

4D-MRI using Internal Surrogates

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Strategies for 4D-MRI

Real time 4D-MRI

- ultra-fast 3D MR sequence
- fast gradient, multi-coils, parallel processing
- inadequate image quality (3-4 mm, 1.5 s/f)

Retrospective 4D-MRI

- fast 2D MR sequence
- breathing signal (surrogate)
- adequate image quality (1.5x1.5x3 mm, 0.3 s/f)

Retrospective 4D-MRI

Image Acquisition	Respiratory Signal
<ul style="list-style-type: none"> ▶ Fast 2D cine MR ▶ Multiple slices ▶ Cine duration > 1 cycle ▶ Frame rate: ~3 f/s ▶ Slice thickness: 3-5 mm ▶ Pixel size: 1-2 mm 	<ul style="list-style-type: none"> ▶ Surrogates <ul style="list-style-type: none"> - External - Internal/Image-based ▶ Signal processing ▶ Phase determination

Internal/image-based Surrogates

- Implanted markers
- Diaphragm
- Air content
- Lung area
- Lung density
- Fourier transform
- Body area (axial, sagittal)
- Normalized cross correlation
- Deformable image registration

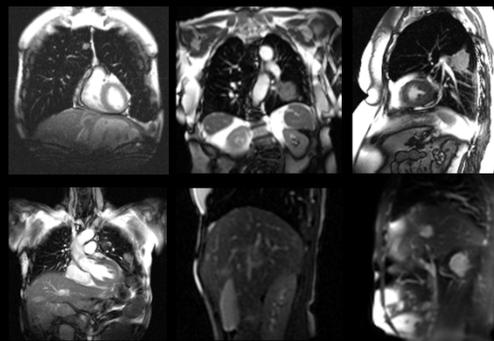


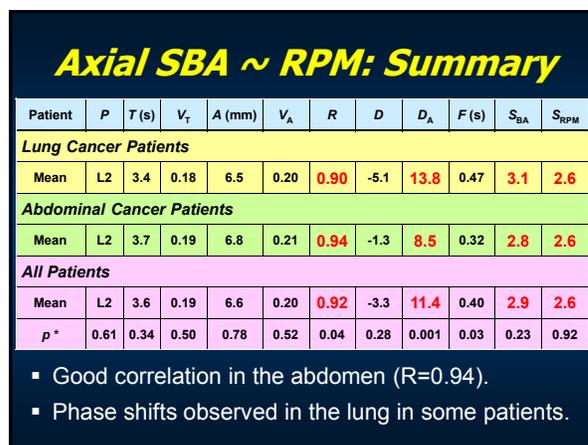
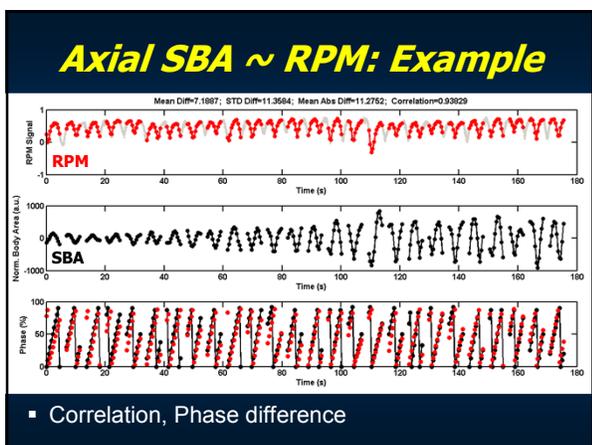
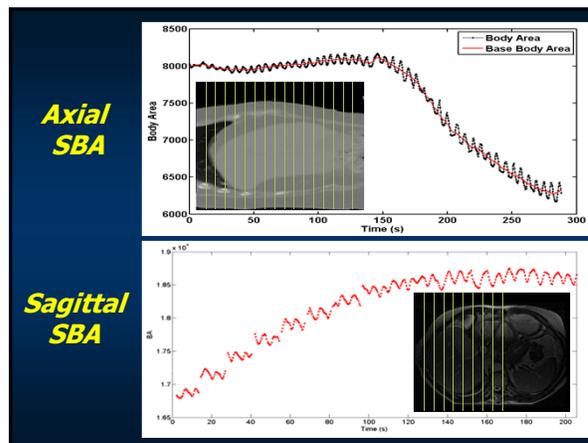
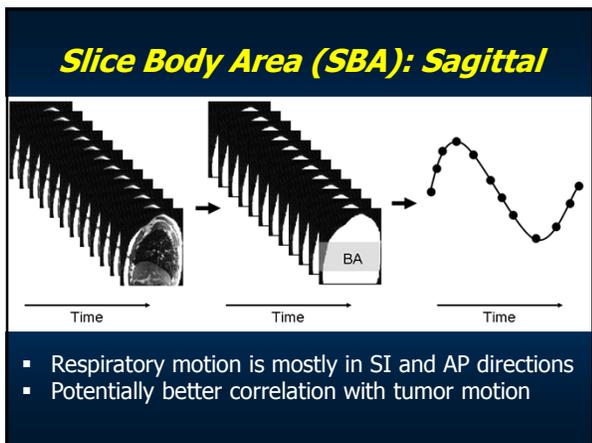
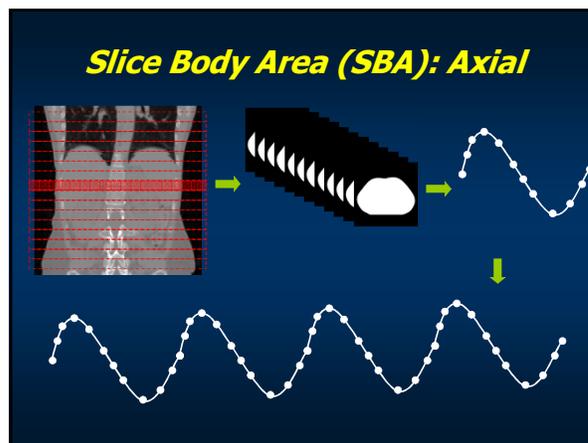
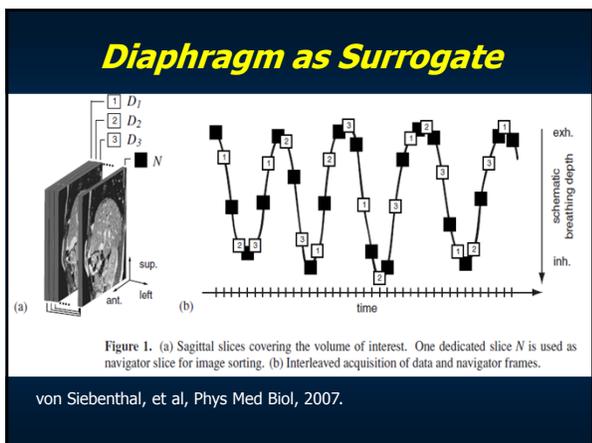
- Simplified process, lower cost, more efficient
- Potentially better correlation with tumor motion

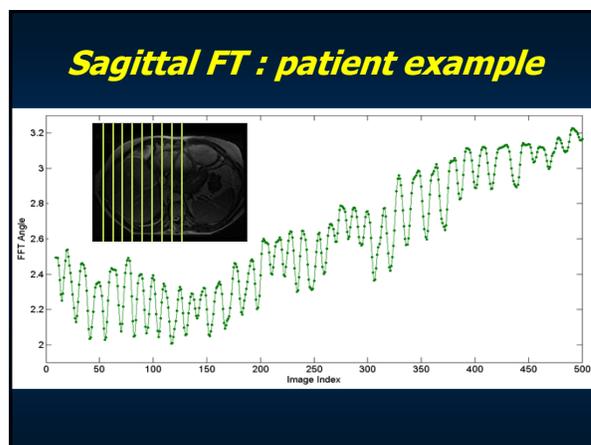
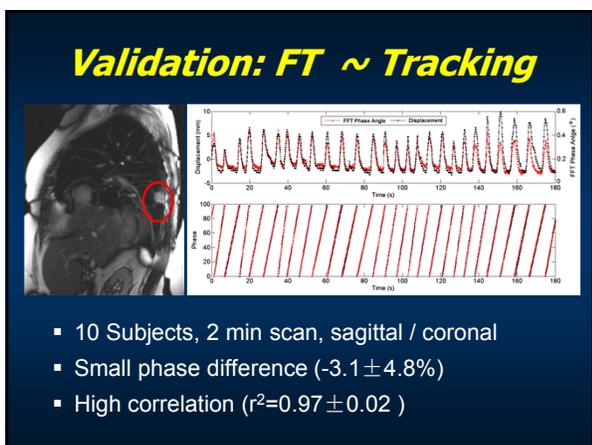
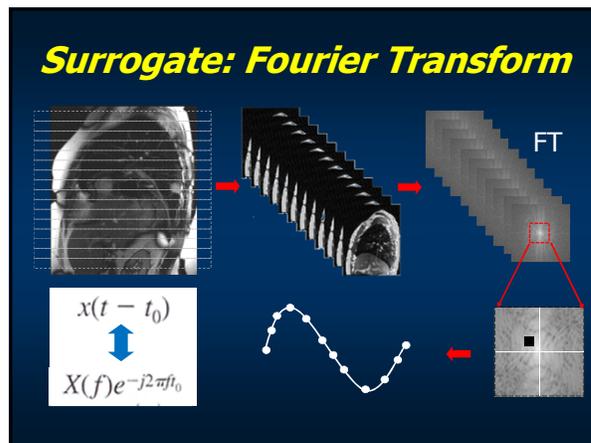
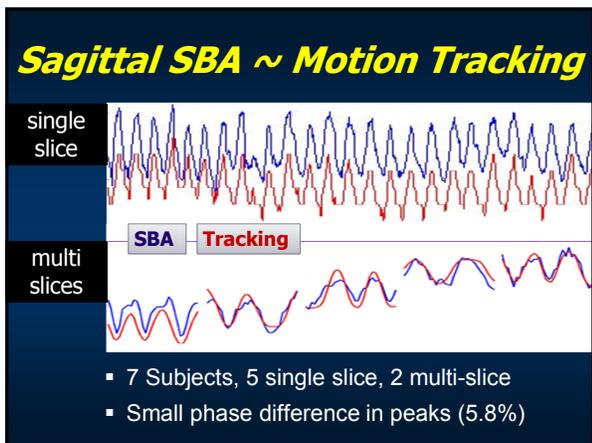
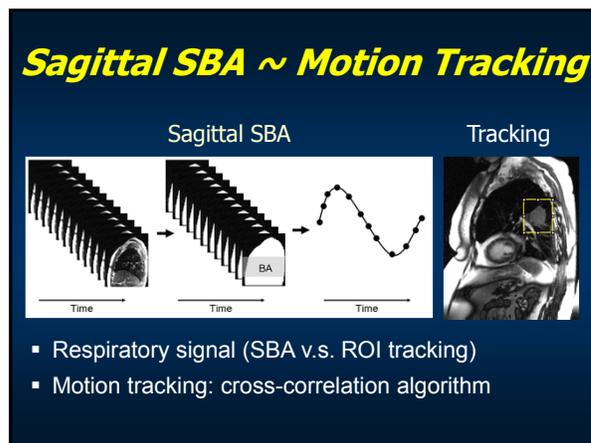
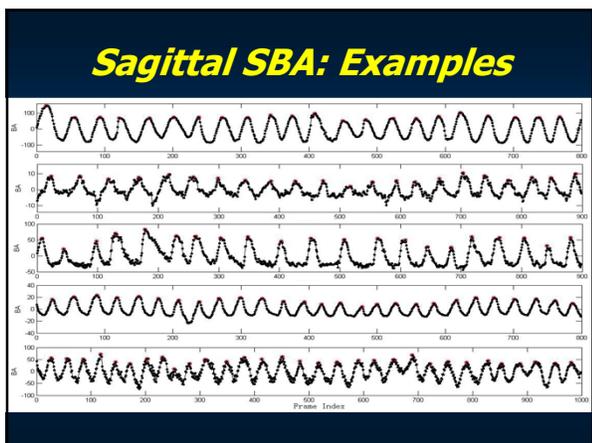
Fast MR Sequences

- ▶ **TrueFISP/FIESTA** (balanced steady state gradient echo)
 - T2*/T1, sensitive to fluid, band artifacts from long TR
- ▶ **HASTE/SSFSE** (single shot fast spin echo)
 - T2, good CNR, signal decay from lung echo train, blurring
- ▶ **FLASH/Fast SPGR** (fast spoiled gradient echo)
 - T1 (poor), tumor hypo-intensity
- ▶ **EPI** (echo-planner imaging)
 - GE-EPI (T2*), SE-EPI (T2), IR-EPI (T1)
 - susceptibility, ghosting, chemical shift, fat suppression

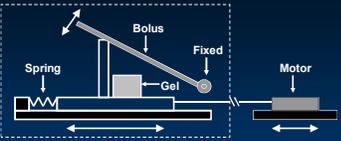
Fast MRI: Examples





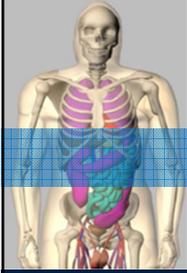


Phantom Validation



	Axial	Coronal	Sagittal
Axial SBA			
Sagittal FT			

4D Digital Human Phantom





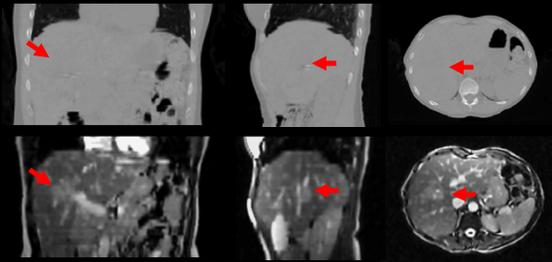






Segars, et al. Med Phys, 2008

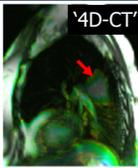
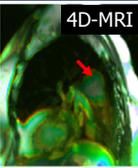
4D-MRI: Patient Example



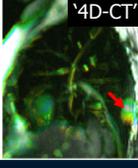
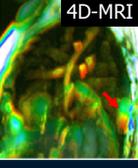
- Tumor CNR: 20.1 in 4D-MRI, 2.5 in 4D-CT.

4D-MRI for lung?

Patient 1

Patient 2

Average Intensity Projection

Summary

- 4D-MRI using internal surrogates is feasible.
- Slice body area and Fourier Transform are potential robust internal respiratory surrogates.
- Validation is essential for using internal respiratory surrogate.

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