# IMPROVED EFFICIENCY FOR RESPIRATORY MOTION COMPENSATION IN 3D FLOW MEASUREMENTS

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**INTRODUCTION:** Phase contrast (PC) cardiac MR (CMR) is widely used to assess blood flow in cardiovascular disease [1,2]. Clinically, the velocity component perpendicular through a 2D plane is used for measurements of blood flow. Recent advances have enabled 3D time-resolved PC CMR that allows measurement and visualization of all three directional components of blood flow [3]. 3D PC CMR is usually acquired during free-breathing using prospective respiratory navigator (NAV), where the k-space lines acquired immediately after the NAV signal are used for image reconstruction only if the navigator signal is within a pre-defined gating window, whereas those outside the gating window are rejected and re-acquired. This rejection-reacquisition scheme prolongs the scan time by 2-3 times. In this study, we hypothesized that respiratory gating the center of k-space only will yield similar measurements to a fully respiratory-gated acquisition, since the phase information mainly comes from the central k-space, and evaluated these two gating approaches in terms of quantification of cardiac indices and imaging efficiency.

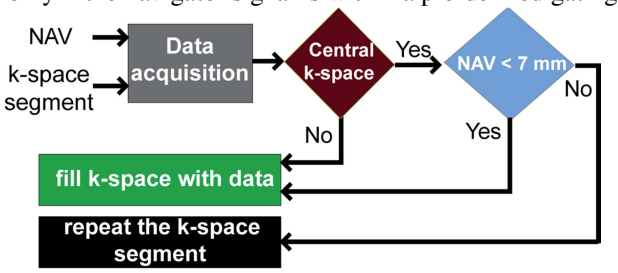


**Fig. 1**: The flow-chart for the proposed center-gated strategy.

**METHODS:** The proposed gating strategy (center-gated) divides the image acquisition into two phases following the NAV preparation phase. First, the central k-space, corresponding to 4% of the k-space, is acquired with NAV gating & tracking using a pre-defined gating window, similar to the prospective NAV acquisition. Subsequently, the remaining outer k-space data are acquired without using any respiratory motion gating. This procedure is depicted in **Figure 1**.

12 subjects were recruited (33±15 years; 5 males) for 3D flow CMR on a 1.5T Philips Achieva magnet. Images were acquired axially using a GRE sequence (TR/TE/α=5.7/3.4ms/10°, resolution=2×2×4mm$^3$, FOV=340×340×40mm$^3$) in a volume covering the ascending and descending aorta, and the aortic bifurcation. Only foot-head flow encoding was used to provide an adequate temporal resolution of 23.2ms for the measurements. The nominal scan time for this scan was 12 minutes at 60 bpm.

For respiratory motion compensation, two gating & tracking strategies were used with a 7mm gating window: 1) Proposed center-gated strategy, 2) All of k-space is acquired within the gating window (fully-gated). Two fully-gated acquisitions were performed to characterize intra-scan variability. Acquisition time was recorded for each scan. Stroke volume measurements were performed both on the ascending and the descending aorta for all acquisitions. Bland-Altman analyses were performed to compare the flow measurements between different gating strategies (fully- vs. center-gated), as well as the intra-scan variation for the fully-gated strategy.

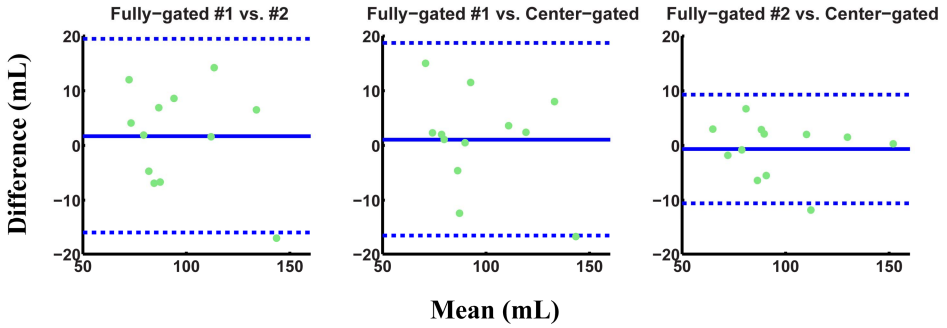


**Fig. 2**: Bland-Altman analysis of the stroke volume through the ascending aorta. The center-gated scans are clinically identical to the fully-gated scans for these acquisitions.

**RESULTS:** **Figure 2** shows the Bland-Altman analysis of stroke volume for the ascending aorta. The intra-scan variability observed for fully-gated scans is equivalent to or higher than the variability observed between fully-gated and center-gated strategies. Similar observations apply to stroke volume for the descending aorta as well. **Figure 3** shows example PC images using the two different strategies. The center-gated scan was half as long as the fully-gated one for this subject. The proposed center-gated strategy was also significantly shorter compared to the fully-gated strategy overall (13:19±3:02 vs. 19:35±5:02, $P$<0.001).

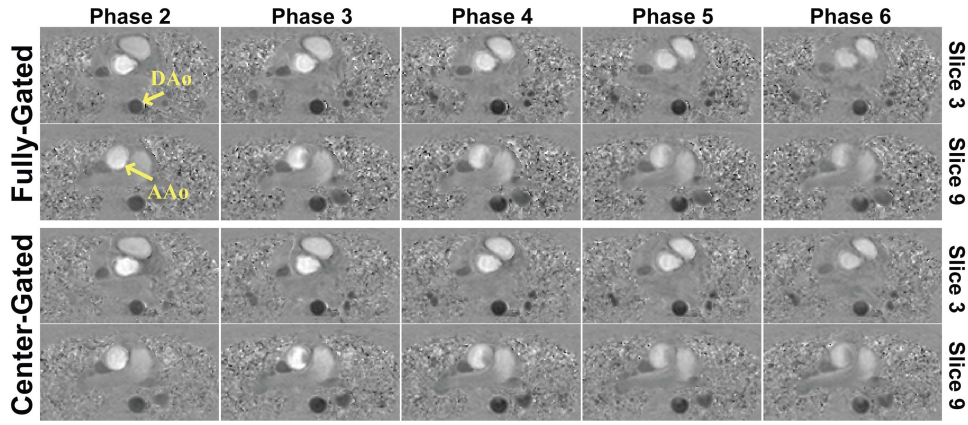


**Fig. 3**: Example slices and cardiac phases from 3D PC images acquired using the two different navigator strategies, depicting cross-sections across the descending aorta (Dao) and ascending aorta (AAo). The PC images are visualized similarly. However, the center-gated acquisition took 12:13 minutes, whereas the fully-gated one was 25:21 minutes.

**CONCLUSIONS:** We demonstrated an efficient respiratory gating strategy for 3D PC CMR. No systematic variation was observed for the stroke volume measurements between the proposed strategy and the fully-gated one, with the proposed strategy having a markedly shorter acquisition time.

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**REFERENCES:** [1] Pelc, MRQ, 1991; [2] Markl, JCMR, 2011; [3] Markl, JMRI, 2003