Engaging MR and RT physicists in implementation, operation, and optimization of pediatric MR simulation

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Disclosure

- I have no relevant financial relationships to disclose.
- Our current MRI simulators are from Philips Healthcare, but I intended to make the presentation vendor-neutral as much as possible.

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Learning objective

Learn how to synergize team efforts in implementing, operating, and optimizing MR simulation for children and adolescents.

After this presentation, you can tell:

- Differences between MR simulation and diagnostic MRI
- Unique needs in pediatric MR simulation
- Limitations of current techniques and potential solutions
- How RT physicists may engage MR physicists

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Outline

- Background
  - Radiation Oncology at St Jude
  - Significance of MR simulator in pediatric RT
- Implementation
  - Site planning, selection of MR system
  - Acceptance test, establishing periodic QA
  - Staff training
- Operation
  - MR safety
  - Patient setup
  - Motion management
- Optimization
  - Ongoing unmet needs
  - Recent developments

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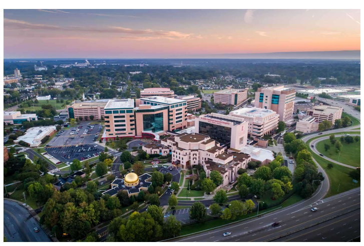
St. Jude Children's Research Hospital, Memphis, TN



- NCI-designated comprehensive cancer center devoted to children
- 5,000 employees
- 8,600 pediatric patients annually
- Brain tumor, leukemia, lymphoma, solid tumors, sickle cell disease, infectious diseases

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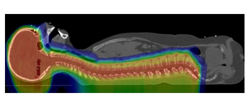
Radiation Oncology at St Jude

- 3-room scanning beam proton therapy since 2015
- Photon therapy linear accelerator
- MRI (1.5T and 3T), spectral CT, PET/CT, CBCT



- Patient age: 3 months – 30s
- 1/3 patients requires anesthesia (typically < 8 years old)
- Cranial, abdominal, and pelvic tumors are most common
- Multiple treatment phases with boost planning and on-treatment imaging

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Dedicated MRI simulators 2004 – present

2004-2012
Philips 0.23T Panorama

Open MRI
Resistive magnet

2012-2016
Scimedix 1.5T SM160

60-cm closed bore
Flat tabletop with coil elements

2016-present
Philips 3T and 1.5T Ingenia MR-RT

70-cm wide bore

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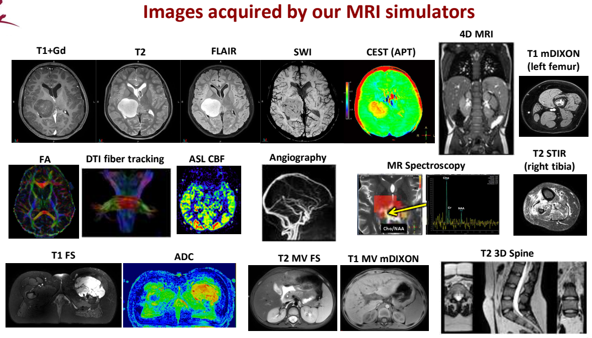
Images acquired by our MRI simulators



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On-treatment MRI for adaptive RT

Clinical Investigation

Adaptive Proton Therapy for Pediatric Patients: Improving the Quality of the Delivered Plan With On-Treatment MRI

Sahaja Acharya, MD, Chuang Wang, PhD, Sophia Quesada, BS, Melissa A. Gargone, MHS, Ozgur Ates, PhD, Jinsoo Uh, PhD, Matthew J. Krasin, MD, Thomas E. Merchant, DO, PhD, and Chia-ho Hua, PhD

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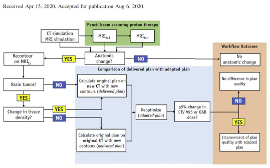
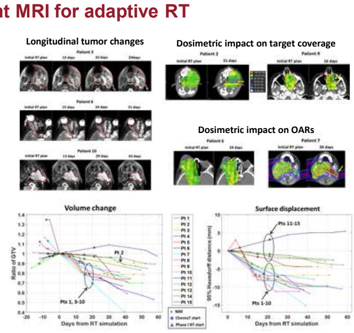
Received Apr 15, 2020. Accepted for publication Aug 6, 2020.



Acharya et al., *Int J Radiat Oncol Biol Phys*, 109:242, 2021



Uh et al. PTCOG 2022

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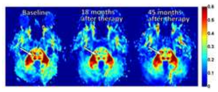
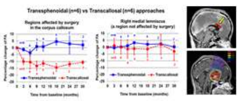
On-treatment/post-treatment diffusion-weighted MRI

Response of brainstem fiber tract to proton therapy



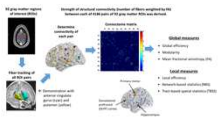
Uh et al., *Int J Radiat Oncol Biol Phys*, 86:292, 2013

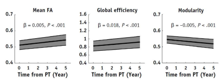
Effects of surgery and proton therapy on white matter



Uh et al., *Int J Radiat Oncol Biol Phys*, 93:64, 2015

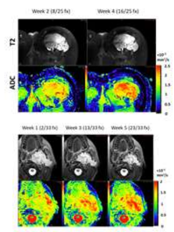
Longitudinal trends in DTI indices and structural connectome features





Uh et al., ASTRO, 2019
Uh et al., *Int J Radiat Oncol Biol Phys*, 109:515, 2021

On-treatment ADC changes in sarcoma



Unpublished data

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Differences between MRI for diagnostic imaging and RT simulation applications

	Diagnostic Imaging (DI)	RT simulation
Purpose	Detection, characterization, and staging of disease	Determination of the 3D disease extent and position relative to adjacent organs at risk
Field-of-view	Volume of interest	Need to cover OAR, landmarks, and body surface as well as target
Slice thickness and spacing	4-5 mm with 0-2mm gaps	Thin slice (<3 mm) or isotropic (1 cu mm) without gap
Geometric distortion	Tolerated as long as diagnostic capability not affected	< 2 mm in all planes
Bandwidth	Tradeoff between fat/water shift and SNR	Intentionally set high
Receiver coil	Dedicated coil	Flexible coil
Patient posture	Accommodate patients' comfort	Treatment planning position
Patient table	Curved	Flat

Partly adopted from Paulson et al. *Med Phys*, 42:28, 2015

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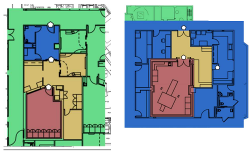
Site planning

Safety zones of St Jude MR simulators

- Zone I: General access
- Zone II: Screening/prep
- Zone III: Control area
- Zone IV: MR scanner room



- ACR-defined safety zones
- Survey fringe field; mark 5 Gauss line
- RF shielding and waveguide
- Considerations for pediatric MR sim site
  - Facility and staffing for anesthesia and child life support
  - Traffic to/from other imaging and treatment rooms
  - Screening and preparation spaces
  - Parents waiting area
- AAPM Report No. 100, TG 284 report

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Selection of static magnetic field (B0)

7T

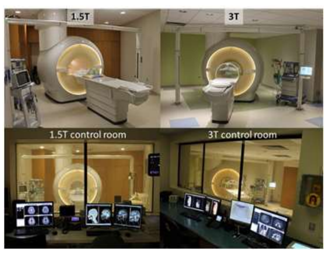
3T

1.5T

1T

0.35T

- Higher B0
  - advantageous in high-end imaging
  - Higher signal/contrast to noise
  - Higher spatial resolution
  - Fast imaging
  - Physiological imaging (diffusion, perfusion)
  - MR spectroscopic imaging (MRSI, CEST)
- Lower B0
  - advantageous in operation/safety and artifact suppression
  - Wide/open bore
  - Lower SAR/PNS
  - Higher B0 homogeneity, lower magnetic susceptibility → less distortion
  - Lower cost
  - MR-Linac



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Selection of equipment

- External laser system
- Flat tabletop
- Receiver RF coils for various body sizes
- MR-safe immobilization devices (thermoplastic mask, vacuum bag, head cushion, mounting board)
- Coil support
- Anesthesia equipment
- Safety equipment (metal detector, ear plug, headset)
- QA phantoms

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Acceptance tests and baseline QA

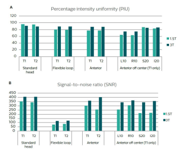
- Selected tests and criteria were based on
  - ACR MRI quality control manual
  - AAPM TG report No. 100
  - Vendor technical specifications
  - Site-specific requirements
- RT-specific tests
  - Geometric fidelity (over 45-cm DSV)
  - Table positioning accuracy
  - External laser system accuracy
  - Image quality tests with RT coil configurations

How do you commission and implement an MRI system for radiation therapy planning?

Experience from St. Jude Children's Research Hospital, Memphis, Tennessee, USA

https://philipsproductcontent.blob.core.windows.net/assets/20191119/a6fa1f759b434b83b68cab0a00f1905c.pdf

Image quality comparison between receiver coil/phantom configurations



List of acceptance tests

Test Name	Institution-Defined Performance Criteria and Source (AAPM/ACR/Philips)
B0 magnetic field homogeneity	Inhomogeneity ≤0.45 ppm rms for 40-cm DSV, ≤0.08 ppm rms for 30-cm DSV, ≤0.022 ppm rms for 20-cm DSV (Philips)
Magnetic field drift	Drift ≤1 ppm/day (AAPM)
Transmitter gain calibration	Maximum signal intensity is demonstrated with 90° spin nutation (AAPM)
Geometric accuracy	Typical inaccuracy ≤1 mm for 32-cm DSV (Philips)
High-contrast spatial resolution	1-mm hole size should be resolved (ACR)
Slice thickness accuracy	Thickness deviation should be <0.7 mm (ACR)
Slice position accuracy	Position offset < 4 mm (ACR)
Image intensity uniformity	Percent integral uniformity ≥87.5% for 1.5T and ≥82% for 3.0T (ACR)
Percent signal ghosting	Ghosting ≤1% (AAPM)
Low-contrast object detectability	≥9 spokes detectable for 1.5T and ≥37 spokes for 3.0T (ACR)
Signal-to-noise ratio (SNR)	Vendor internal criteria (Philips)
EPI ghosting	Coefficient of variation of the signal intensity <0.25% and ghosting ratio ≤3% (AAPM)
Spectral quality of spectroscopy	Percent difference between two runs in area ratio and amplitude ratio of NAA/Cr and NAA/Cho <15%
Spike noise	Track down source of spike noise if detected per AAPM report 100
Eddy current compensation	Vendor internal criteria
Table position accuracy	Longitudinal travel deviation (forward and backward) ≤0.5 mm (Philips)

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Imaging protocols specific to anatomic site and patient size

Departmental Site-Specific Imaging Protocols

Site	Receiver Coil* Large FOV	Receiver Coil* Small FOV	Typical FOV (mm³) Large FOV	Typical FOV (mm³) Small FOV	Protocol†	Typical Intrinsic Resolution‡ (mm³) Large FOV	Typical Intrinsic Resolution‡ (mm³) Small FOV	Typical Band Width (Hz/pixel)	Typical Scan Time (min)	Typical TR/TE (ms)	Typical Flip Angle (degrees)
Brain w/ immobilization devices	Flex L	Flex M	250 × 200 × 200	220 × 180 × 180	3D T2 TSE	1.0 × 1.0 × 2.0	0.9 × 0.9 × 1.8	936	5.2	2500/229	90
					3D T1 TFE			455	6.3	8.0/3.5	8
					3D T2 FLAIR w/SPIR	1.2 × 1.2 × 2.0	1.2 × 1.2 × 2.0	1092	6.4	4800/316	40
Brain w/o immobilization devices	Standard head or 32-channel head		250 × 200 × 200		3D T2 TSE	0.8 × 0.8 × 1.7		797	5.5	2500/259	90
					3D T1 TFE	0.9 × 0.9 × 1.8		456	3.9	8.0/3.5	8
					3D T2 FLAIR w/ SPIR	1.0 × 1.0 × 2.0		936	5.4	4800/354	90
					3D TOF MRA	0.4 × 0.6 × 1.2		108	5.1	23/3.5	18
					2D TSE DWI w/ SPIR	2.0 × 2.0 × 4.0		704	4.9	14783/71	90
					2D EPI DTI w/ SPIR	2.4 × 2.5 × 2.5		32	6	2854/84	90
					2D PCASL w/ SPIR	2.7 × 2.7 × 5.0		41	4.3	4120/16	90
					3D SWI	0.6 × 0.6 × 2.0		255	4.5	31/7.2	17
Head and neck	Head-neck or anterior		260 × 330 × 330		3D T2 TSE	1.1 × 1.1 × 2.2		841	6	2000/213	40
					3D T1 TFE			457	5.6	6.6/3.2	8
					3D T1 FFE w/ SPAIR	1.2 × 1.2 × 2.4		721	5.2	3.7/1.87	10
					2D T2 w/ mDIXON	1.2 × 1.2 × 4.0		461	5.3	2814/100	90
Cervical spine	Flex L	Flex M	250 × 320 × 250	200 × 250 × 200	3D T2 TSE	1.1 × 1.1 × 2.2	1.0 × 1.0 × 2.0	1034	5.7	2500/227	90
					3D T1 TFE			455	6.4	8.0/3.5	8
Thoracic/ lumbar spine	Anterior		250 × 380 × 380	200 × 285 × 285	3D T2 TSE	1.1 × 1.1 × 2.2	1.0 × 1.0 × 2.0	870	6.6	2200/200	90
					3D T1 TFE			455	5.6	7.6/4.2	8
Pelvis	Anterior		280 × 440 × 280	250 × 310 × 250	3D T2 TSE w/ or w/o SPAIR or mDIXON	1.3 × 1.3 × 2.6	1.2 × 1.2 × 2.4	804	5.5	2200/250	90
					3D T1 FFE w/ or w/o SPAIR or mDIXON			457	5	7.5/4.2	8
			280 × 440 × 250	250 × 310 × 200	2D DWI w/ SPIR	3.0 × 3.0 × 5.0	3.0 × 3.0 × 4.0	38	3.4	4906/71	90
Abdomen	Anterior		310 × 390 × 280	200 × 300 × 270	3D T2 TSE NAV	1.3 × 1.3 × 2.6	1.1 × 1.1 × 2.2	792	6.1	2200/250	90
					3D T1 TFE NAV			481	5.8	10/4.6	25
					2D T2 TSE NAV w/ or w/o SPAIR	1.5 × 1.7 × 4.0	1.3 × 1.6 × 4.0	490	2.3	1000/80	90
			340 × 340 × 240	300 × 300 × 200	2D T2 MV SPIR w/ or w/o RespTrig	1.4 × 1.4 × 4.0	1.4 × 1.4 × 4.0	1272	5.0	2725/78	90
			310 × 390 × 200	200 × 300 × 190	2D DWI SPIR w/ NAV or RespTrig	2.7 × 2.7 × 5.0	2.7 × 2.7 × 4.0	32	6.3	2657/77	90
			350 × 350 × 200	300 × 300 × 160	4D MRI (slice-wise dynamic 2D bFFE)	1.8×1.8×4.0	1.8 × 1.8 × 4.0	1012	19.2	3.2/1.6	70
Extremity	Flex S/M/L or anterior		300 × 300 × 350	250 × 250 × 250	3D T2 TSE w/ or w/o SPAIR	1.3 × 1.3 × 2.6	1.1 × 1.1 × 2.2	700	5.8	2000/250	90
					3D T1 TFE			454	5.6	22/2.4	30
					2D T2 w/ or w/o SPAIR	1.0 × 1.0 × 5.0	1.0 × 1.0 × 5.0	296	4.3	8082/65	90
					2D T1 mDIXON			382	4.4	657/20	90

Hua, Uh, et al., *J Med Imaging Radiat Sci*, 49:153, 2018

- Reduce parallel imaging factor (SENSE, GRAPPA) with RT coil configurations.
- Increase band width to reduce distortion.

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- Reduce parallel imaging factor (SENSE, GRAPPA) with RT coil configurations.
- Increase band width to reduce distortion.
- Consider variations in body size, patient posture, target location, and field-of-view.
  - Compensate reduced SNR for a small FOV and a high resolution
  - Concatenate multiple image components acquired at different table positions.
- Incorporate motion suppression techniques (radial acquisition, triggering/gating)

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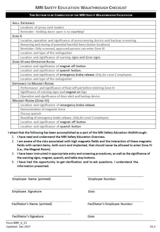
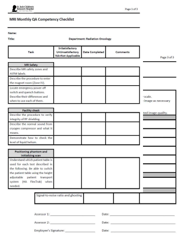
Staff training

- Vendor-provided on-site training for imaging therapists
  - Operation of MR-RT system
  - Patient screening
  - General MR simulation workflow
  - Review of anatomic site-specific workflow:
    - ✓ Patient setup
    - ✓ Use of appropriate receiver coils
    - ✓ Imaging parameters
  - Daily QA and troubleshooting
- Safety walkthrough for Level 1 and Level 2 MR personnel
- Training physicists and physicist assistants for QA procedure

MRI safety walkthrough checklist



MR QA competency checklist



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MRI hardware and safety

- Magnet
  → Safety zone, material labeling, cryogen
- Transmit RF coil
  → Specific absorption rate (SAR)
- Gradient coil
  → Peripheral nerve stimulation (PNS), acoustic noise

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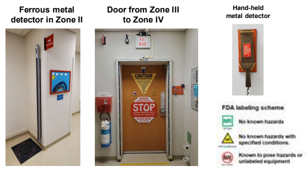
Safety considerations for pediatric MR simulation

- Crossing safety zones
  - Doors should be kept closed until the patient is ready.
  - Careful screening with multiple types of metal detectors.
- Patients with implants
  - Restrict SAR/PNS according to manufacturer specifications.
- Secure fitting of earplug and headset



International Electrotechnical Commission (IEC) 60601-2-23 standard

Operating mode	Explanation	Safety measures	SAR limits	Gradient output
Level 0 (Normal)	No physiological stress factors are expected.	• Routine patient observation	• Whole body < 2 W/kg • Head < 3.2 W/kg	≤ 80% of the mean threshold level
Level I (First level controlled)	MRI scanning may cause physiological stress.	• Patient monitoring with medical expertise • Particular caution for patient at risk	• Whole body ≥ 2 W/kg and < 4 W/kg • Head < 3.2 W/kg	> 80% and ≤ 100% of the mean threshold level
Level II (Second level controlled)	This operating mode is not accessible.	The system is limited to reach Level II.	• Whole body ≥ 4 W/kg • Head ≥ 3.2 W/kg	> 100% of the mean threshold level

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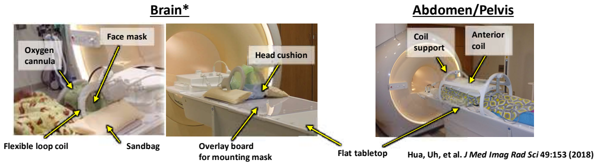
Patient setup and coil configurations



Hua, Uh, et al. *J Med Imag Rad Sci* 49:153 (2018)

* Dedicated head coils (15 or 32 channels) are optionally used for on-treatment imaging when registration to CT is of less concern.

Extremities

- Various combinations of anterior and loop coils depending on anatomy, FOV, and immobilization devices

Head & neck

- Loop coil with anterior coil

Spine

- Cervical: loop coil
- Thoracic, lumbar: posterior coil (imbedded in patient table)
- Anterior coil is mostly added to boost signal

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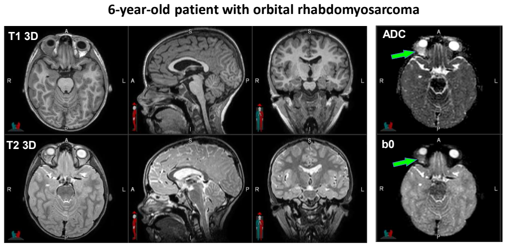
Cranial images with RT coil configuration*

6-year-old patient with orbital rhabdomyosarcoma



Resolution: 1 x 1 x 2 mm³

Resolution: 2 x 2 x 3.5 mm³

*EPI-based fast imaging (DTI, fMRI, ASL, DSC) and spectroscopic imaging (MRS, CEST) are not feasible with the RT coil configuration.

Unpublished data

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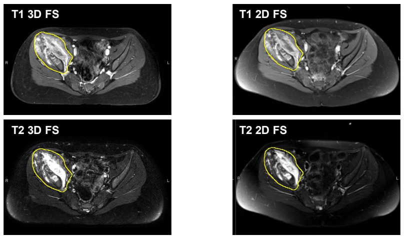
Pelvic images with RT coil configuration

12-year-old patient with Ewing's sarcoma

RT simulation on flat tabletop | **Diagnostic imaging on curved tabletop**



Unpublished data

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Motion management (voluntary) without anesthesia

- **Immobilization devices (thermoplastic mask, head cushion, vacuum bag)**
- **Familiarize patients with MRI scan environments: mock scanner, MR sound clip, decorating thermo mask**
- **Instruction via microphone between scans**
- **Measures to relieve stress: music, video, audiobook, stress ball, weighted blanket**
- **Child life support**

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Motion management (involuntary)

- **Managed motion**
  - Respiratory
  - Cardiac
- **Type of acquisition control**
  - Triggering
  - Gating
- **Surrogate signal**
  - External
    - Bellows pressure sensor
    - Video-based tracking (e.g., RPM)
    - Spirometry
    - EKG, pulse oximeter
  - Internal
    - Navigator RF pulse
    - Self-navigator:
      - Central spoke of radial k-lines
      - Principal component analysis
      - Mutual information
- **Imaging technique**
  - Radial imaging
    - PROPELLER/BLADE/MultiVane
  - Fast imaging
    - TSE/EPI, parallel imaging, partial Fourier
    - Compressed sensing
    - Simultaneous multi-slice excitation

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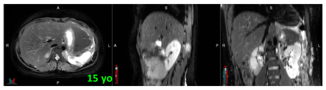
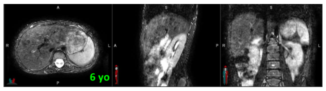
Radial imaging for motion suppression

T2 2D FS radial imaging without triggering/gating*



T2 3D FS without any motion suppression



*Can be combined with triggering/gating for further improvement.

Unpublished data

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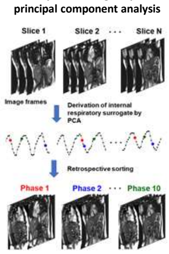
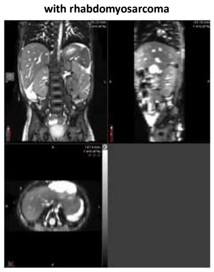
Respiratory-correlated 4D MRI

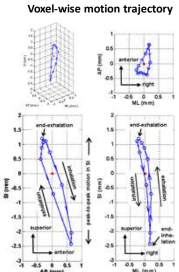
Retrospective sorting of slice-wise dynamic images by principal component analysis



4-year-old patient with rhabdomyosarcoma



Voxel-wise motion trajectory



Uh et al., *Phys Med Biol*, 61:7812, 2016; Uh et al., *Int J Radiat Oncol Biol Phys*, 99:227, 2017

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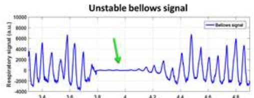
Challenges in pediatric 4D MRI

- **Irregular and asymmetric motion**
- **Variations in breathing rate and extent of motion**
- **Anesthesia effect**
- **Unstable external surrogate signal because of loose bellows belt or shallow breathing**

Unstable bellows signal



Uh et al., AAPM, 2019

Peak-to-peak organ motion in pediatric patients

Patient number	Age (years)	Respiration rate (breath/min)	Liver COM	Spleen COM	L Kidney COM	R Kidney COM
1	1	47.3	1.1	1.8	1.2	1.2
2	2	49.0	0.8	0.6	0.6	1.2
3	2	9.2	6.6	5.5	0.8	2.7
4	2	36.8	3.4	1.5	1.3	2.6
5	3	20.7	2.5	3.6	1.9	1.5
6	3	25.1	1.6	3.0	1.9	1.3
7	3	20.7	2.7	1.8	0.9	1.9
8	4	34.4	1.7	2.5	0.9	1.3
9	4	25.0	1.7	3.6	2.8	1.5
10	4	21.5	6.2	2.0	1.9	3.8
11	5	29.1	3.6	1.2	1.0	3.4
12	5	34.5	2.2	2.2	1.4	2.2
13	5	27.3	2.1	1.7	1.1	1.9
14	5	17.0	0.9	4.2	1.6	-
15	6	18.1	4.9	3.9	2.5	2.5
16	6	15.0	7.7	10.8	4.5	4.0
17	7	24.4	4.1	1.8	1.0	3.3
18	9	29.5	6.8	6.2	4.5	3.2
19	11	19.2	8.9	5.3	3.5	4.3
20	11	21.5	10.2	11.2	8.2	7.7
21	12	28.0	1.8	1.6	0.9	1.3
22	12	19.6	7.7	7.2	4.4	3.6
23	12	21.3	7.5	9.2	4.7	6.0
24	13	23.3	3.8	6.1	2.8	2.7
25	15	31.6	5.1	1.5	1.6	3.6
26	15	24.9	2.9	3.4	2.8	2.6
27	15	20.1	7.8	19.5	13.0	6.2
28	15	17.8	5.5	9.4	7.8	-
29	17	22.5	5.8	9.1	5.3	7.3
30	17	17.7	6.5	5.1	-	-
31	18	19.3	9.6	6.4	5.7	9.1
32	19	18.0	9.8	7.5	3.7	5.1
33	19	14.0	3.5	1.9	2.9	1.8
34	19	17.2	7.9	7.2	6.0	6.8
35	20	15.3	11.0	6.9	2.8	3.7

Uh et al., *Int J Radiat Oncol Biol Phys*, 99:227, 2017

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Outline

- Background
  - Radiation Oncology at St Jude
  - Significance of MR simulation in pediatric RT
- Implementation
  - Site planning, selection of MR system
  - Acceptance test, establishing periodic QA
  - Staff training
- Operation
  - MR safety
  - Patient setup
  - Motion management
- **Optimization**
  - **Ongoing unmet needs**
  - **Recent developments**

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Ongoing unmet needs

- Geometric fidelity with a large FOV
- Accelerated acquisition
  → beneficial for motion management, reducing anesthesia, simpler workflow
- Physiological imaging (diffusion/perfusion, spectroscopy) in a high resolution without severe distortion and motion artifacts
- Metallic artifact reduction
- MR-only simulation

with RT coil configurations! (applies to: Accelerated acquisition; Physiological imaging; Metallic artifact reduction)

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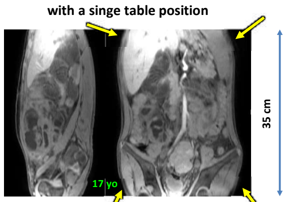
Moving table MRI – stitching image volumes at different table positions

T1 3D radial imaging

with a singe table position



Distortion and nonuniformity

with two different table positions

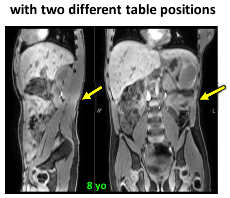


Image discontinuity at the junction of 2 volumes

Unpublished data

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Fast imaging to reduce scan time

2306 IEEE TRANSACTIONS ON MEDICAL IMAGING, VOL. 40, NO. 9, SEPTEMBER 2021

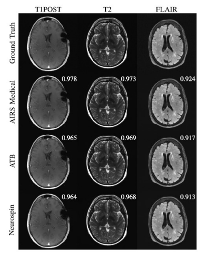
Results of the 2020 fastMRI Challenge for Machine Learning MR Image Reconstruction

Matthew J. Muckley, *Member, IEEE*, Bruno Riemenschneider, Alireza Radmanesh, Sunwoo Kim, *Member, IEEE*, Geunu Jeong, Jingyu Ko, Yohan Jun, Hyungseob Shin, Dosik Hwang, Mahmoud Mostapha, Simon Arberet, Dominik Nickel, Zaccharie Ramzi, *Student Member, IEEE*, Philippe Ciuciu, *Senior Member, IEEE*, Jean-Luc Starck, Jonas Teuwen, Dimitrios Karkalousos, Chaoping Zhang, Anuroop Sriram, Zhengnan Huang, Nafissa Yakubova, Yvonne W. Lui, and Florian Knoll, *Member, IEEE*

TABLE II
FINALIST MODEL PROPERTIES

Team	# Params	Init.	Coil Meth.	GPUs	Tr. Time
AIRS	200 M	GRAPPA	ESPIRiT	4 (V100)	7 days
ATB	21 M	Zero-Filled	U-Net	8 (TITAN)	10 days
MRR	16 M	Zero-Filled	ESPIRiT	1 (V100)	14 days
Nspin	155 M	Zero-Filled	U-Net	1 (V100)	7 days
Res	841 k	ESPIRiT	U-Net	4 (RTX 8000)	21 days

4-fold acceleration by deep learning models



Muckley et al., *IEEE Trans Med Imaging*, 40:2306, 2021

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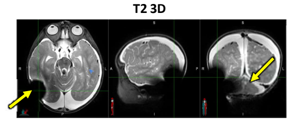
Metal artifact reduction

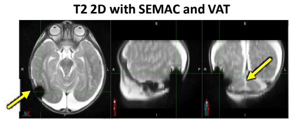
- **Adjusting imaging parameters**
  - Turbo spin echo without parallel imaging and uniformity correction
  - High BW, high resolution, thin slice, short TE, signal averaging, etc.
- **View angle tilting (VAT)**
  - An extra gradient is applied with the read-out gradient to compensate off-resonances in a tilted view.
- **Slice encoding for metal artifact correction (SEMAC)**
  - Multi-spectral sequence to acquire additional off-resonance data (z-encodings)
  - Limited to 2D spin echo
  - Longer scan time, increased SAR

2-year-old patient with ependymoma who underwent a VP shunt placement

T2 3D



T2 2D with SEMAC and VAT



Unpublished data

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Alternative posterior receiver coil designs

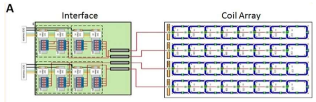
Flat tabletop with imbedded coil elements

Unpublished data

Technical Note: A custom-designed flexible MR coil array for spine radiotherapy treatment planning

Neelam Tyagi[a)#]
Department of Medical Physics, Memorial Sloan-Kettering Cancer Center, New York, NY 10065, USA

A



B

Tyagi et al., *Med Phys*, 47:3143, 2020

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Head and neck receiver coils for RT simulation

Physics in Medicine & Biology

NOTE

Characterization and evaluation of a flexible MRI receive coil array for radiation therapy MR treatment planning using highly decoupled RF circuits

McGee et al., *Phys Med Biol*, 63:08NT02, 2018

Physics in Medicine & Biology

PAPER

A mask-compatible, radiolucent, 8-channel head and neck receive array for MRI-guided radiotherapy treatments and pre-treatment simulation

Zijlema et al., *Phys Med Biol*, 67:135006, 2022

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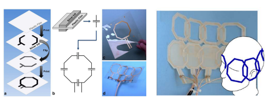
Screen-printed flexible RF coils

Full Paper

Materials and methods for higher performance screen-printed flexible MRI receive coils

Joseph R. Corea, P. Balthazar Lechene, Michael Lustig, Ana C. Arias



Corea et al., *Magn Reason Med*, 78:775, 2017

Radiology

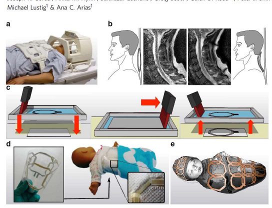
Evaluation of a Flexible 12-Channel Screen-printed Pediatric MRI Coil

Winkler et al., *Radiology*, 291:180, 2019

ARTICLE

Screen-printed flexible MRI receive coils

Joseph R. Corea[1], Anita M. Flynn[1], Balthazar Lechêne[1], Greig Scott[2], Galen D. Reed[1,3], Peter J. Shin[1,3], Michael Lustig[1] & Ana C. Arias[1]



Corea et al., *Nat Commun*, 7:10839, 2016

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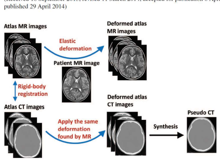
Methods of synthesizing CT from MRI refined for pediatric images

MRI-based treatment planning with pseudo CT generated through atlas registration

Jinsoo Uh and Thomas E. Merchant

Yimei Li and Xingyu Li

Chiaho Hua



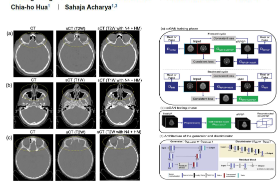
Uh et al., *Med Phys*, 41:051711, 2014

RESEARCH ARTICLE

MEDICAL PHYSICS

Toward MR-only proton therapy planning for pediatric brain tumors: Synthesis of relative proton stopping power images with multiple sequence MRI and development of an online quality assurance tool

Chuang Wang | Jinsoo Uh | Tushar Patni | Thomas Merchant | Yimei Li | Chia-ho Hua | Sahaja Acharya



Wang, Uh, et al., *Med Phys*, 49:1559, 2022

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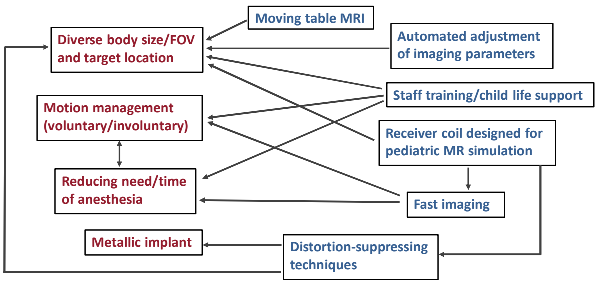
Challenges and opportunities in pediatric MR simulation



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Engaging MR and RT physicists in pediatric RT simulation

- What MR physicists should know – geometric requirements for RT sim
  - Patient in treatment position
  - A large field-of-view
  - Isotropic resolution
  - Tolerance of distortion
- What RT physicists should know – capabilities and limitations of MRI
  - Limited image coverage
  - Weak signal → deliberate use of coils
  - Trade-off between quality and time
  - Everything depends on specific sequence
- Where diagnostic MR physicists may contribute
  - Identifying most suitable imaging techniques
  - Optimizing imaging parameters
  - Training staff in operation and QA
  - Implementing new developments
- Engaging diagnostic MR physicists in RT simulation
  - Inter-departmental seminar
  - Let MR physicists shadow RT staff
  - Discussion on common needs

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Acknowledgement

St. Jude Children's Research Hospital

Radiation Oncology
- Thomas E. Merchant, DO, PhD
- Matthew J. Krasin, MD
- John T. Lucas Jr., MS, MD
- Christopher Tinkle, MD, PhD
- Sahaja Acharya, MD
- Maria Carlson, MSN
- Li Zhao, PhD
- Yuting Li, PhD
- Hanna Smith, Olivia Huling, and all therapists
- Chia-ho Hua, PhD
- Austin Faught, PhD
- Ozgur Ates, PhD
- Yue Yan, PhD
- Chuang Wang, PhD
- Jared Beckfort, PhD
- Fakhriddin Pirlepesov, PhD
- Shahad Al-Ward
- Fang Xie
- David Sobczak

Diagnostic Imaging
- Robert Ogg, PhD
- M Ayaz Khan, PhD
- Matt Scoggins, PhD
- Pat Hanby

Biostatistics
- Yimei Li, PhD

Financial support from ALSAC

Philips Healthcare
- Lizette Warner, PhD
- Mo Kadbi , PhD
- David Brazzle
- Gregory Thomas
- Joseph Entrekin
- Jerry Wyner
- Trey White
- David Reese
- Alex Dresner, PhD

SciMedix, Inc.
- Henry Jang
- Hyun Min Lee

Memorial Sloan Kettering Cancer Center
- Neelam Tyagi, PhD

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