Beyond Conventional CT Simulation: MR-only Treatment Planning & MR-SIM Neelam Tyagi, PhD

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Disclosures

MSKCC has a master research agreement with Philips Healthcare



### Diagnostic scans are not always sufficient for RT



Flat couch, Immobilization



Curved couch, no Immobilization

# MR-RT systems or MR simulators for imaging in treatment position

- Integrated Flat table with indexing to fit immobilization
- Big bore size (70 cm)
  Coil bridge support
  MR compatible immobilization
- Lasers for alignment and marking
- Coils integrated posterior coil and an anterior surface coil







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# In the presence of Metal Artifacts



MR (T2w)



# Metal artifact reduction sequences for MR-SIM

Philips implementation: OMAR





T2 TSE

Courtesy: Mo Kadbi, Philips Healthcare

# MR-SIM: Immobilizations and Coil configuration









Coil sensitivity of surface coils drops very rapidly as the distance from the coil increases

Not all scanners are equipped with flexible surface coils

# Commercial solution: GE adaptive image receive (AIR) Coils





McGee et al, 2018, Phys Med Biol 63 (8)



### CT+MR simulation: clinical challenges

 Keeping rectal and bladder filling consistent between CT & MR can be challenging



May also result in potential target (seminal vesicles) miss if rely completely on MR









- 1. Bulk density based methods
- 2. Atlas-based methods
- 3. Direct conversion/voxel-based/ classification-based methods

accuracy < 2%

Dose calculation

4. Combination methods

Review Article by Johnstone et al, IJROBP 2018

61 articles on synthetic CT



Network Summary for Synthetic CT generation						
<u> </u>	→ Neural Ne	Neural Network				
Network Name	What it does	Image Set Requirement	Reference			
AutoEncoder	Unsupervised transformation	Paired	LeCun, 1987*			
Unet	Regression fit of MR to CT	Paired	Ronneberger, 2015			
GAN	Fits marginal distribution of MR intensities	Paired/Unpaired	Goodfellow, 2014			
cGAN or Pix2Pix	Conditional distribution P(CT MR)	Paired	Isola, 2016			
Cycle GAN	Conditional distribution with a consistent transformation constraint	Unpaired	Zhu, 2017			
Slide courtesy: Harini Veeraraghavan, Peter Klages, MSKCC						





Commercial synthetic CT solution: MRI Planner







# MR-only clinical Evaluation at MSKCC

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Tyagi et al, PMB 2017





# MR-only planning: Automated workflows for registration and autosegmentation



### Tyagi et al, Radiation Oncology (2017)



# Example Deep learning-based Detection and Segmentation of Prostate Cancer





Clinical Summary				
	# of prostate patients planned and treated using MR-only planing			
SBRT (800 cGy x 5)	318			
Moderate hypofractionation (270 cGy x 26)	54			
Standard fractionation (180 cGv x 40)	213			

Simulated, planned and treated 575 MR-only cases to date

- 14 patients failed synthetic CT reconstruction
- I 16 patients underwent a backup CT scan because of artifacts on the MR
- 20 patients where the fiducials were misidentified on MR and caught on fiducial QA
- a ~ 10% cases required repeat MR due to motion



# Automatic gold FM localization for MR-only planning



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3D (								
3D (	Seeds implanted	Seeds counted on CT	TP	FP	FN	Dice overlap	Mean distance to CT (mm)	Standard deviation (mm
3D (	Seeds implanted 1047	Seeds counted on CT 1046	TP 1008	FP 39	FN 38	Dice overlap 0.96	Mean distance to CT (mm) 0.79	Standard deviation (mm) 0.38



# Motion on MRs due to long acquisition times



Foley catheter Full bladder









# Conclusions

- Tremendous progress in the development of MR-RT systems are enabling MR-based treatment planning
- Further developments/improvements
  - Reduce MR acquisition time
    - Compressed sensing
  - **¤** Development of more motion robust sequences
  - Coil development in radiotherapy position to allow integration of advanced MR sequences into treatment planning

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