The Flexible Triggered Segmentation Optimizes Thoracic ECG-Gated Contrast Enhanced MR Angiography

Yutaka Natsuaki[1], Randall Kroeker[2], J. Paul Finn[3], Peter Schmitt[4], and Gerhard Laub[5]

[1]*Siemens Healthcare, Los Angeles, CA, United States,* [2]*Siemens Healthcare, Winnipeg, MB, Canada,* [3]*Radiology, UCLA, Los Angeles, CA, United States,* [4]*Siemens AG Healthcare, Erlangen, Germany,* [5]*Siemens Healthcare, San Francisco, CA, United States*

Introduction: The current work introduces the flexible triggered segmentation, a novel approach to the ECG-gated contrast enhanced MR angiography (gated ceMRA) of the thorax [1-3]. The current approach further improves scan time efficiency, allows timing flexibility, and enables full-coverage high-resolution gated ceMRA within a single breath hold.

Methods: Our approach is based on a Cartesian ECG-gated 3D FLASH sequence optimized for ceMRA. For conventional gated ceMRA, all of the in-plane phase encoding steps (k_y direction) are acquired within a single R-R interval (triggered segmentation with k_y direction being the inner loop direction). The triggered segmentation acquisition is then repeated in linear order for all through-plane phase encoding values (in k_z direction). With a short TR of 2.7ms and typically less than 150 in-plane phase encode steps, the data acquisition window during each heartbeat is much less than the average R-R interval, resulting in an inefficient acquisition scheme with extensive wait time. Assuming that a breath hold of less than 25 sec is necessary to avoid breathing motion, this inefficiency in the conventional gated CEMRA limits the image resolution and coverage since it only allows about 25-30 slice encoding steps. Our previous work [3] addresses this issue by acquiring multiple complete phase encodings in either direction (k_y or k_z) in saw-tooth like pattern. While this improves the scan time efficiency, it still cannot utilize the entire acquisition window. Moreover, the rigid segmentation structure (i.e. number of phase encoding steps per shot must be an integer divisor of the complete phase encodings and acquired in linear inner loop direction) limits further scan time optimizations and cannot specify the acquiring cardiac phase.

Our proposed method (Fig.1) modifies the triggered segmentation to be non-rigid, thus allowing any given acquisition window to be filled, eliminating unnecessary wait time. Inner loop phase encoding direction is no longer defined in one direction. The boundary between two triggered segments is balanced with a fuzzy pseudo-random algorithm. Such flexible and edge-balanced segments are compatible with any typical scan time optimization strategy (e.g. Partial Fourier, iPAT, elliptical scanning, etc.) to help compensate its inherent scan efficiency loss (typically 25-30%). The cardiac phase of the image is determined by the time when the center of the triggered segments is acquired (k_z=0 in Fig1). Since an extended linear-centric reordering is applied independently to every triggered segment, the center of the triggered segments acquisition can be set anywhere within the segmented acquisition window.

Results: The proposed sequence was implemented at 1.5T scanner and verified in a series of 10 volunteers under an IRB approved protocol by running both gated and non-gated versions of the same sequence. The parameters were closely matched (single dose Magnivest (Gd-DTPA) or Gadofosveset (MS-325) injection, coronal orientation, TR/TE 2.7 ms/ 0.9 ms, FA 30, BW 610Hz/pixel, iPAT x 3, image matrix 288x512, slices 120, in-plane resolution 1.3x1.0 mm^2, and slice resolution 1.88mm interpolated to 1.3mm). Scan time for the gated ceMRA was on average 23 sec, while the non-gated was exactly 21sec. The results from the direct comparison show greatly improved definition of the cardiac structures and ventricular outflow, relative to the non-gated acquisition (Fig.2).

Discussion and Conclusion: Not only *within* a triggered segment, *in between* triggered segments are also reordered to match desired overall time to center (TTC). Due to the pseudo-randomness of each trigger segment, the method minimizes the k-space data cohesiveness and may reduce the motion artifacts. The flexible triggered segmentation has successfully optimized the gated ceMRA without a compromise, and the proposed sequence holds promise for a variety of thoracic imaging applications such as electro physiology pre-operative segmentations.

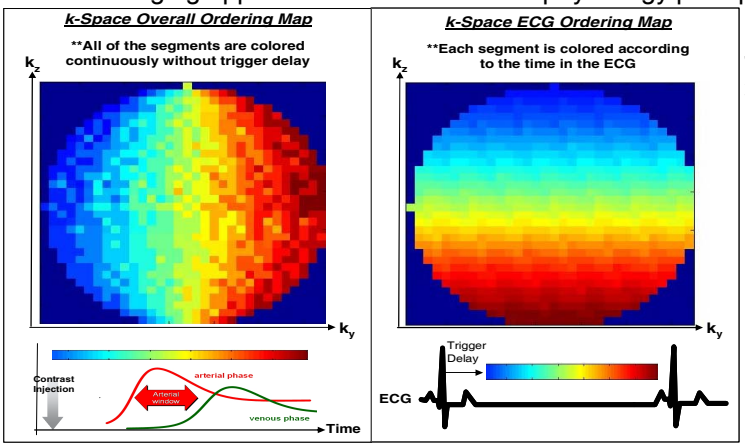

Figure 1: Schematic diagram of the k-space order maps for the proposed gated ceMRA with elliptical scan (overall ordering (left) and ECG ordering (right)).

References: [1] Simonetti OP, Finn JP, R.D.W, Bis KG, Shetty AN, Tkach J, Flamm SD, and Laub G. Proc.ISMRM 1996. [2] Spincemaille P, Zhao XH, Cheng L, Prince M, and Wang Y. Proc.IEEE EMBS 2006. [3] Natsuaki Y, Wagner PM, Finn JP, Kroeker R, and Laub G. Proc.ISMRM 2011.

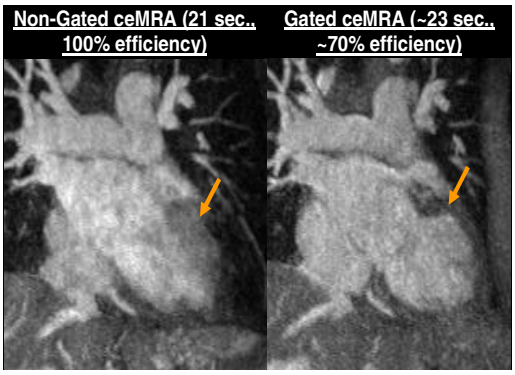

Figure 2: Coronal thinMIPs of the non-gated (left) and the gated (right) ceMRA on the same volunteer. This case was with a blood-pool contrast agent: non-gated acquired as the 2nd pass and the gated as the 3rd pass. With the gated ceMRA, fine details of the cardiac structures can be depicted.