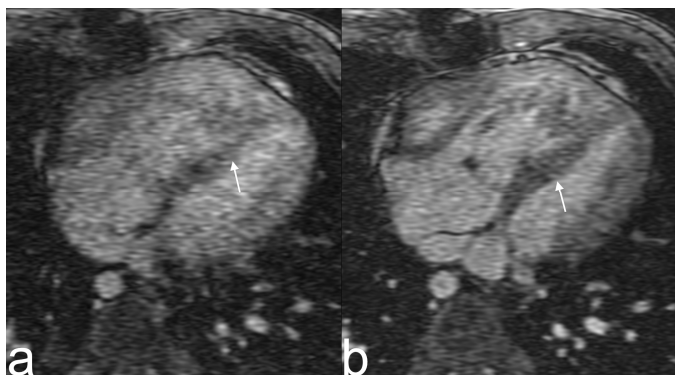
**RESULTS:** Patient ages were 0-16 years (mean 4.5 years). The fraction of cases with various scores of image quality for each anatomic structure are shown in Fig. 1 for triggered and non-triggered images. Triggered images were given higher scores by each reader for all anatomic structures (Wilcoxon rank-sum test,  $p < 0.05$  in all cases). Triggered images were more likely to be preferred than non-triggered images for most structures and both image reviewers (one-sided binomial test,  $p < 0.05$ ). For one reader, the ventricular septum, coronary arteries, and aortic arch trended towards preference of triggered images, but did not reach a statistical level of significance ( $p = 0.105$ ). For the other reader, the aortic arch also trended towards preference on triggered images without reaching statistical significance ( $p = 0.39$ ). A representative example is shown in Figure 2.

**CONCLUSION:** Delineation of anatomic structures in pediatric cardiovascular MRA significantly improves with combined respiratory and cardiac triggering, an approach enabled by a blood pool contrast agent despite its longer scan time. The approach enables higher quality imaging without suspended respiration, and thus may permit a lighter depth of anesthesia and obviate the need for an artificial airway.

**REFERENCES:** [1]: S Sarikouch et al, *Pediatric Cardiol* 30:146-152, 2009. [2]: Drugs R D 2004. [3]: M Prompona et al, *Acad Radiol* 17 :862-870. [4]: M Prompona et al. *Invest Radiol* 44 :369-374, 2009. [5]: M Stuber et al, *MRM* 10 :790-799, 1999. [6]: M Wagner et al, *Eur. J. Radiol.* 75 :166-172. [7]: CP Naehle et al, *JACC Cardiovasc Imag* 3 :504-513. Research funded in part by NIH RR09794-15, NIH R01 EB009690, Tashia & John Morgridge Foundation, and GE Healthcare.



**Fig 1.** Quality of delineation of structures on non-triggered (top) and triggered (bottom) acquisitions. Note higher fraction of triggered cases with better quality. RV = right ventricle. PA = pulmonary arteries. PV = pulmonary veins.



**Fig 2.** Non-triggered (a) and triggered (b) axial reformats from coronal acquisitions on a 7 year old with D-TGA status post atrial switch and PA banding. Note ventricular septum (arrow).