Cardiac MRI: 3.0T

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3 Tesla: Advantages

![SNR x 2 graph with field strength]

Field Strength
3 Tesla: Disadvantages

Cardiac MRI at 3.0T

- Why?
  - Needs to compete favorably with cardiac MRI at 1.5T

Tim Trio          Tim Avanto

45 mT/SR200 50 cm

Tim Trio          Tim Avanto

45 mT/SR200 50 cm
Cardiac Cine MRI at 1.5T
*Breath-hold Segmented SSFP Cine


Segmented TrueFISP Cine: **1.5T**

General Trends at 3.0T vs 1.5T
Increased SAR

- Limits flip angles and minimum TR for high-performance sequences
  - SSFP cine
  - Spin echo train imaging
  - CEMRA

Increased SNR

- Potential benefits for techniques which have borderline SNR
  - Perfusion imaging
  - Viability imaging with delayed enhancement
  - Coronary imaging

B1 Inhomogeneity

- Shading in some regions
- Inhomogeneous contrast in some regions
- May make calibration of RF transmitter voltages difficult – varying flip angles within body regions
B1-Inhomogeneity

Increased sensitivity to flow-induced noise on ECG trace can make gating more problematic

Magneto-hydrodynamic effect

- Increased sensitivity to flow-induced noise on ECG trace can make gating more problematic

Cine MRI at 3.0T vs 1.5T

- SSFP now the standard at 1.5T
- TrueFISP
- FIESTA
- Balanced FFE

- At 3.0T, SSFP cine is challenging
Cine MRI at 3.0T vs 1.5T

- Ideal conditions for TrueFISP cine
  - TR as short as possible
  - Flip angle high and uniform
  - Very homogeneous magnetic field

- At 3.0T, all of these conditions are violated due to a combination of SAR, patient-induced susceptibility gradients and dielectric resonance effects.

3T Functional Cardiac Imaging

SSFP cine: off-resonance artifact

SAR-Limitations:
Effects on TrueFISP cine

$\alpha = 50$ deg

$\alpha = 30$ deg

$\Rightarrow$ lower CNR
**Dark-blood Imaging @ 3T: long “TR”**

- db-HASTE
- db - TSE

**Cardiac Function @ 3T**

- TrueFISP, 40°
- FLASH, 20°

• Use longer RF pulses than at 1.5T
• Flip angle around 30° - 40° (less signal and contrast)

**Cardiac TrueFISP imaging at 3T**

- 8-channel cardiac array coil
- with PAT of TA 6 sec
Parallel Imaging @ 3T

- without iPAT: 15 sec
- with iPAT x2: 8 sec

Temporal resolution = 25 ms
Matrix: 256x256
TrueFISP short axis

Cardiac Function @ 3T

- Cine TrueFISP
- iPAT x2
- 4 slices in 12 sec
- 3.5 x 2.8 x 8 mm
- Temporal resolution = 25 ms

Tagging

Longer T1 @ 3T keeps tags visible longer
**Functional MRI @ 3T (LVH)**

- TrueFISP cine
- Grid tagging

**But: With TrueFISP Cardiac Tagging at 1.5T**

- Better persistence of tags than with SGRE
- 1.0mm x 1.5mm x 6 mm voxels
- 30 msec temporal resolution
- 7 second acquisition

**Cardiac Function @ 3T**

- Cine TrueFISP
courtesy of Dr. Miller, University of Tuebingen
Cardiac Function @ 3T

Cine TrueFISP
courtesy of Dr. Miller, University of Tuebingen

Current status of Cine MRI at 3.0T vs 1.5T

- SSFP cine at 3.0T is more sensitive to off-resonance effects than at 1.5T
- Can be ‘managed’ by attention to shim status and by adjusting frequency offsets on a slice-orientation basis
- In an individual case, may work; or may not

Contrast Enhancement in Infarction

Ex-vivo comparison of TTC and Gd-enhanced MRI in infarcted myocardium
courtesy of Dr. R. Judd, Northwestern University, Chicago
Evaluation of Viability and Myocardial Perfusion with IV contrast

Note: Gd is not FDA approved for cardiac imaging

Left Circumflex distribution infarction: 1.5T

Segmented TrueFISP: Cine and Viability @ 1.5T
Non-Ischemic Cardiomyopathy

IR TrueFISP: 64 lines / heart beat
Viability @ 3T

IR single shot TrueFISP

Courtesy of Dr Regenfuss, University of Erlangen

Viability & Function @ 3T

Cine TrueFISP
IR single shot TrueFISP

Viability & Function @ 3T

Cine TrueFISP
IR TurboFLASH

courtesy of Dr. Miller, University of Tuebingen
Perfusion @ 3T
SR single shot
Turboflash
First pass
iPAT x2
4 slices/heartbeat

First-Pass Imaging at 3.0T
TurboFLASH + iPAT
Optimized Saturation Recovery Pulse for
Reduced B1 Sensitivity

Adenocarcinoma RVOT: 3.0T

ISMRM 2006
Coronary MRA @ 3T

3T TrueFISP Coronary MR Angiography (breath-hold, 28 heart beats)

- 8-channel cardiac array
- Active electrode ECG triggering
- 1D PACE for motion correction
- TA: 6:27 min
- Pixelsize: 0.9 x 0.9 x 1.2 mm

Coronary MRA

Contrast-enhanced FLASH

1.5T

3.0T

Courtesy of Drs X. Bi, D. Li, Northwestern University, Chicago.
X. Bi, D. Li, Northwestern University
3T Coronary MRA: Results
Courtesy Matthias Stuber, PhD. Johns Hopkins University
3T Coronary MRA in-vivo & in humans

But: Coronary CT Angiography!

Right Heart Failure
TIM Trio: Thorax - dissection

6ml Gd, 12 measurements each 1.7 s apart
21 s breath hold: iPAT x 3

Rest (R)
Stress + Stenosis (SS)
SS - R

Myocardial BOLD Imaging at 3T

Dog with LCx stenosis

Shea, D Li. Northwestern University, Chicago, Illinois.
Promising results for cardiac MR @ 3T.

Limitations for SSFP cine

The increased SNR is advantageous for viability imaging, dynamic angiography and perfusion imaging.

Areas to be addressed
- protocols and sequence design with reduced SAR, reduced B1 sensitivity
- Contrast agents?

3T Functional Cardiac Imaging

Gadomer, pig study. Schering AG, Inc.
Thank you