Background Velocity Error in Phase Contrast MR Imaging

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Introduction: Phase-contrast (PC)-based velocity-encoding sequences are available on most modern clinical scanners. This technique, coupled with semi-automated commercial software for phase difference analysis, is widely utilized in clinical practice to measure blood flow. However, while the accuracy of the original PC methods (without k-space segmentation) has been well validated in phantoms and *in vivo*, there is minimal data published on the accuracy of fast (i.e., breath-hold length) PC sequences using k-space segmentation and the offline analysis techniques used in modern clinical practice (1). There are several potential sources of error in the flow quantification as measured by PC; these include background phase error due to concomitant gradients and eddy currents induced in the scanner structure from time-dependent gradient fields (2). Despite the lack of published data on the magnitude of these errors and the resulting effect on flow quantification using modern, fast commercial pulse sequences and analysis software, PC is often taken as the non-invasive "gold standard" of flow measurement in the heart and great vessels. While correction methods exist to account for background errors, the corrections require special computational techniques and are time-consuming, and are therefore not usually done in clinical practice. Even a small systematic error in the background velocity can contribute a large absolute error in the time-integrated flow, particularly when the region of interest (ROI) is large. The purpose of this study was to determine the error in PC-determined velocities and time-integrated flow that result from errors in the background phase using a clinically relevant PC acquisition and standard processing methods.

Methods: A phantom was constructed with sealed, water-filled cylindrical 50-ml centrifuge tubes fixed in a rigid pressboard framework to provide zero flow. The tube cross-sectional area of 5 cm^2 was chosen for analogy to the human thoracic aorta. The framework was positioned in the scanner in three ways to allow axial, coronal, and sagittal scanning with slices in which the tubes were seen in cross-section. Scans were performed on a GE Signa 1.5 T scanner using a surface coil and a segmented k-space technique (2 views per segment) with through-plane velocity encoding; the imaging sequence (Fast 2D PC) was a standard clinical sequence as provided by GE Medical Systems (Milwaukee, WI). An artificial ECG trigger was used for gating 20 acquisition phases with a 256 x 256 matrix, 40 cm field of view, slice thickness 1 cm, and v_{ENC} 200 cm/s. The readout (frequency) direction was switched for each scan plane so that two readout directions were obtained for each velocity encoding direction. The data was analyzed with the program CV FLOW (version 2.0; Medis, Netherlands). ROI contours were drawn for the areas indicated in Figure 1A using semi-automated edge detection and the average velocity and temporal RMS noise in each ROI was determined. Four acquisitions were obtained under each condition.

Results: A nonzero background error velocity was found for each ROI and velocity encoding direction (Figure 1B) and ranged from ± 6 cm/s. There was a spatial dependence of this value when the velocity encoding was in the coronal or sagittal directions; the spatial dependence was minimal with velocity encoding in the axial direction. The background error velocity and the noise were also dependent on the slice orientation/velocity encoding direction, with axial encoding giving the smallest background error. The background error also showed a dependence on the readout direction. The RMS noise was small (< 1 cm/s for all orientations and ROIs; smallest for a coronal scan plane) and the reproducibility excellent (standard deviation of the 4 repetitions < 1 cm/s for all conditions). Though the background errors are small compared to the v_{ENC}, they can result in a non-negligible error of up to 2 liter/min over an ROI of the size used here (e.g., 6 cm/s velocity error x 5 cm^2 area x 60 seconds/min = 1.8 liter/min of error "flow").

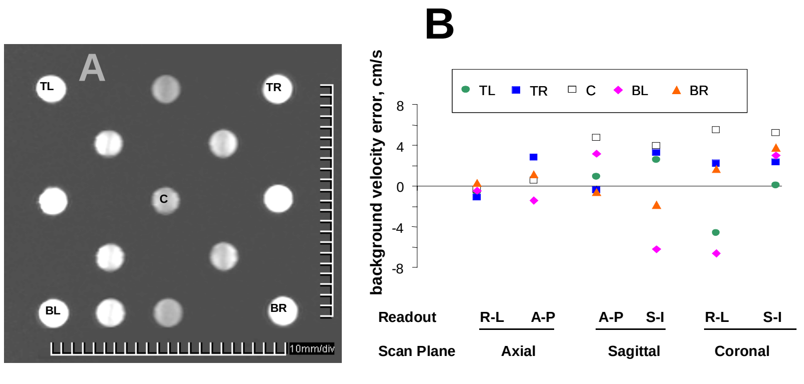

Figure 1. *A*, Axial plane magnitude images depicting the ROIs used in the study. TL, top left; TR, top right; BL, bottom left; BR, bottom right; C, center. *B*, Background velocity in the axial, sagittal, and coronal scan planes with frequency readout direction shown. Standard deviations of the four measurements and temporal RMS noise were < 1 cm/s.

Conclusions: Background velocity errors in PC imaging may contribute a significant error in time-integrated flow, particularly when the flow ROI is large. Such errors may lead to erroneous conclusions regarding absolute vascular flow or cardiac output. They are particularly problematic when comparing flow in two or more large vessels, since this frequently requires different scan planes (with different background errors) for each vessel. It is difficult to correct for such errors without complex post-processing methods. The magnitudes and spatial dependence of the errors may be unique for each scanner, but the simple technique described here can allow an estimate of their impact and enable the user to choose a scan plane and acquisition parameters that minimize these errors.

References:

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