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Accelerated spiral Fourier velocity encoding using UNFOLD and partial Fourier reconstruction

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Why Fourier Velocity Encoding?

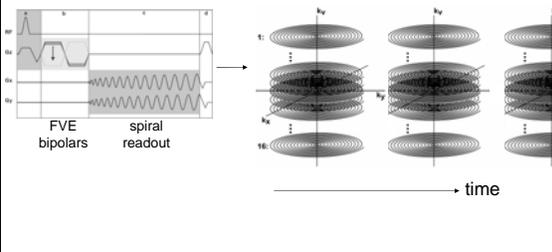
- Phase Contrast (PC)
 - Turbulent flow: multiple velocities
 - Partial volume
 - Peak velocity underestimation
- Fourier Velocity Encoding (FVE)
 - Full velocity distribution
 - Robust to partial volume
 - Longer scan time

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Spiral FVE

- ISMRM'06 p.1906
- Velocity distribution in a single breath-hold



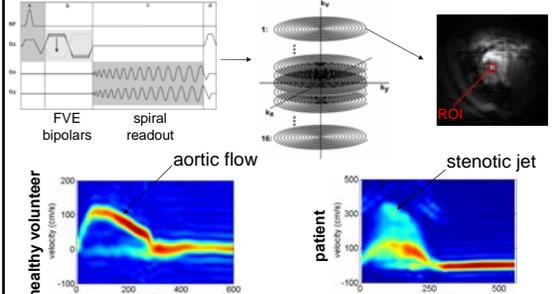
FVE bipolars spiral readout

time

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Spiral FVE

- ISMRM'06 p.1906



FVE bipolars spiral readout

ROI

aortic flow

stenotic jet

healthy volunteer velocity (cm/s) time (ms)

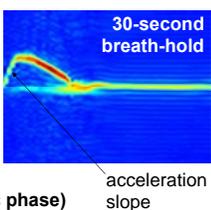
patient velocity (cm/s) time (ms)

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View-Ordering

- Fully sampled:

HB1	1	1	1	1	1	1	1
HB2	2	2	2	2	2	2	2
HB3	3	3	3	3	3	3	3
HB4	4	4	4	4	4	4	4
HB5	5	5	5	5	5	5	5
HB6	6	6	6	6	6	6	6
HB7	7	7	7	7	7	7	7
HB8	8	8	8	8	8	8	8



30-second breath-hold

acceleration slope

time (cardiac phase)

heartbeats

– Long breath-hold

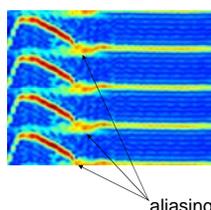
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Undersampling

- 4-fold undersampling:

	1			1			
HB1		2			2		
			3			3	
				4			4
HB2	5				5		
		6				6	
			7				7
				8			



aliasing

– Short breath-hold

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View-sharing

- **Sliding-window:**

	1	2	3	4	5	6	7	8
HB1		2	2	2	2	2	2	2
		3	3	3	3	3	3	3
			4	4	4	4	4	4
HB2	5	5	5	5	5	5	5	5
	6	6	6	6	6	6	6	6
		7	7	7	7	7	7	7
			8	8	8	8	8	8

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UNFOLD

- **Low-pass filter:**

	1	2	3	4	5	6	7	8
HB1		2	2	2	2	2	2	2
		3	3	3	3	3	3	3
			4	4	4	4	4	4
HB2	5	5	5	5	5	5	5	5
	6	6	6	6	6	6	6	6
		7	7	7	7	7	7	7
			8	8	8	8	8	8

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Why UNFOLD doesn't work

- Pulsatile flow → Wide bandwidth
- Low-pass filters signal components
- Aliasing components overlap
- Pre-processing required

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Pulsatility Removal

- **Peak-tracking***
 - Follow highest intensity
 - Flatten time frames

*Macgowan and Madore, ISMRM'06 p.872

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UNFOLD'ed Spiral FVE

- Flattening reduces bandwidth
- Allows 4-fold acceleration

* 8-second breath-hold

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Problem

- Accurate flattening reference is crucial
- Peak-tracking fails in turbulent flow

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Alternatives

- Phase contrast reference
- Unaliased reference

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Phase contrast reference

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Unaliased reference

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Unaliased reference

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Flattening - Results

- 4-fold acceleration

PC reference

Unaliased reference

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Conclusions

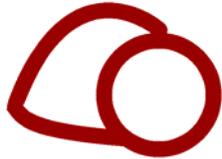
- Breath-hold in Spiral FVE 4x reduced using UNFOLD
- Flattening methods for turbulent flow
- Not shown: 1.7-fold acceleration with partial Fourier along k_v
- Combined to almost 7-fold
 - Not as robust

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- NIH (HL074332)
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- GE Healthcare

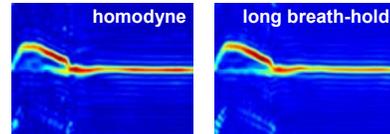


<http://mrel.usc.edu>



Partial Fourier Acceleration

- Homodyne reconstruction along velocity dimension
- 60-70% increase in velocity resolution
- Or ~40% reduction in scan time



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