Workflow Integrated Interactive Realtime Radial Flow Measurement with Dynamic VENC Adjustment for Accurate Peak Velocity Estimation

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Motivation:
MR phase contrast flow measurements are an integral part of MR exams in valvular and vessel diseases. For optimal flow quantification, velocity encoding (venc) gradients must be adjusted to the maximum velocity. If the flow encoding is chosen too high, the SNR of the phase-difference-based measurement drops. If the flow encoding is chosen too low, phase wrap occurs. Venc optimization can be achieved by first running test measurements with a discrete set of venc values, then selecting the optimal setting by visual inspection of the images, i.e., the lowest value where no phase wrap occurs. Finally the selected value is copied into the clinical measurement. Also, as velocity is encoded only in one spatial direction at a time, and typical protocols employ one encoding direction (through-plane) only, it is necessary to correctly align this direction with the expected flow. Depending on the vessel anatomy the choice is more or less obvious and, in difficult cases, must be found by trial and error. Therefore we suggest a faster and easier way to optimize the parameters of the clinical measurement based on an interactive real-time radial flow measurement with dynamic venc setting.

Methods:
Sequence: A FLASH based product phase contrast flow sequence on a MAGNETOM Skyra (Siemens AG, Erlangen) 3T scanner was turned into an interactive real-time venc scout for through-plane phase contrast flow measurements by adding radial k-Space sampling and interactive control of both through-plane venc, and scan plane, based on the product implementation of the interactive real-time sequence. Radial imaging has been shown to be an effective means for accelerating phase contrast measurements [1]. Only a few radial spokes are necessary to create phase difference images with negligible streaking artefacts because the signal from the stationary tissue is largely suppressed. Images were reconstructed frame-by-frame using lookup-table-based regridding [2]. No temporal or spatial filtering was applied. In order to avoid stimulation and SAR problems due to interactive venc changes, the initial venc setting could interactively only be increased but not decreased with respect to the initial setting.
Interactive UI: The venc-control was placed prominently on a customized parameter card, eliminating the need to page to the single numerical interactive parameter. This was achieved by end-user-accessible configuration in the Dot Engine framework (Siemens AG, Erlangen). The scan plane geometry is manipulated graphically in the standard UI for pre-scan slice planning.
Automatism: Upon stopping the scout scan, assuming the correct venc setting has been found, the final venc setting is automatically copied to the subsequent standard clinical measurement steps. This was achieved by scripting in the Dot Engine framework. If desired the scan plane information is also transferred.
Scanning: The venc scout was applied in a volunteer during free breathing at different positions along the thoracic aorta (TR 67.5 ms, 15 projections, FoV 300 mm, 2.3mm in-plane res., 10 mm slice). The venc was changed interactively during scanning until no aliasing occurred. The resulting venc was considered as the apparent peak velocity. At the same slice positions standard breath-hold venc scouts were performed and evaluated and the resulting venc was used in a subsequent standard segmented flow acquisition (TR 48 ms, FoV 340 mm, 1.8 mm in-plane res., 6 mm slice, TA 15s).

Results:
The interactive real-time radial phase contrast images allowed an easy detection of venc aliasing in the aorta. Within a few heartbeats (typically 10), the optimal venc could be determined. The resulting peak velocity values were very consistent and in good agreement with the values as determined from the segmented flow measurements (average rel. difference 5.5%, see fig 1). Typical phase contrast images of segmented and real-time acquisitions are shown in fig. 2.

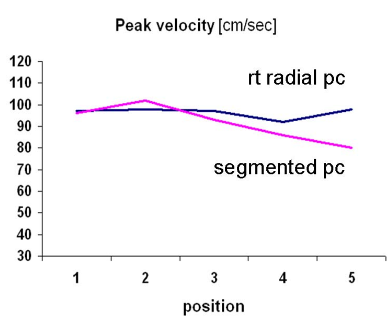

Fig.1: peak velocity in through-plane flow measurements for different slice positions along thoracic aorta

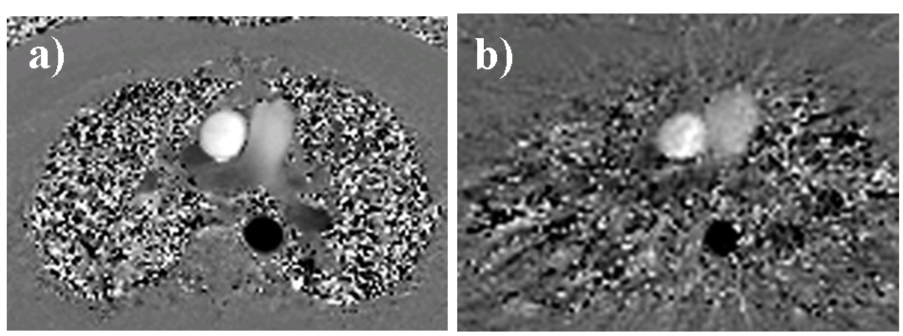

Fig.2: representative diastolic phase contrast images of through-plane flow measurements in aorta at pulmonary level; a) standard segmented, b) interactive real-time radial

Discussion:
The new sequence and workflow enabled a very efficient way of determining peak velocities and applying them to subsequent clinical high-resolution breath-hold flow scans. The accuracy of the peak velocity estimate of the new sequence is comparable to the standard breath-hold venc scout. The real-time technique may be improved further in terms of temporal and spatial resolution by applying more sophisticated reconstruction methods with real-time capabilities.

References:
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