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# Intracardiac cardiovascular magnetic resonance velocity mapping: comparison of k-t BLAST and SENSE accelerated 4D acquisitions with 2D-flow at 1.5 T and 3 T

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## Introduction

Three-dimensional time-resolved (4D) cardiac flow can be visualized and quantified with velocity encoded phase contrast (PC) MRI, but requires a long scanning time. k-tBLAST is an efficient technique to reduce scan time, but has not been validated for in vivo 4D-flow applications.

## Purpose

To quantitatively compare flow using k-t BLAST and SENSE 4D-acquisitions with standard 2D-flow at 1.5 T and 3 T.

## Methods

Cardiac 4D-flow with k-tBLAST and SENSE and non-accelerated 2D-flow measurements of the aorta and pulmonary trunk were obtained from 7 healthy volunteers (36 ± 15 years, 5 males) in a 1.5 T and 3 T Philips MRI Scanner. Typical 4D-flow parameters for k-t BLAST were: speedup factor 5, 15 time phases, TE/TR/flip: 3.7/7.6 ms/8°, and for SENSE: parallel imaging factor 2, 40 time phases, TE/TR/flip: 3.7/6.3 ms/8°. The voxel size was 3 × 3 × 3 $mm^3$. 2D-flow was acquired with a PC-FFE sequence with TE/TR/flip: 5.3/8.6 ms/15°. 2D-flow was acquired with 35 time phases and voxel size 1.2 × 1.2 × 6 $mm^3$. The different sequences for each volunteer were acquired in a random order during a single session. From the 4D datasets, 2D-images perpendicular to the aorta and pulmonary artery were reconstructed using in-house developed software. Flow was measured by outlining the aorta and pulmonary trunk in the velocity encoded 2D-images and these contours were transferred to the reconstructed 4D-images. Stroke volumes (SV) and flow were compared using Wilcoxon's test, linear regression and Bland-Altman analysis.

## Results

2D-flow measurements of the aorta and pulmonary artery showed a strong correlation ($r^2$ = 0.94) and low bias (2.8 ± 6.1%). 4D-flow scan time was reduced using k-tBLAST from >45 min to<10 min. One k-tBLAST 4D data set was excluded from the 3 T because of suboptimal image quality. Flow from 4D-SENSE showed similar flow curves compared to 2D-flow (Figure 1) but peak flow was lower on both 1.5 T and 3 T ($p < 0.05$). Peak flow on 4D k-t BLAST was lower than 2D and 4D SENSE flow ($p < 0.05$).

**Table 1: Comparison of 4D vs. 2D. Peak flow with 2D at 1.5 T: 431 ± 93 and 3 T: 445 ± 101 ml/s**

| Sequence | $r^2$ | SV, bias ± SD | Peak flow ml/s |
|---|---|---|---|
| 1.5 T SENSE = 2 | 0.84 | -6.2 ± 16.5% | 387 ± 100 |
| 3 T SENSE = 2 | 0.90 | -2.5 ± 8.4% | 415 ± 91 |
| 1.5 T k-t BLAST = 5 | 0.65 | -19.8 ± 15.6% | 325 ± 75 |
| 3 T k-t BLAST = 5 | 0.63 | -4.7 ± 12.3% | 376 ± 60 |

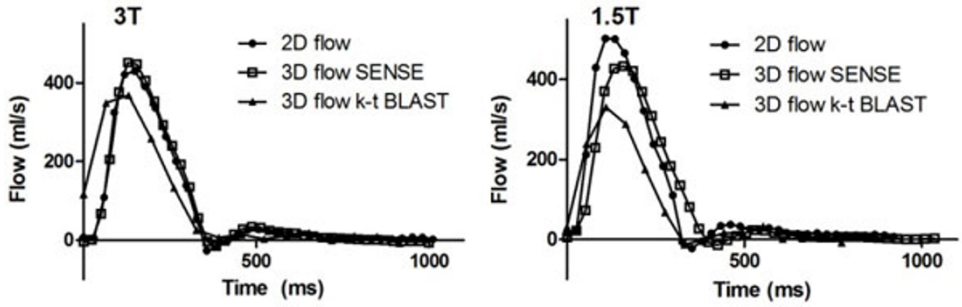


**Figure 1**

The comparison of SV measurements on the 2D- and 4D-flow sequences from both scanners is shown in Table 1. The measurements of SV on 4D-SENSE was not significantly different from 2D on either scanner ($p = 0.33$ on 1.5 T and $p = 0.36$ on 3 T). SV quantified on 4D k-tBLAST was lower compared to 2D on 1.5 T scanners ($p < 0.001$) but not on 3 T ($p = 0.47$).

## Conclusion

Quantitative analysis of flow from 4D-PC-MRI is accurate and reproducible with SENSE. Speed up with k-tBLAST yields lower stroke volumes, peak flows and a weaker correlation compared with 2D-acquisitions.

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