Investigating the use of Ultra High-Field MRI as a Theranostic Thermal Therapy Platform

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Brain Mets: Motivation and Challenges

• Most common type of brain tumors
  • ~200,000 cases per year (USA)
  • > all intracranial tumors
  • Primary cancers: Lung, Breast, Melanoma

• Treatment options
  • Surgical resection
  • Whole-brain radiation therapy (WBRT)
  • Corticosteroids
  • Stereotactic Radiosurgery (SRS)

• Median overall survival:
  • Untreated: 1 month
  • With treatment: 3-11 months
One Solution: MR Guided Focused Ultrasound (FUS)
FUS Through Skull Flap

No Correction

After Phase Correction

Courtesy of Scott Almquist – Univ. Of Utah
Multiple Brain Metastases

Fink, SNI, 2013
Ultra High-Field MRI

- MRI w Gd leads in BM detection
- 66-75% of patients who present with a single lesion on CT actually have multiple lesions
- Higher Field = More Signal
- Increase: Resolution, speed, etc

Fink et al, SNI, 2013
Ultra High-Field MRI: Challenges

SPGR
TR=4000ms
FA = 30°

Local SAR MIP (W/kg)

FA error (%)

Sagittal  Coronal  Axial

BIRDCAGE MODE

Courtesy of: Mehir Pendse, ISMRM 2015 #573
Ultra High-Field MRI: Challenges

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TR=4000ms
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BIRDCAGE MODE

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Local SAR MIP (W/kg)

SAGITTAL
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AXIAL

SAGITTAL
CORONAL
AXIAL

SAR UNAWARE

Grissom, MRM 2012;68:1553–1562

Courtesy of: Mehir Pendse, ISMRM 2015 #573
Ultra High-Field MRI: Challenges

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BIRDCAGE MODE

SAR UNAWARE¹

IMPULSE

FA error (%)

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Ultra High-Field MRI: Challenges

**SPGR**
- TR = 4000 ms
- FA = 30°

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<td>0</td>
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**ΔT**
- 0.45°C
- 0.86°C
- 0.51°C

**BIRDCAGE MODE**

**SAR UNAWARE**

**IMPULSE**

*Grissom, MRM 2012;68:1553–1562*

Courtesy of: Mehir Pendse, ISMRM 2015 #573
Q: Can this undesired heating been turned into something positive?
Focused RF (FRF)
Hardware Configurations

#1: Dedicated RF Applicator

Magnet

Dedicated RF applicator

#2: All-In-One

Magnet

pTx Coil Used as RF Applicator & Imaging
FRF Design Study
SPEAG Sim4Life

• FDTD Electromagnetic simulations

• Virtual Family – Realistic body models

• Working with SPEAG on accelerating simulations
FRF Coil Design Study

1. Set Element Design
2. Simulate Element Tuning
3. Generate Array Coil
4. Full n-Chan EM Simulation
FRF Coil Design Study

1. Set Element Design
2. Simulate Element Tuning
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4. Full n-Chan EM Simulation
ElemeD Design

- Can vary multiple parameters:
  - Width
  - Height
  - Conductor width
  - Radius of corner curvature
  - Cuts on horizontal rungs
  - Cuts on vertical rungs
  - Cut width
FRF Coil Design Study

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Element Tuning Simulation
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Sherlock Computing Cluster

- Sherlock – 48 GPUs
  - 2 * 8x Tesla 20X
  - 3 * 8x Titan Black
  - 1 * 8x K80

- Collaborating with SPEAG S4L

- Granted us a special multi-GPU license
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FRF Coil Design Study

1. Set Element Design
2. Simulate Element Tuning
3. Generate Array Coil
4. Full n-Chan EM Simulation
5. Targeting with Max-SAR
6. Simulate Temperature Rise
Complex Channel Weightings

SAR Maximum Intensity Projections

Target 1

Target 2

Target 3

Complex Channel Weightings
Potential

• FRF has all the positives of MRgFUS
  • Non-invasive, monitoring, free of ionizing radiation, etc.

• Hyperthermia
  • Can improve outcomes of radiation and chemotherapy
  • Treat multiple metastases

• Ablation - Direct cell death
  • May not be possible

• BBB Opening
Conclusion & Next Steps

• Design study of FRF coils using S4L
  • Realistic body models
  • Built automated tools for generating arrays

• Simulations working on Sherlock GPU Cluster
  • Design study would be very difficult otherwise
  • Has application to real-time Min-SAR pTx pulses

• Experimentally verify simulations in simple phantom
Acknowledgements

• Stanford SCIT (NCI)
  – Prof. Brian Rutt
  – Dr. Riccardo Stara
  – Mihir Pendse
  – Scott Almquist

– SPEAG sim4life
THANK YOU!