MR in radiotherapy planning

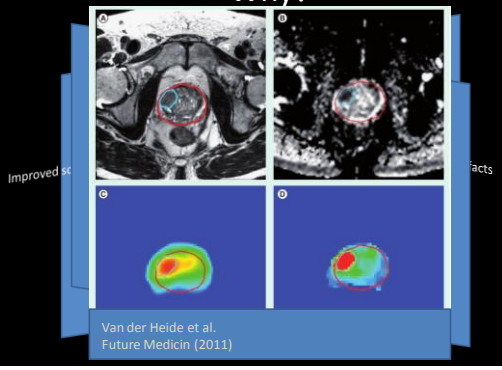
Tufve Nyholm

MRI for treatment planning

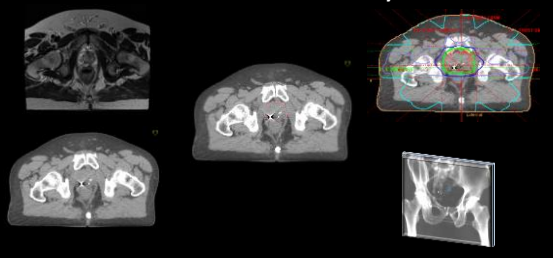
Presentation outline

- MR/CT based workflow
  - What is the problem?
- MR only workflow
  - Issues and possibilities
- Treatment planning systems
  - What is needed before we can make full benefit of MR?
- Image quality and distortions

Why?



Workflow of today



Images | Registration / Target definition | Treatment planning

Problem

Registration

RESULTS OFA MULTI-INSTITUTIONAL BENCHMARK TEST FOR CRANIAL CT/MR IMAGE REGISTRATION
Ulin et al.
Int. J. Radiation Oncology Biol. Phys., Vol. 77, No. 5, pp. 1584–1589, 2010

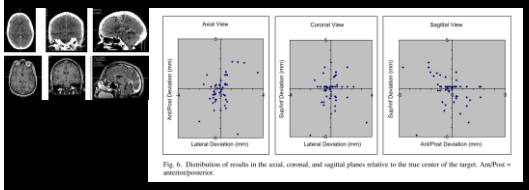


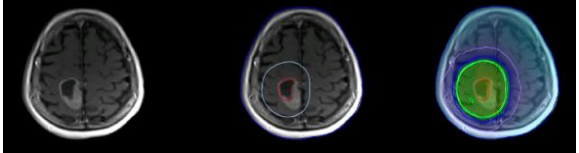
Fig. 6. Distribution of results in the axial, coronal, and sagittal planes relative to the true center of the target. Ant/Post = anterior/posterior.

Method
MR and CT examinations of head case were sent to 45 clinics for registration

Result
Standard deviation: 2.2 mm

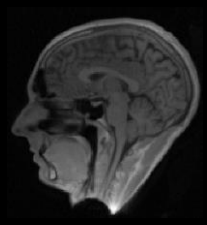
Switch from CT based to MR based workflow

Imaging | Target definition | Treatment planning



Which issues needs to be addressed

- Geometrical accuracy

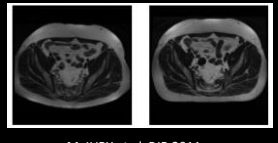


Which issues needs to be addressed

- Geometrical accuracy
- Imaging of markers

Which issues needs to be addressed

- Geometrical accuracy
- Imaging of markers
- Imaging in fixation

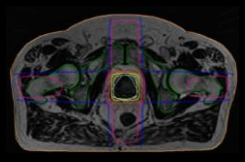


McJURY et al. BJR 2011

Hanvey et al. Phys Med Biol. 2011

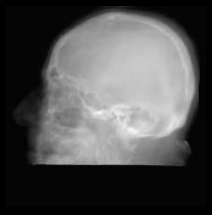
Which issues needs to be addressed

- Geometrical accuracy
- Imaging of markers
- Imaging in fixation
- Dose calculation



Which issues needs to be addressed

- Geometrical accuracy
- Imaging of markers
- Imaging in fixation
- Dose calculation
- Positioning reference



Which issues needs to be adressed

- Geometrical accuracy
- Imaging of markers
- Imaging in fixation
- Dose calculation
- Positioning reference

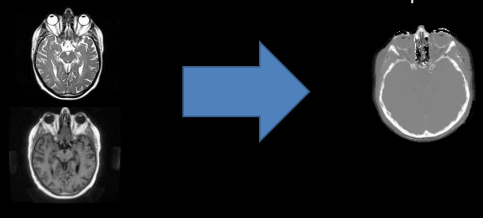
Not specific for MR only radiotherapy

Specific for MR only radiotherapy

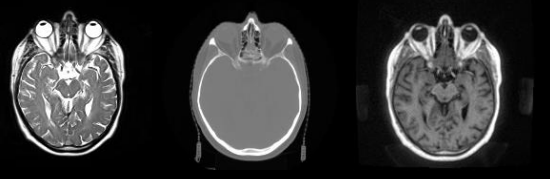
How?

Dose calculation | Positioning reference

MR → CT equivalent



MR signal



T2w | CT | UTE (Ultra short echo time)

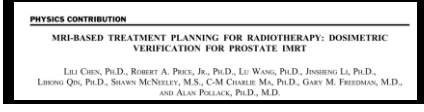
Manual segmentation and bulk densities

Dosimetric evaluation of MRI-based treatment planning for prostate cancer

L Chen, R A Price Jr, T-B Nguyen, L Wang, J S Li, L Qin, M Ding, F Palacio, C-M Ma and A Pollack

Radiotherapy treatment planning of brain tumours using MRI alone

A W BEAVIS, PhD, BSc, P GIBBS, PhD, BSc, R A DEALEY, FRCR and V J WHITTON, MSc, BSc



PHYSICS CONTRIBUTION

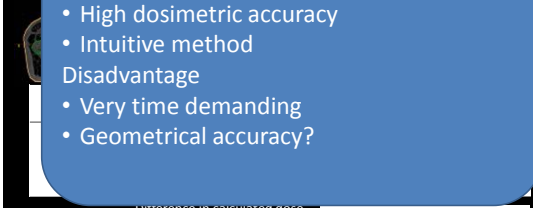
MRI-BASED TREATMENT PLANNING FOR RADIOTHERAPY: DOSIMETRIC VERIFICATION FOR PROSTATE IMRT

Lili Chen, Ph.D., Robert A. Price, Jr., Ph.D., Lu Wang, Ph.D., Jinsheng Li, Ph.D., Liming Qin, Ph.D., Shawn McNeeley, M.S., C-M Charlie Ma, Ph.D., Gary M. Freedman, M.D., and Alan Pollack, Ph.D., M.D.

Manual segmentation and bulk densities

Advantage
- High dosimetric accuracy
- Intuitive method

Disadvantage
- Very time demanding
- Geometrical accuracy?



Difference in calculated dose

Jonsson *et al. Radiation Oncology* 2010, **5**:62
http://www.ro-journal.com/content/5/1/62

Registration based

An Atlas-Based Electron Density Mapping Method for Magnetic Resonance Imaging (MRI)-Alone Treatment Planning and Adaptive MRI-Based Prostate Radiation Therapy

Jason A. Dowling, Ph.D.,* Jonathan Lambert, B.Sc.(Hons),†‡ Joel Parker, B.App.Sc.,† Olivier Salvado, Ph.D.,* Jurgen Fripp, Ph.D.,* Anne Capp, M.Med.(ClinEpi),†§ Chris Wratten, MB., BS.,†‖ James W. Denham, M.D.,†‡ and Peter B. Greer, Ph.D.†‡

MR-based attenuation correction for hybrid PET-MR brain imaging systems using deformable image registration

Eduard Schreibmann[a)]
Department of Radiation Oncology, School of Medicine, Emory University, Atlanta, Georgia 30322
Jonathon A. Nye, David M. Schuster, Diego R. Martin, and John Votaw
Department of Radiology, School of Medicine, Emory University, Atlanta, Georgia 30322
Tim Fox
Department of Radiation Oncology, School of Medicine, Emory University, Atlanta, Georgia 30322

MRI-Based Attenuation Correction for PET/MRI: A Novel Approach Combining Pattern Recognition and Atlas Registration

Matthias Hofmann[1–3], Florian Steinke[1], Verena Scheel[1], Guillaume Charpiat[1], Jason Farquhar[2], Philip Aschoff[4], Michael Brady[3], Bernhard Schölkopf[1], and Bernd J. Pichler[2]

Registration based

Advantage
- High dosimetric accuracy
- Automatic

Disadvantage
- Geometrical accuracy?

Int J RadiatOncol Biol Phys 2012

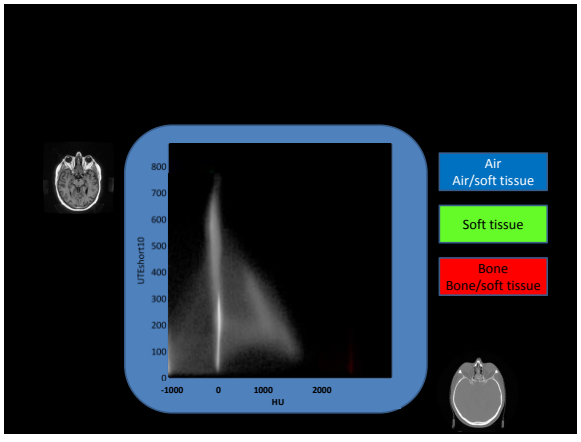
Automatic segmentation and bulk densities

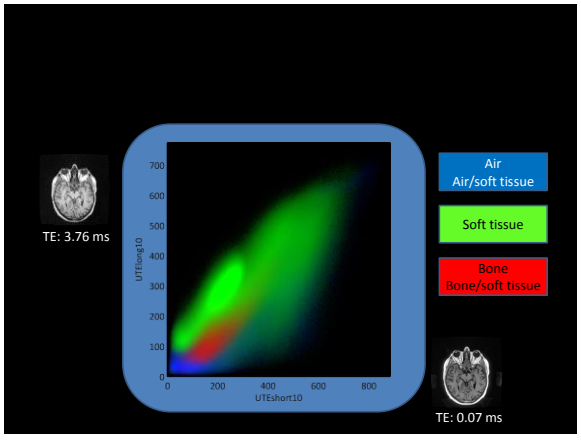
Investigation of a method for generating synthetic CT models from MRI scans of the head and neck for radiation therapy

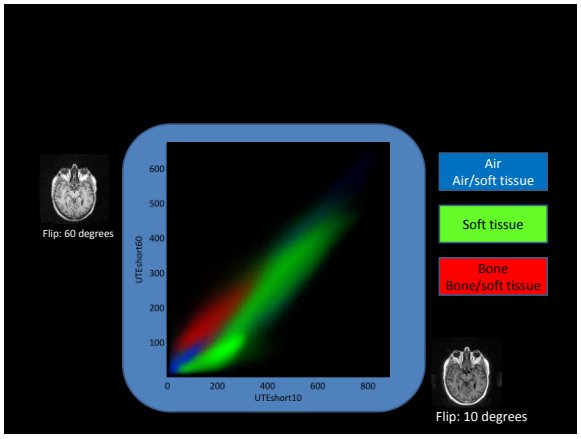
Shu-Hui Hsu, Yue Cao, Ke Huang, Mary Feng and James M Balter

MRI-Based Attenuation Correction for Hybrid PET/MRI Systems: A 4-Class Tissue Segmentation Technique Using a Combined Ultrashort-Echo-Time/Dixon MRI Sequence

Automatic, three-segment, MR-based attenuation correction for whole-body PET/MR data







Automatic segmentation and bulk densities

Advantage
- High dosimetric accuracy
- High geometrical accuracy

Disadvantage
- Not intuitive – Need for QC
- Not shown to work below the H&N region

models from MRI scans of the head and neck for radiation therapy

Direct voxel-vise conversion

CT substitute derived from MRI sequences with ultrashort echo time

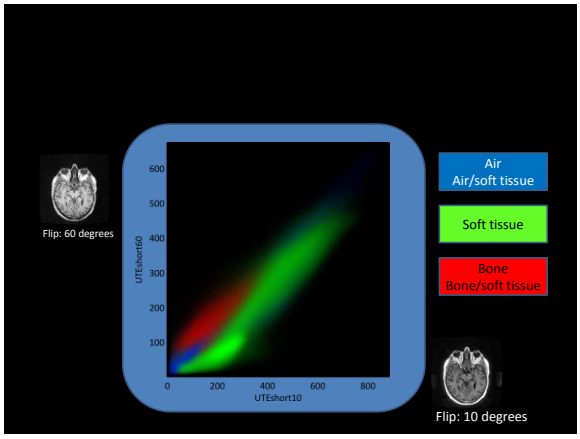
Adam Johansson, Mikael Karlsson, and Tufve Nyholm

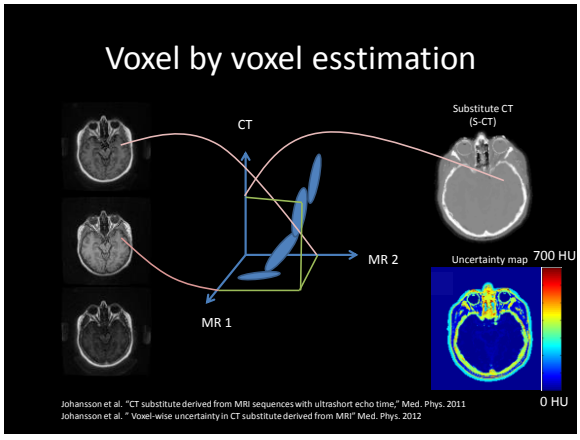
Department of Radiation Sciences, Umeå University, Umeå, Sweden

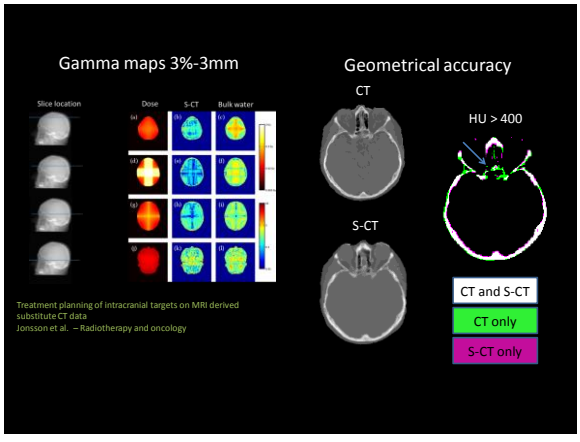
MRI-based treatment plan simulation and adaptation for ion radiotherapy using a classification-based approach

Treatment planning of intracranial targets on MRI derived substitute CT data

Joakim H. Jonsson, Adam Johansson, Karin Söderström, Thomas Asklund, Tufve Nyholm


Flip: 60 degrees
UTEshort60
600
500
400
300
200
100
0
200
400
600
800
UTEshort10
Air
Air/soft tissue
Soft tissue
Bone
Bone/soft tissue
Flip: 10 degrees


Voxel by voxel esstimation
CT
Substitute CT
(S-CT)
MR 2
MR 1
Uncertainty map
700 HU
0 HU
Johansson et al. "CT substitute derived from MRI sequences with ultrashort echo time," Med. Phys. 2011
Johansson et al. " Voxel-wise uncertainty in CT substitute derived from MRI" Med. Phys. 2012


Gamma maps 3%-3mm
Slice location
Dose
S-CT
Bulk water
Treatment planning of intracranial targets on MRI derived
substitute CT data
Jonsson et al. – Radiotherapy and oncology
Geometrical accuracy
CT
S-CT
HU > 400
CT and S-CT
CT only
S-CT only

Comparison CT/substitute-CT

Advantage
- High dosimetric accuracy
- High geometrical accuracy

Disadvantage
- Not intuitive – Need for QC
- Not shown to work below H&N region

TPS and MRI

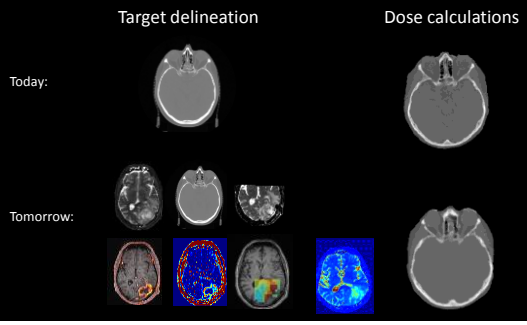


Image quality

(some personal reflextions)

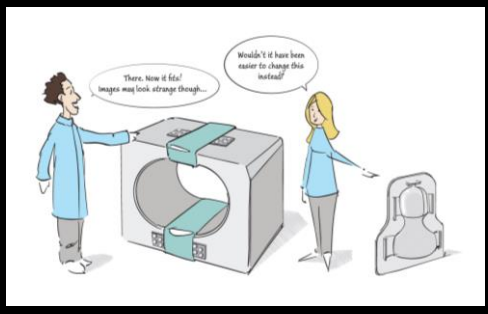
The definition of the target volume and OAR's are the most important steps of the radiotherapy workflow

Point with MR: Image quality → better possiblities to define relevant volumes

So we should do what we can to maintain the image quality..

This could mean that RT needs to adopt to MR instead of the other way around

Image quality
(some personal reflextions)



Distortions

Patient dependent
Gradient none-linearity

Target defintion
Dose calculation (MR only workflow)
Registrations (CT/MR workflow)

Distortions

Patient dependent
Chemical Shift
Susceptibility
Gradient none-linearity


Seminars in Radiation Oncology
Volume 24, Issue 3, July 2014, Pages 160–168
Magnetic Resonance Imaging in Radiation Oncology

Magnetic Resonance Imaging Acquisition Techniques for Radiotherapy Planning

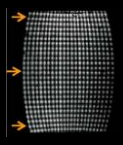
Gary P. Liney, PhD[1], Marinus A. Moerland, PhD[2]

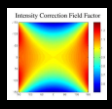
"Patient-related image distortions can be reduced by applying relatively strong slice selection and frequency-encoding gradients, for example, by setting the pixel bandwidth at twice the water-fat shift, all patient-related distortions are expected to be smaller than the pixel size."

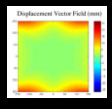
440 Hz at 1.5 T
880 Hz at 3 T

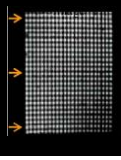
Distortions

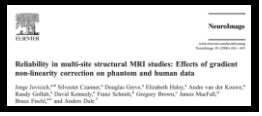
Patient dependent
Gradient none-linearity











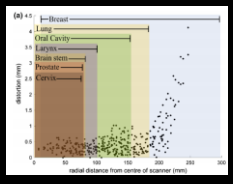
Neuroimage

Reliability in multi-site structural MRI studies: Effects of gradient non-linearity correction on phantom and human data

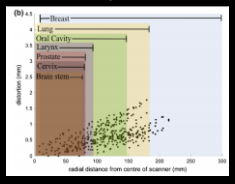
Jorge Jovicich,[a,*] Silvester Czanner,[a] Douglas Greve,[a] Elizabeth Haley,[a] Andre van der Kouwe,[a] Randy Gollub,[b] David Kennedy,[b] Franz Schmitt,[d] Gregory Brown,[c] James MacFall,[c] Bruce Fischl,[a,e] and Anders Dale[a]

Distortions

1.5T



3T



Australasian Phys. Eng. Sci. Med. (2014) 37:103–113
DOI 10.1007/s13246-014-0252-3

SCIENTIFIC PAPER

MRI distortion: considerations for MRI based radiotherapy treatment planning

Amy Walker · Gary Liney · Peter Metcalfe · Lois Holloway

Umeå
European capital of culture 2014

VÄSTERBOTTENS LÄNS LANDSTING

Thank You!

UMEÅ UNIVERSITET