Journal of Cardiovascular Magnetic Resonance

Meeting abstract

Open Access

# 1121 Increasing the velocity-to-noise ratio in time-resolved 3D blood flow measurements

Jochen von Spiczak*, Gérard Crelier, Peter Boesiger and Sebastian Kozerke

Address: Institute for Biomedical Engineering, University and ETH Zurich, Zurich, Switzerland

* Corresponding author

*from* 11th Annual SCMR Scientific Sessions
Los Angeles, CA, USA. 1–3 February 2008

Published: 22 October 2008

*Journal of Cardiovascular Magnetic Resonance* 2008, **10**(Suppl 1):A246 doi:10.1186/1532-429X-10-S1-A246

This abstract is available from: http://jcmr-online.com/content/10/S1/A246



## Introduction

Time-resolved phase contrast (PC) imaging permits the assessment of volumetric, multi-directional blood flow velocities [1]. The resulting vector field data can be visualized in different ways using streamlines, arrows, and particle traces [2]. These visualization modes allow for an accurate and intuitive analysis of blood flow characteristics in normal and pathological cases [3]. Despite the advantages of the method, wide-spread acceptance in a clinical setting has been hampered by the long scan durations.

In order to reduce the long measurement times, parallel imaging [4] may be employed. Noise amplification from parallel imaging can partly be compensated for by conducting the measurements at high field. Since the velocity-to-noise ratio (VNR) is not only dependent on base signal-to-noise but also scales inversely with the encoding velocity (Venc), lowering Venc may be considered an alternative approach to improving VNR. If Venc is chosen smaller than the actual blood velocities, phase aliasing arises and needs to be corrected. Phase unwrapping is a well studied field and has been extensively discussed for two [5] and more dimensions [6].

It was the objective of the present work to improve VNR by using low Venc phase contrast imaging in conjunction with an automatic phase unwrapping algorithm suited for time-resolved 3D blood flow measurements.

## Methods

### *Data acquisition*

Time-resolved 3D PC data covering the left-ventricular outflow tract, ascending and descending aorta were acquired on a Philips 3 T Achieva system (Philips Medical Systems, Best, The Netherlands). Scan parameters of the navigated and retrospectively triggered fast gradient-echo sequence were: FOV = 320 × 260 × 51 mm$^3$, matrix = 128 × 128 × 17, $T_R$ = 3.95/3.85ms, flip angle = 5°, cardiac phases = 25. Healthy subjects were scanned twice with $Venc_{1x, y}$ = 200cm/s, $Venc_{1z}$ = 100cm/s avoiding phase wraps and $Venc_{2x, y}$ = 100cm/s, $Venc_{2z}$ = 50cm/s intentionally accepting phase wraps.

### *Phase unwrapping*

The phase unwrapping algorithm was designed to take into account appropriate prior knowledge about the phase evolution during one heart cycle: a) absence of phase wraps was assumed for the first heart phase; b) phase wraps can only occur between two mate extremes of the first derivative v'(t); and c) the intermediate curvature given by the second derivative v"(t) must fit the remainder of the velocity curve. To correct residual aliases a 5 × 5 median filter was applied, correcting single misjudged voxels with respect to the 2π level of the median.

### *Data evaluation*

After unwrapping, the VNR of both the high Venc data series and the unwrapped low Venc series were calculated for regions-of-interests in the ascending aorta. Velocity noise was determined from the phase noise in static tissue as automatically identified using temporal statistics of the velocity data. Both data series were then used to calculate traces for particles interspersed in the aortic arch during mid systole.

## Results

The phase algorithm was able to correct for the aliasing in the low Venc acquisition. Only the area right above the aortic valve remained difficult to correct automatically due to the large displacement of the aortic annulus during systole. Comparing VNR of the low and high Venc acquisitions resulted in a ratio of 1.87 on average being only slightly below the theoretical prediction of a factor of two. Figure 1 displays VNR curves for the three velocity encoding directions over time. Particle traces of the high Venc, uncorrected low Venc, and corrected low Venc acquisitions are shown in Figure 2.

## Discussion

It has been shown that lowering the encoding velocity with subsequent phase unwrapping is a feasible method to improve VNR in time-resolved PC. The unwrapping algorithm proposed features linear complexity and high accuracy and is therefore well suited for time-resolved 3D multi-directional velocity data.

## References

1. Wigstrom L: *MRM* 1996, **36(5):**800-3.
2. Buonocore MH: *MRM* 1998, **40(2):**210-26.
3. Markl M: *Circulation* 2007, **116(10):**e336-7.
4. Pruessmann KP: *MRM* 1999, **42(5):**952-62.
5. Strand J: *Appl Opt* 1999, **38(20):**4333-44.
6. Abdul-Rahman HS: *Photon* 2006.

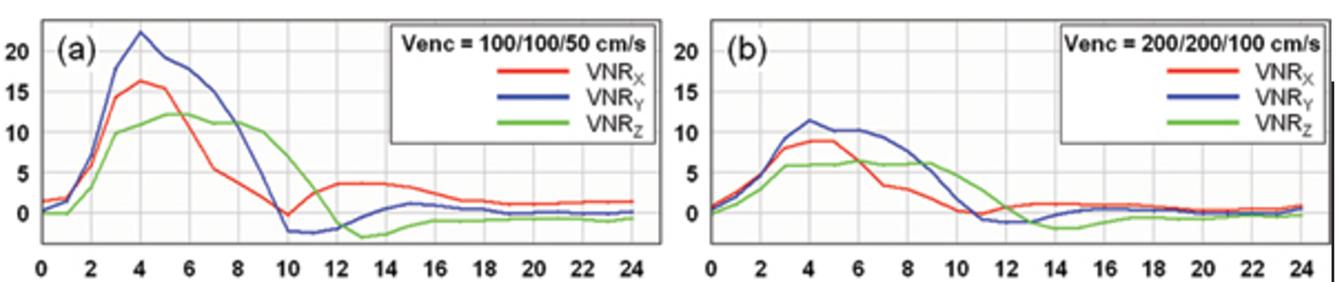


**Figure 1**

Comparsion of VNR over time measured in the ascending aorta. Values of unwrapped data with low Venc = 100/100/50 cm/s (a) and values of originally correct data with high Venc = 200/200/100 cm/s (b).

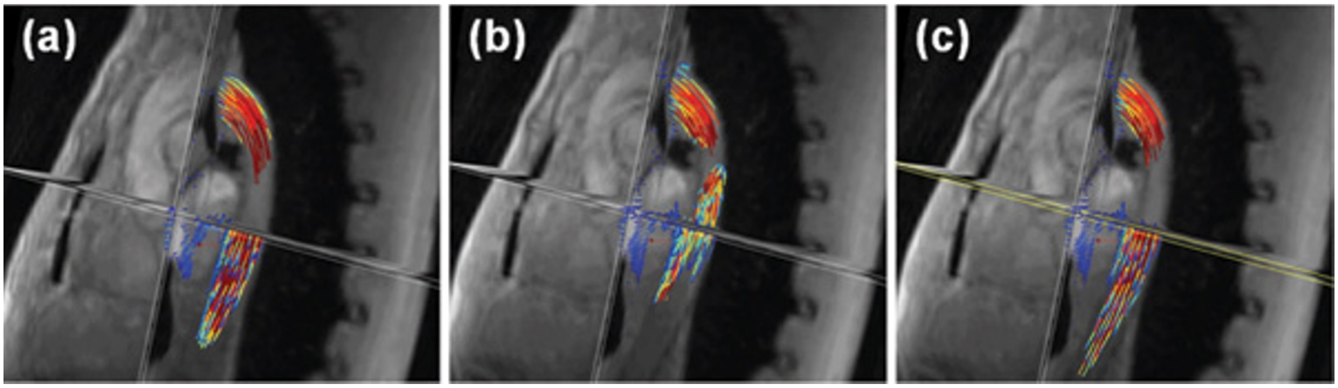


**Figure 2**
Particle trace visualization calculated from data with high Venc = 200/200/100 cm/s (a), wrapped (b), and unwrapped (c) data with lox Venc = 100/100/50 cm/s.