Radial Flow-Gated Phase Contrast Imaging in Carotid Artery

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Introduction

The estimation of flow measurements by phase contrast (PC) imaging generally requires an ECG signal to synchronize the acquisition of imaging data with pulsatile flow pattern. ECG gating could however be complicated in the presence of arrhythmia or weak ECG signals. Recently, self-gated [1] and flow-gated [2] methods are reported for acquiring PC images on major cardiac vessels without usage of ECG. For carotid arteries with much weaker flow than the larger vessels, flow gating without ECG becomes challenging. A technique based on radial scanning is therefore proposed in combination with sophisticated processing algorithms to achieve such a goal.

Materials and Methods

Our study population consisted of 7 healthy subjects without history of cardiovascular disease (female:2; male:5; age: 26.2±5.38 years). All MR images were acquired on a 3T clinical imager (Siemens Trio, Erlangen, Germany). The radial FLASH sequence [1] (TR/TE=23/7.1 ms, flip angle=30^0, VENC=110 cm/sec, FOV=140x140 mm^2, matrix size=256x256) was applied at the common carotid artery level in each subject. For the purposes of measuring a flow-gating signal, the phase data were processed with complex-difference subtraction to retain signal from spins moving in the flow-encoded direction while eliminating signal from stationary tissue. To generate the flow-gating waveform, we used the sum of the pixel intensities of an ROI selected from the low-resolution complex-difference images [2], each reconstructed using 8 echoes covering roughly 180° of k-space. We down-sampled each echo by a factor of 4 to improve the SNR of complex-difference images for more accurate flow-gating waveform. A template matching method was used to correlate the cyclic patterns of flow to derive the flow-gating times. Correlation coefficients were calculated for each offset of the template pattern with respect to the flow-gating waveform. The magnitude and phase images of radial FLASH data were reconstructed by re-gridding method with a 3x3 Kaiser-Bessel kernel. For comparison purpose, a conventional 2D FLASH sequence (TR/TE=42/6.6 ms) was also applied at identical slice position of each subject with ECG gating, sampling 85~90% of the cardiac cycle. Flow-related measurements were calculated to quantitatively compare the images of conventional FLASH and radial FLASH. Correlations between flow-related parameters obtained using two different methods were assessed.

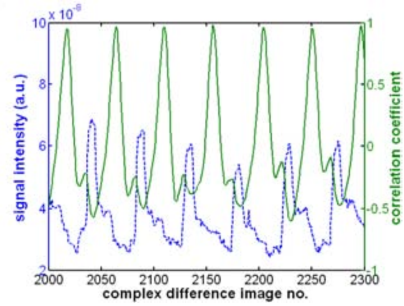

Fig.1. Even with beat-to-beat variations in signal intensity, the correlation coefficients from complex-difference image were highly consistent.

Results

Fig.1 displays the signal intensity of flow-gating waveform and corresponding correlation coefficients with using complex-difference calculation, which demonstrates that even with variations in the flow patterns, the correlation method on complex difference images was able to extract the gating information robustly. Figs.2(b) and 2(d) show the retrospectively reconstructed magnitude and phase images of radial FLASH, respectively, in close similarity with the magnitude and phase images of conventional FLASH acquired with ECG-gating shown in Figs.2(a) and 2(c). The high correlation coefficients between flow-related parameters obtained with conventional FLASH and radial FLASH listed in Table 1 further suggest that reliable flow measurements without ECG gating is feasible for vessels having weak flow.

Discussion and Conclusions

Radial scan has the inherent advantage of self-gating by retrospectively arranging each k-space line [1]. The original self-gated method [1], however, is not suitable for extracting gating signal from small vessels due to weak flow. The complex-difference images, echo down-sampling, and correlation-based template-matching are all important steps for finding accurate flow-gating times and thus have strong impact on the reconstructed image quality in small vessels with weak flow. In our experience, this method is also suitable for the basilar artery, again without usage of ECG gating (data not shown). The good agreement in image appearance and flow parameter estimations between conventional and radial FLASH suggest that reliable flow measurements without ECG gating is highly feasible. The noticeable discrepancy in the mean flow rate likely arose from different cardiac phases used in the conventional prospectively ECG-gated FLASH versus the flow-gated radial scan. Another factor that could account for the difference is that the conventional FLASH sequence acquired only 85~90% of the cardiac cycle. In conclusion, the radial flow-gated PC imaging is applicable to vessels with weak flow such as intracranial vessels. The advantages of this method includes that the intracranial flow information can be obtained reliably without additional setting for ECG gating. Furthermore, it is potentially a helpful technique to be used for patients in the presence of arrhythmia or weak ECG signals.

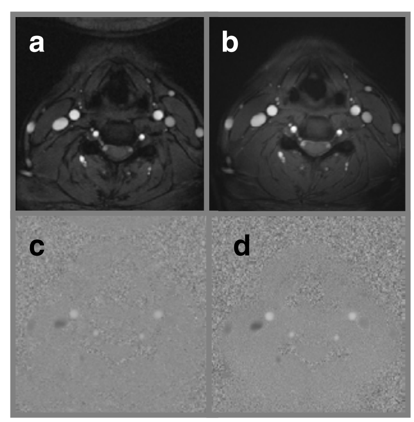

Fig. 2. (a)(b) magnitude images of conventional FLASH and radial FLASH, respectively. (c)(d) phase images of these two sequences. All images are the mean images of all cardiac phases.

Table 1.

	mean velocity(cm/s)	mean flow rate(cm^3/s)	flow volume(cm^3)
slope	0.81	0.53	0.86
R	0.96	0.92	0.87

References

1. Larson et. al, MRM 51 : 93-102 (2004).
2. Thompson et al, MRM 52 : 598-604 (2004).