Clinical Application of Imaging: An Overview

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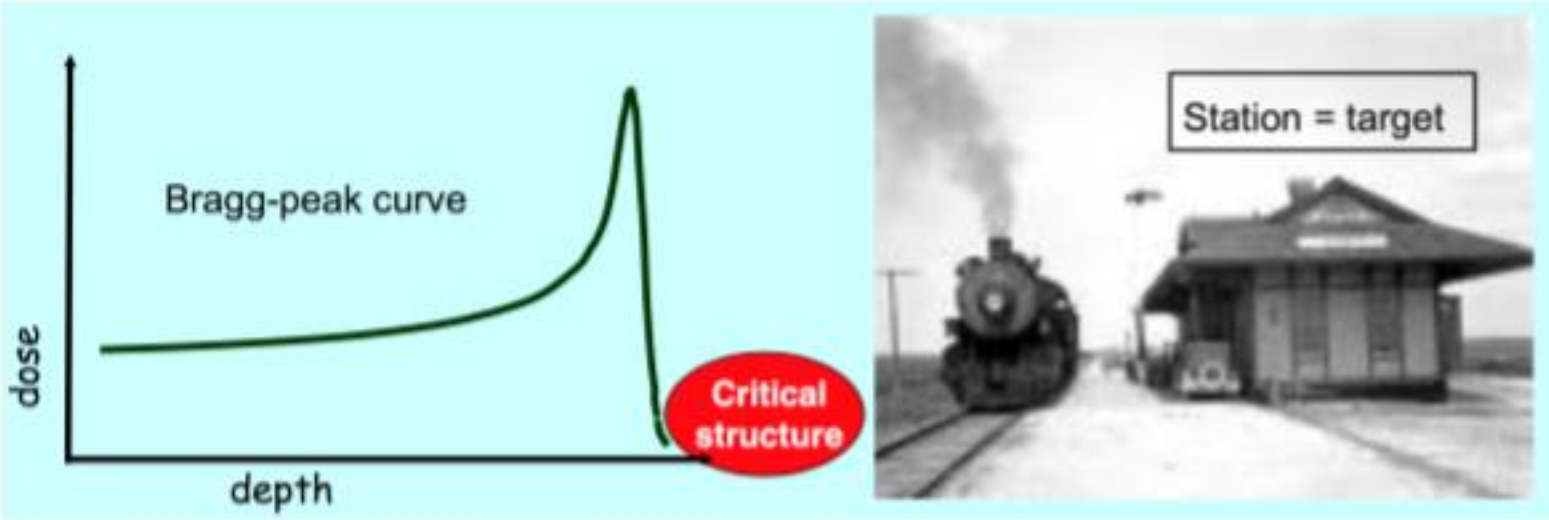
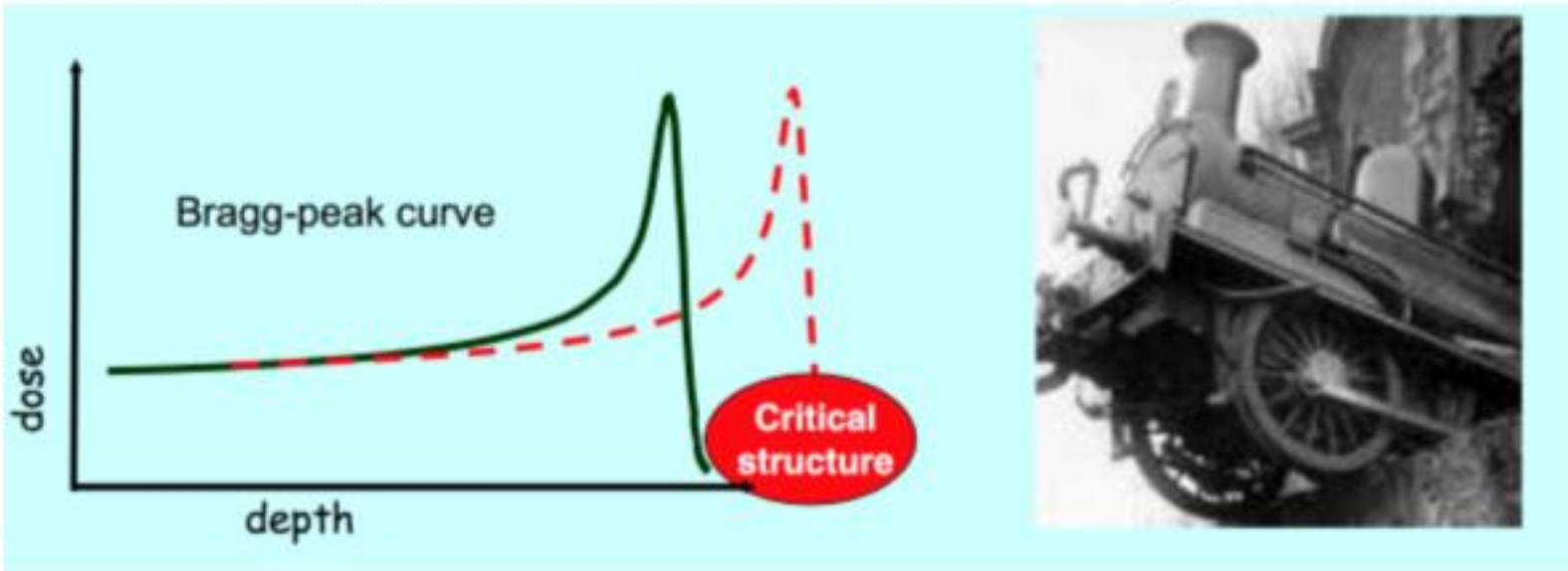
ENLIGHT Annual Meeting
UCL, London, UK
June 25-27, 2018

@ProtonAdvanceRT

The advantage of protons is that they stop.



The disadvantage of protons is that we don't always know where...



ELSEVIER

Medical Dosimetry, Vol. 35, No. 3, pp. 179-194, 2010

0958-3947/10/$–see front matter

doi:10.1016/j.meddos.2009.05.004

ION STOPPING POWERS AND CT NUMBERS

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Proton Therapy, Inc., Colton, CA; Long Beach Memorial Medical Center, Long Beach, CA; City of Hope National Medical Center, Duarte, CA; and Loma Linda University Medical Center, Loma Linda, CA

IOP PUBLISHING — PHYSICS IN MEDICINE AND BIOLOGY

Phys. Med. Biol. **57** (2012) 4095–4115 — doi:10.1088/0031-9155/57/13/4095

Comprehensive analysis of proton range uncertainties related to patient stopping-power-ratio estimation using the stoichiometric calibration

Ming Yang[1,2], X Ronald Zhu[1,2], Peter C Park[1,2], Uwe Titt[1,2], Radhe Mohan[1,2], Gary Virshup[3], James E Clayton[3] and Lei Dong[1,2,4]

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[2] Medical Physics Program, Graduate School of Biomedical Sciences, The University of Texas Health Science Center at Houston, 7000 Fannin St, Houston, TX 77030, USA
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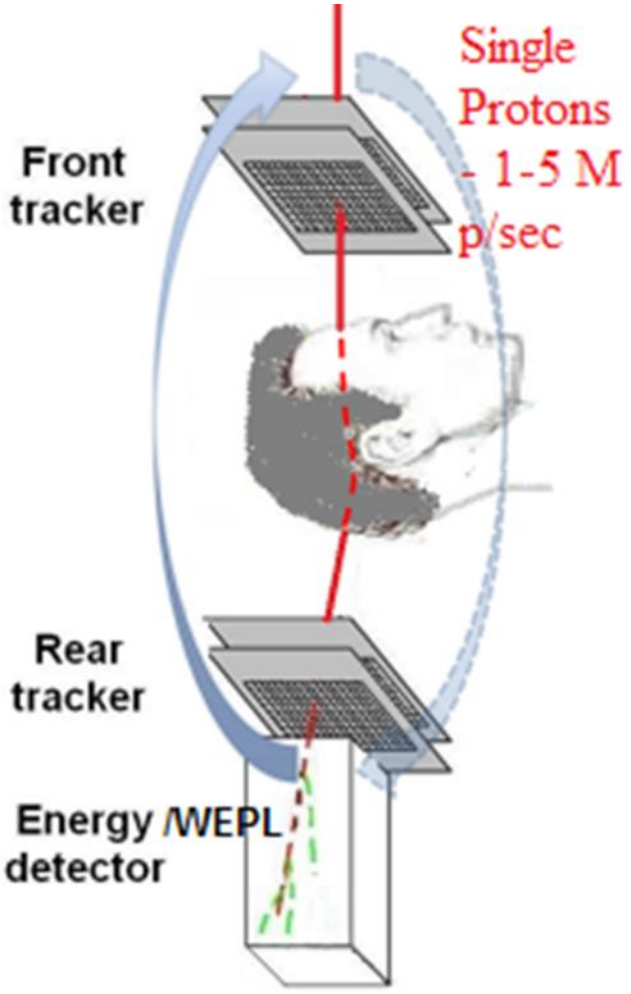
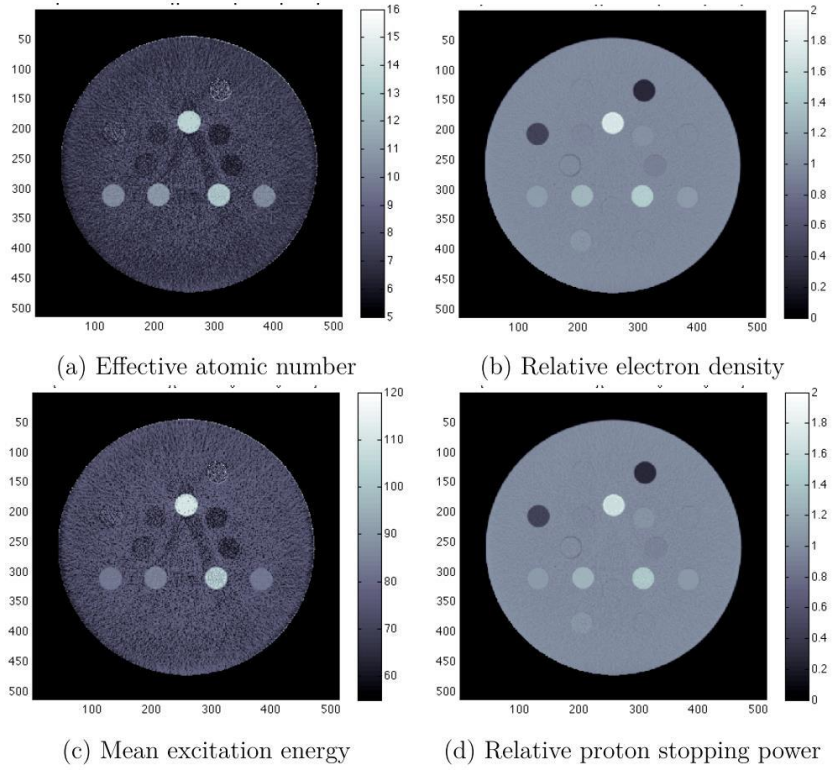
Proton CT (pCT)



Dual Energy CT (DECT)



(a) Effective atomic number

(b) Relative electron density

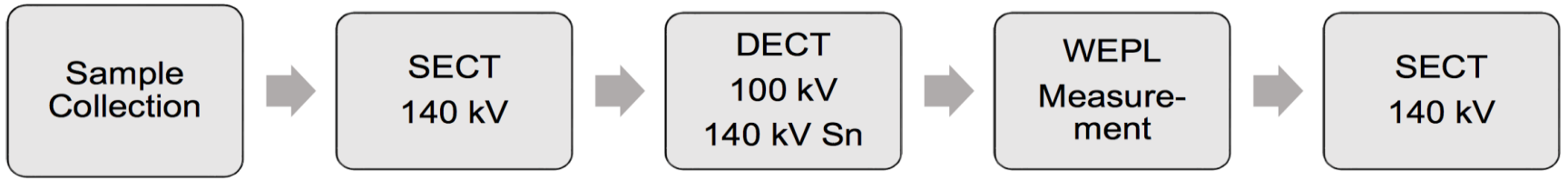
(c) Mean excitation energy

(d) Relative proton stopping power

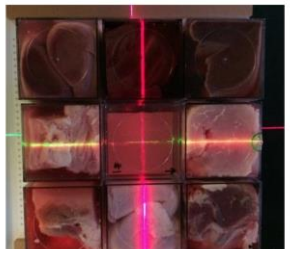
- More information – greater accuracy
- Reduction in CT artifacts

Validate DECT determined SPR with tissue substitutes and animal tissue samples – Esther Bär

National Physical Laboratory



Animal tissues



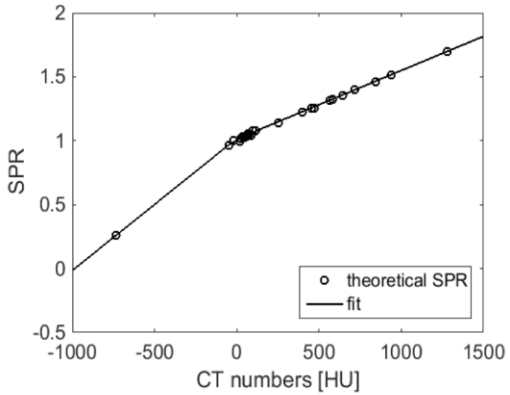
Siemens Somatom Definition Flash

Siemens Somatom Definition Flash

Dose extinction

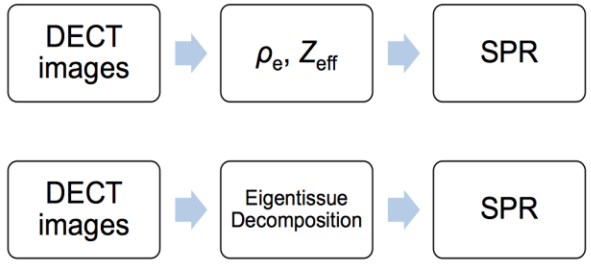
Check for tissue movement and deformation

SECT



- Stoichiometric calibration, Schneider *et al.* (1996)

DECT



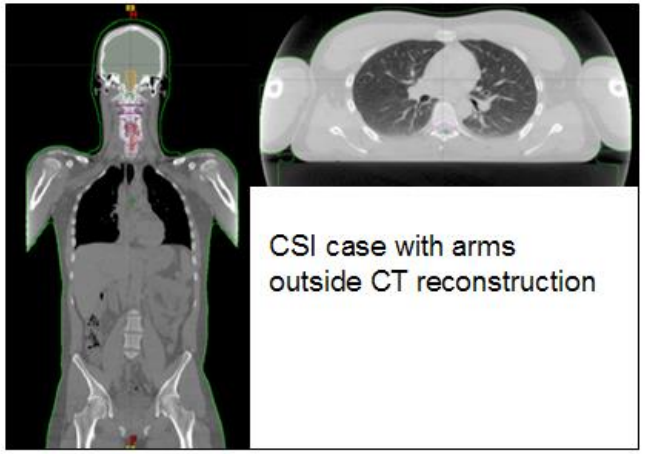
- Bourque *et al.* (2014)
- Lalonde and Bouchard 2016

Discussion

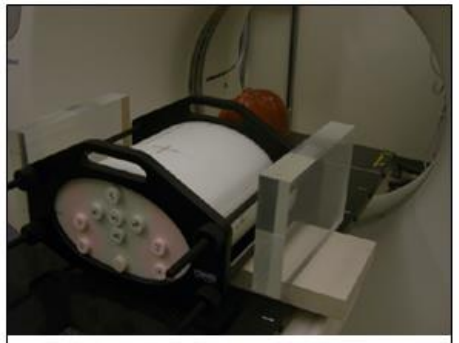
- Successfully validated on tissue substitutes
- We show an improvement in WEPL estimation with DECT determined SPR values in both samples
- Our results indicate possible improvement in range prediction by the use of DECT

Bär et al (2017). The potential of dual-energy CT to reduce proton beam range uncertainties. *Med Phys*

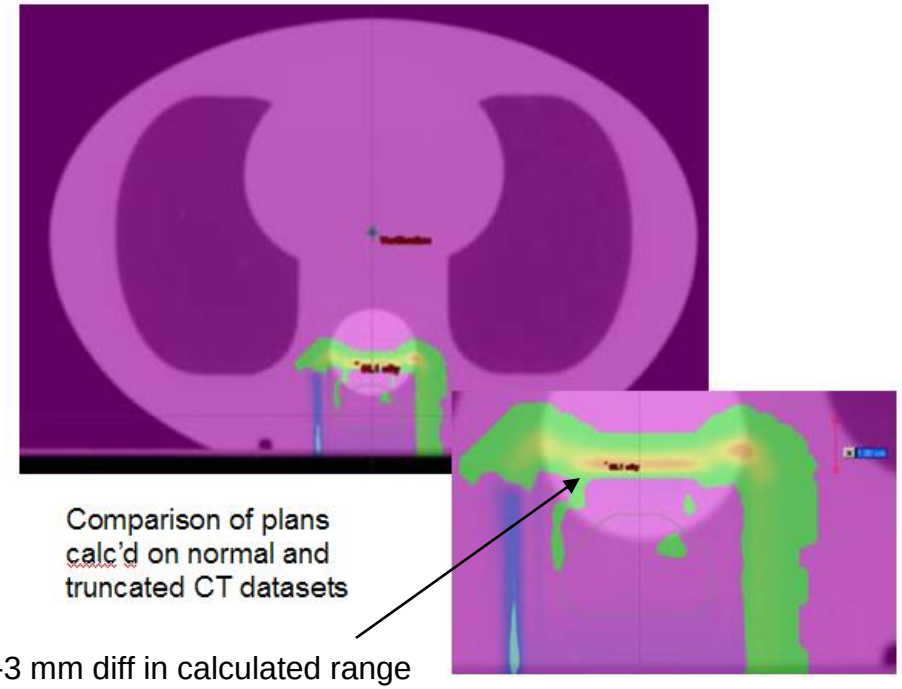
Wu R, Amos RA, *et al.* Effect of CT truncation artifacts on proton dose calculation. *Med Phys* **35**, 2697 (2008)



CSI case with arms outside CT reconstruction

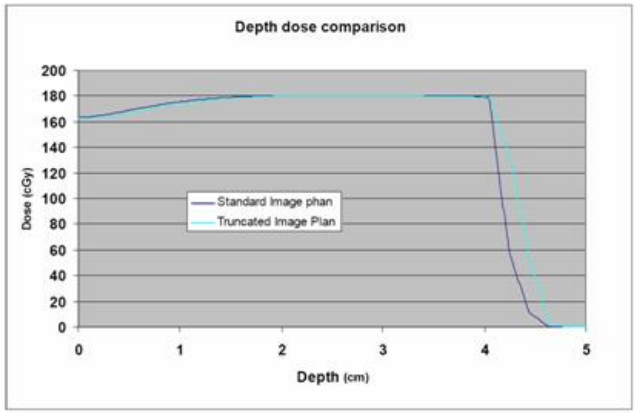


Thoracic phantom scanned with tissue equiv. material truncated

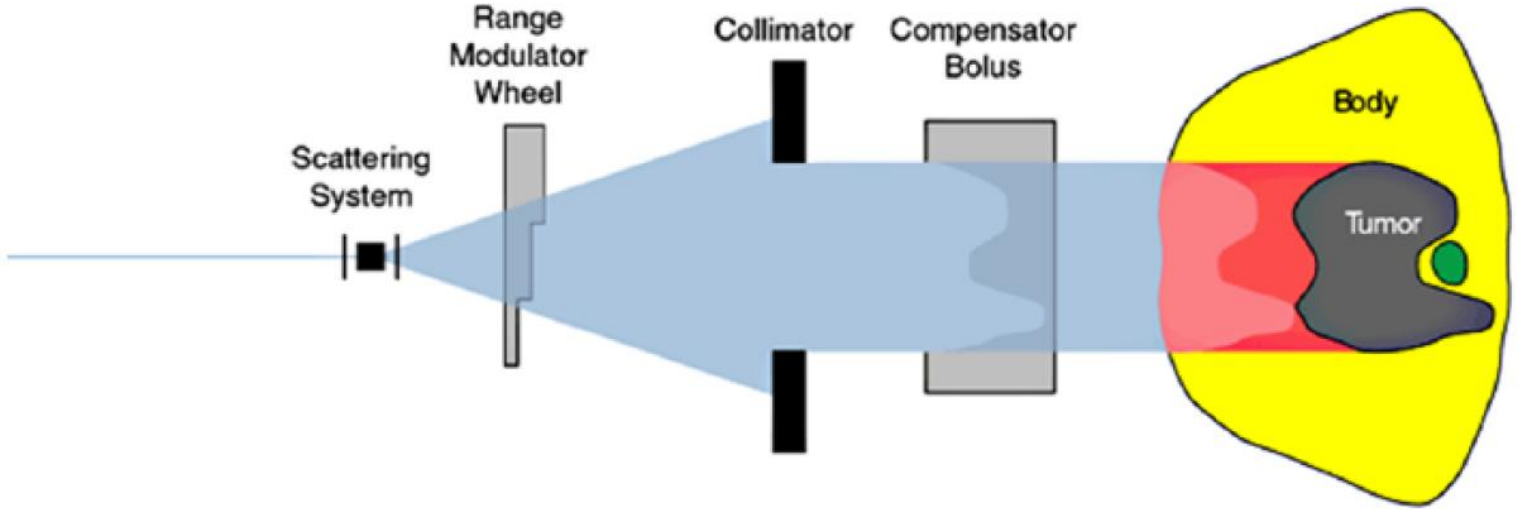


Comparison of plans calc'd on normal and truncated CT datasets

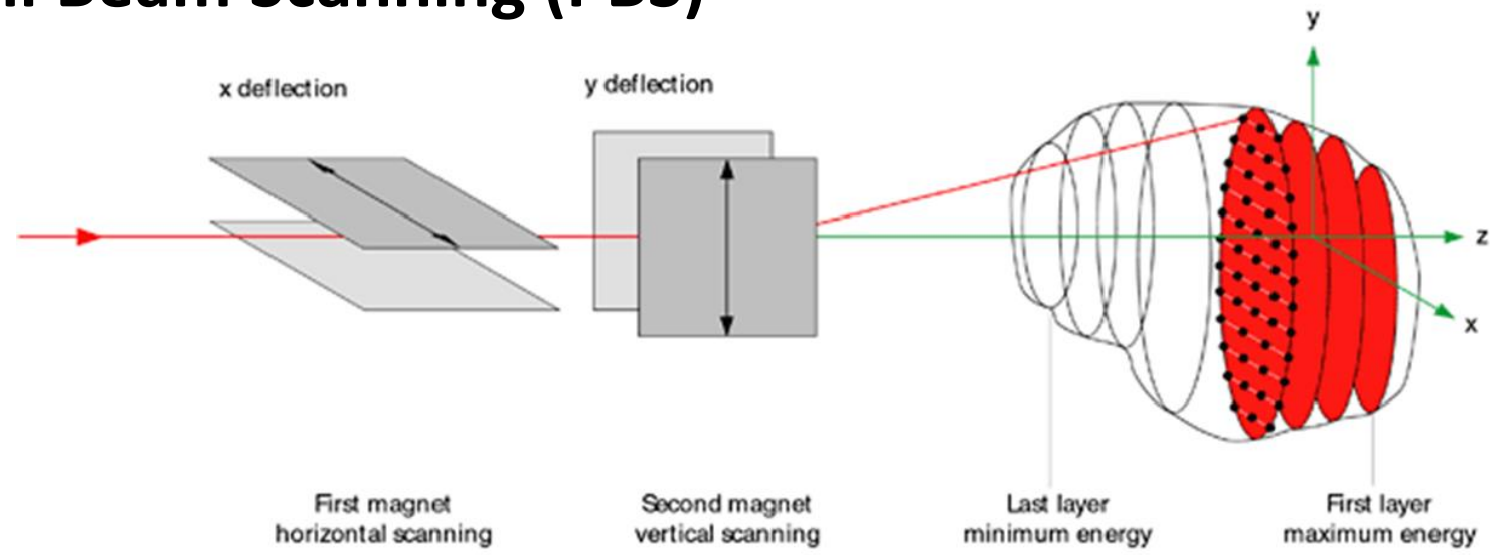
2-3 mm diff in calculated range



Passive Scattering



Pencil Beam Scanning (PBS)



Positional uncertainty and anatomical variation over course of treatment

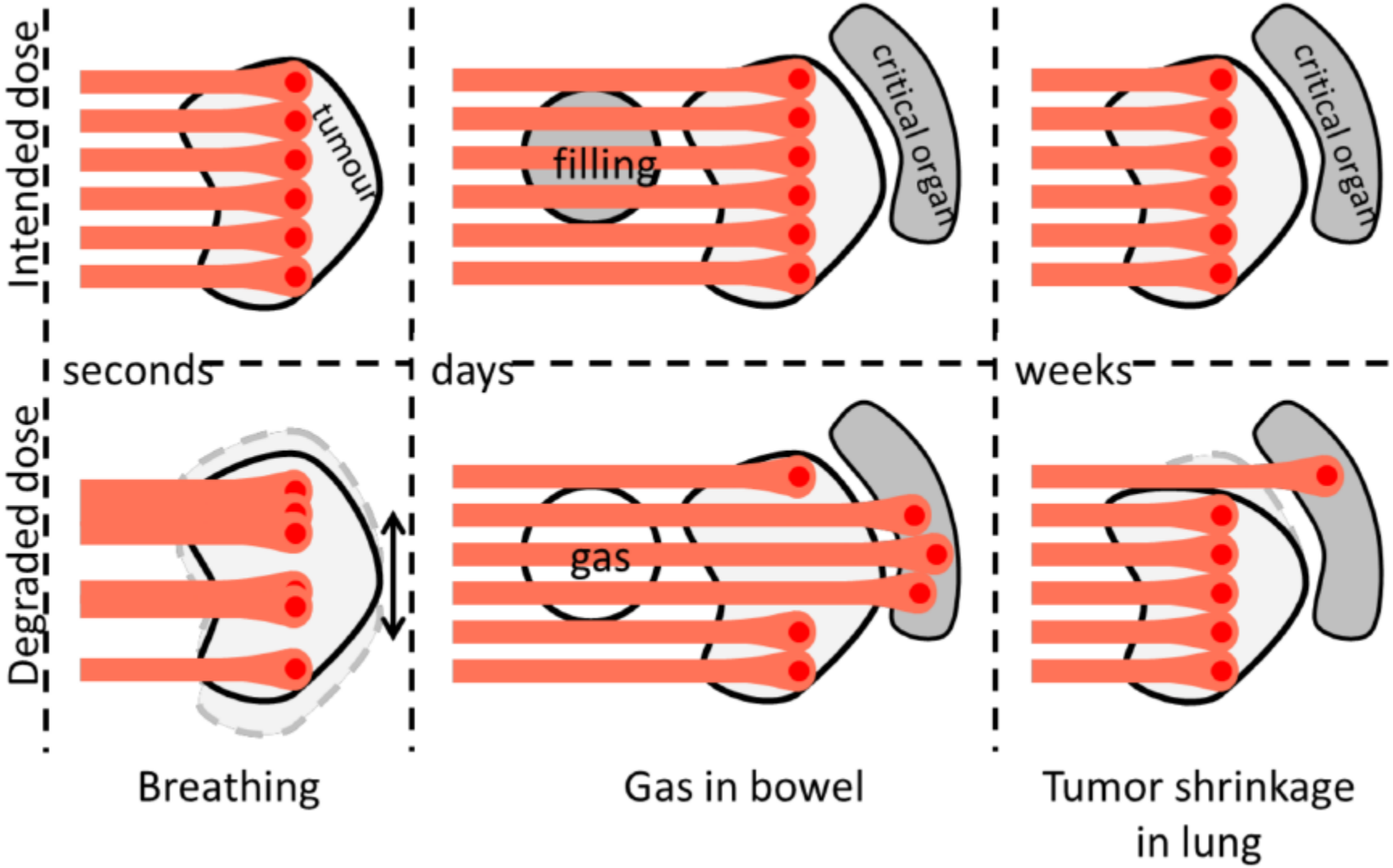
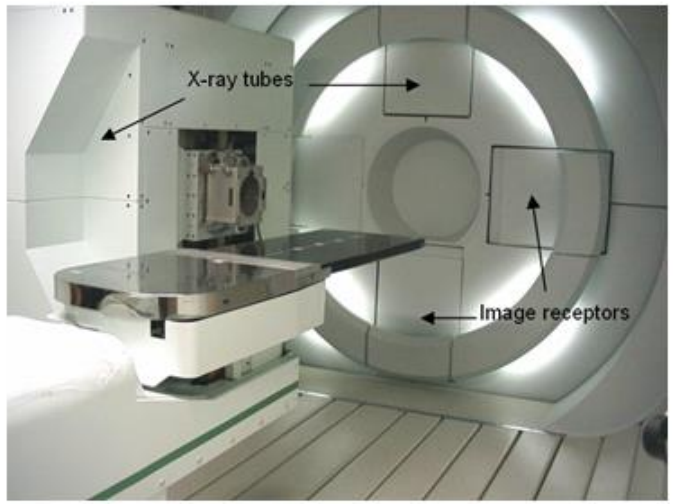
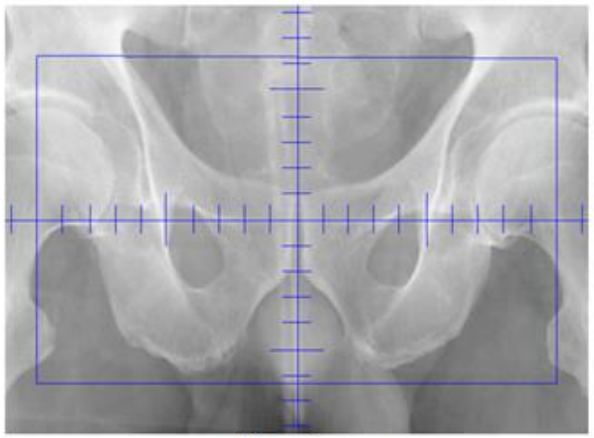


Image-guidance

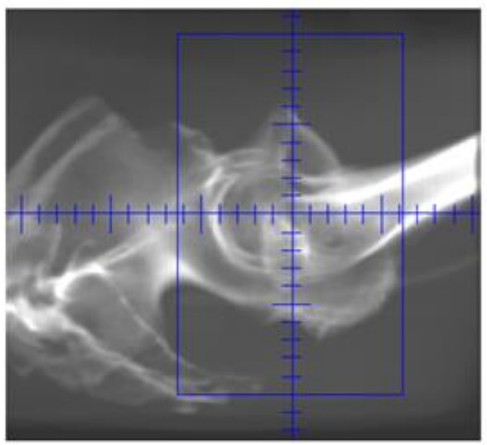
- Daily orthogonal kV x-rays taken to align anatomy with reference DRR's using 2-D matching



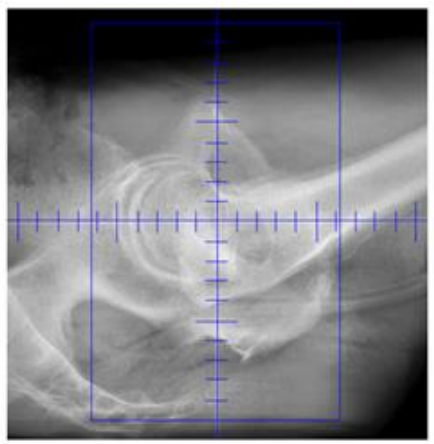
AP DRR



AP x-ray image



Rt Lat DRR



Rt Lat x-ray image

DOSIMETRIC CHANGES RESULTING FROM PATIENT ROTATIONAL SETUP ERRORS IN PROTON THERAPY PROSTATE PLANS

SAMIR V. SEJPAL, M.D., M.P.H.,* RICHARD A. AMOS, M.S.,* JAQUES B. BLUETT, M.S.,* LAWRENCE B. LEVY, M.S.,* RAJAT J. KUDCHADKER, PH.D.,* JENNIFER JOHNSON, M.S.,* SEUNGTAEK CHOI, M.D.,* AND ANDREW K. LEE, M.D., M.P.H.*

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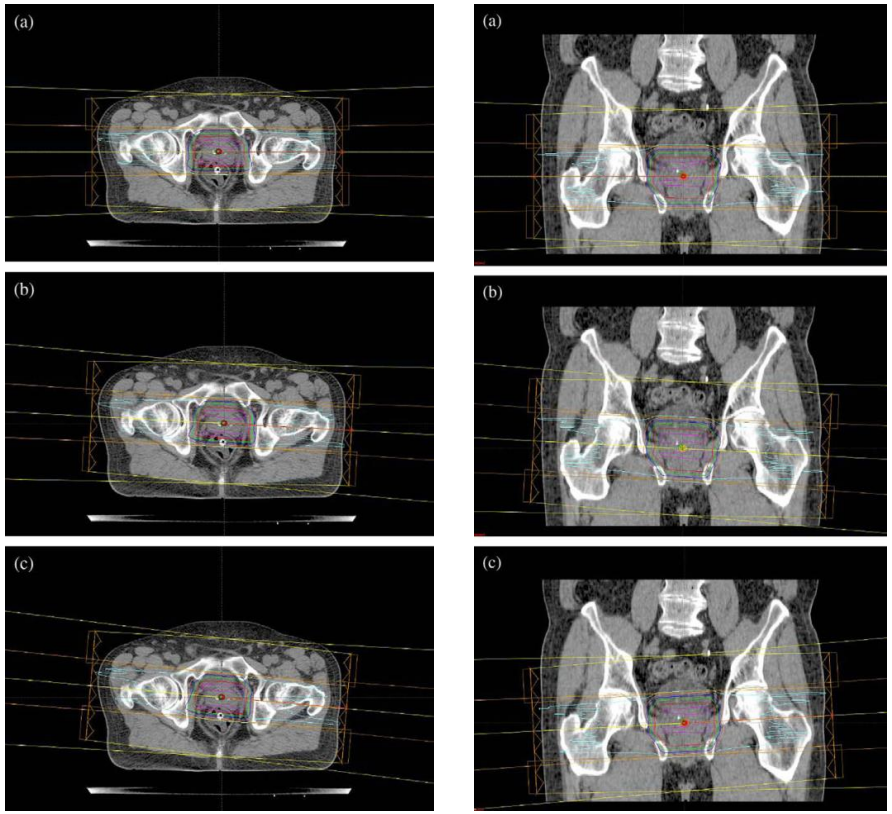
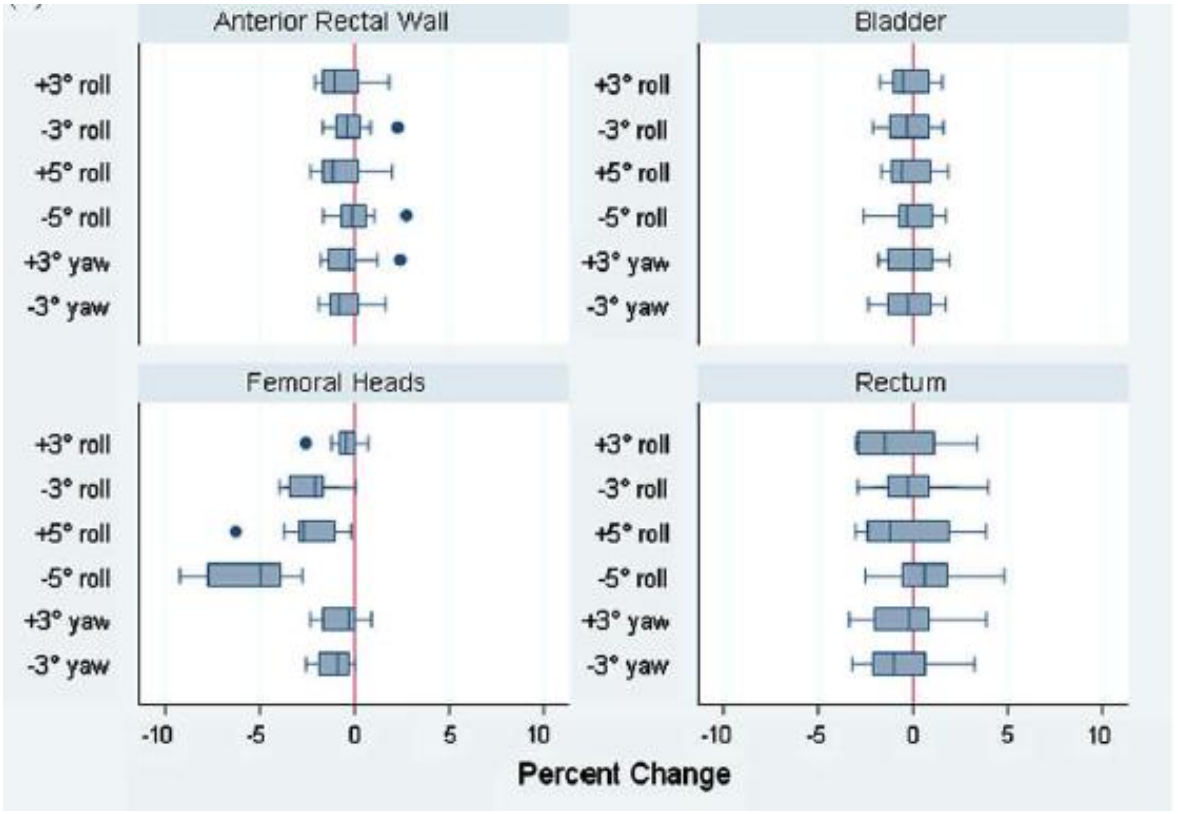
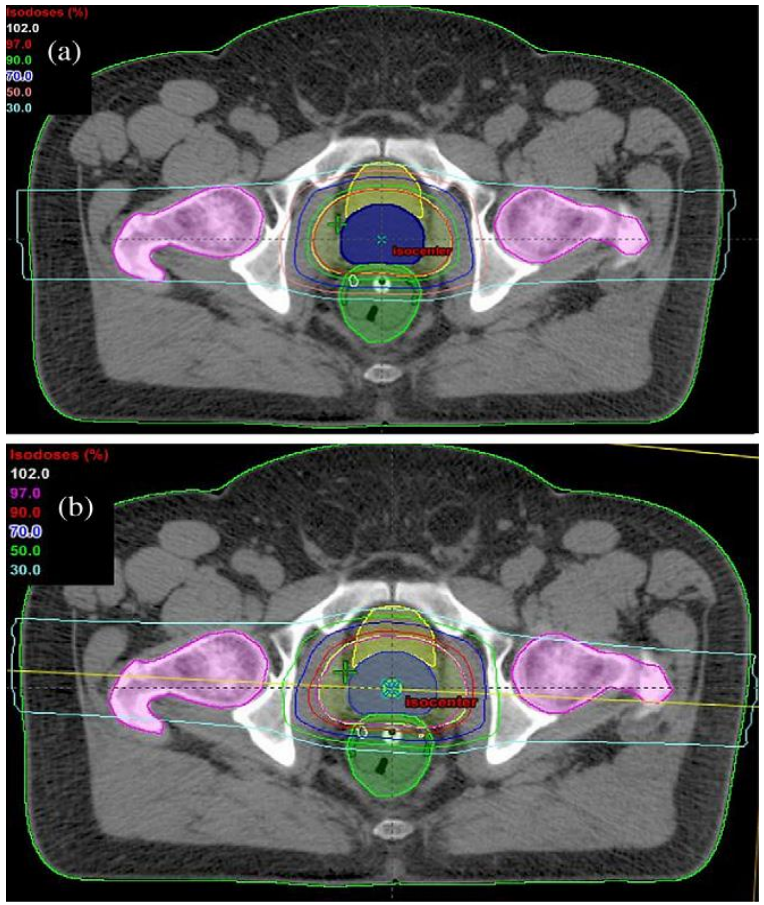


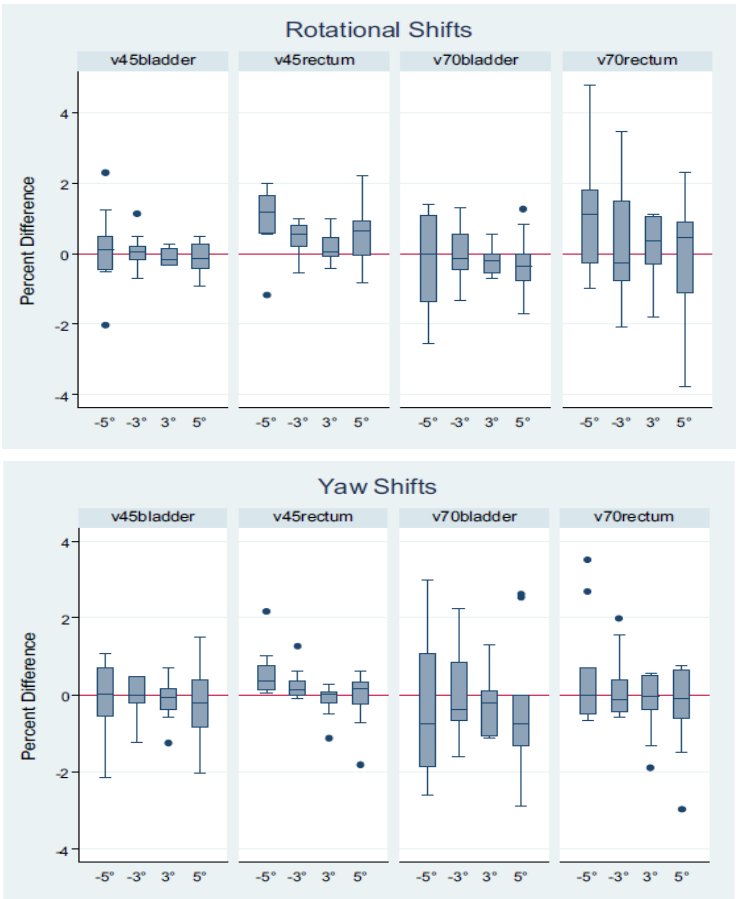


SPOT SCANNING PROTON BEAM THERAPY FOR PROSTATE CANCER: TREATMENT PLANNING TECHNIQUE AND ANALYSIS OF CONSEQUENCES OF ROTATIONAL AND TRANSLATIONAL ALIGNMENT ERRORS

JEFF MEYER, M.D.,* JAQUES BLUETT, M.S.,* RICHARD AMOS, M.S.,* LARRY LEVY, M.S.,* SEUNGTAEK CHOI, M.D.,* QUYNH-NHU NGUYEN, M.D.,* X. RON ZHU, PH.D.,* MICHAEL GILLIN, PH.D.,* AND ANDREW LEE, M.D., M.P.H.*

From the *University of Texas-M.D. Anderson Cancer Center, Houston, TX

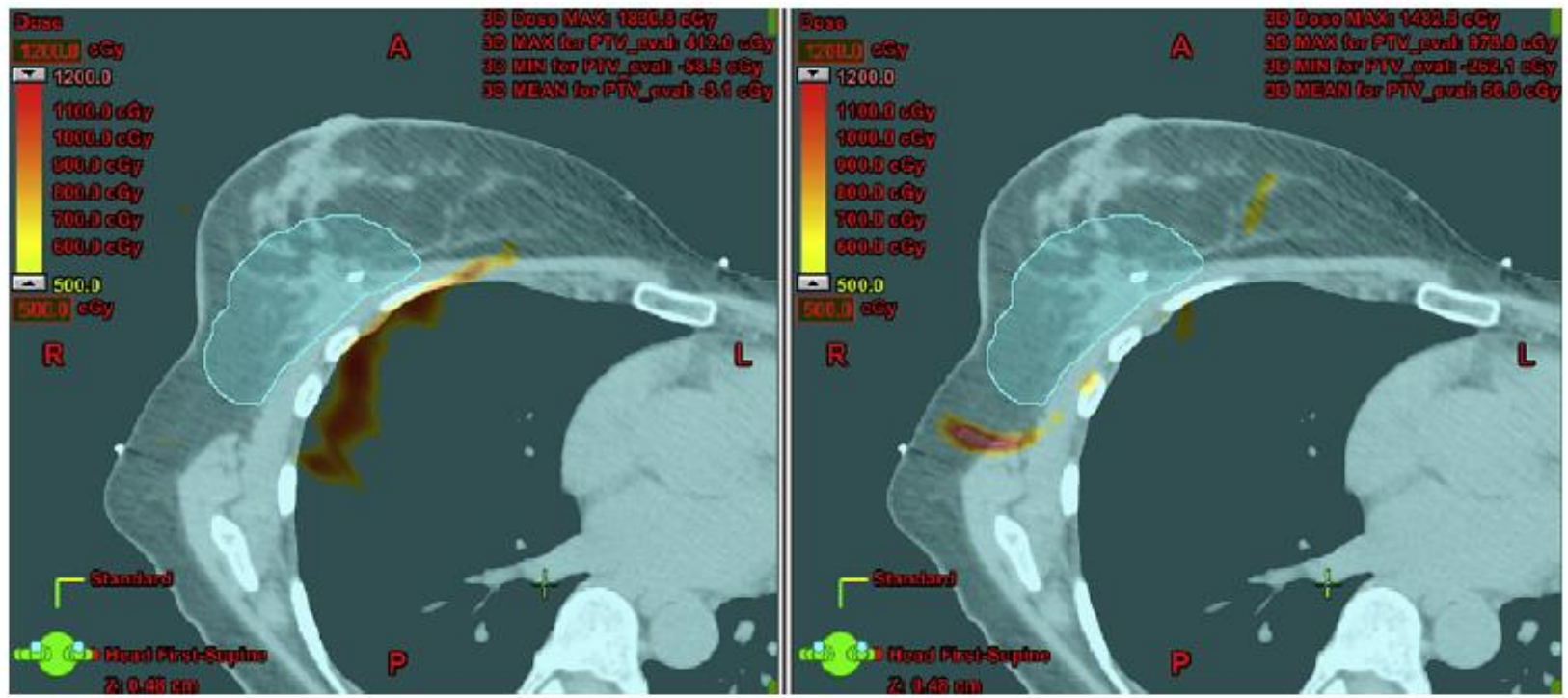




EXTERNAL-BEAM ACCELERATED PARTIAL BREAST IRRADIATION USING MULTIPLE PROTON BEAM CONFIGURATIONS

XIAOCHUN WANG, PH.D., RICHARD A. AMOS, M.SC., XIAODONG ZHANG, PH.D., PHILLIP J. TADDEI, PH.D., WENDY A. WOODWARD, M.D., PH.D., KAREN E. HOFFMAN, M.D., TSE KUAN YU, M.D., PH.D., WELELA TEREFFE, M.D., JULIA OH, M.D., GEORGE H. PERKINS, M.D., MOHAMMAD SALEHPOUR, PH.D., SEAN X. ZHANG, PH.D., TZOU LIANG SUN, M.S., MICHAEL GILLIN, PH.D., THOMAS A. BUCHHOLZ, M.D., AND ERIC A. STROM, M.D.

Departments of Radiation Physics and Radiation Oncology, The University of Texas, M. D. Anderson Cancer Center, Houston, TX



one beam towards chest wall tangential beams

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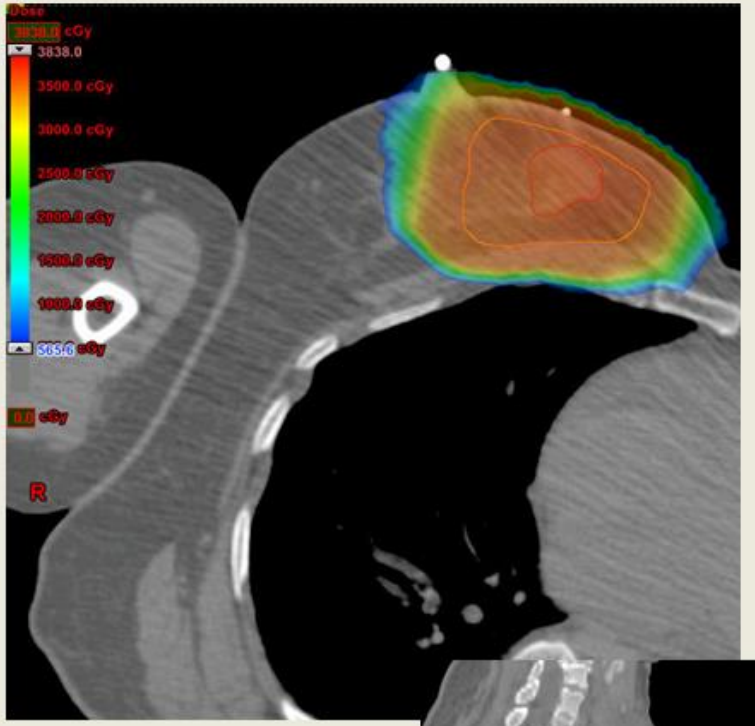
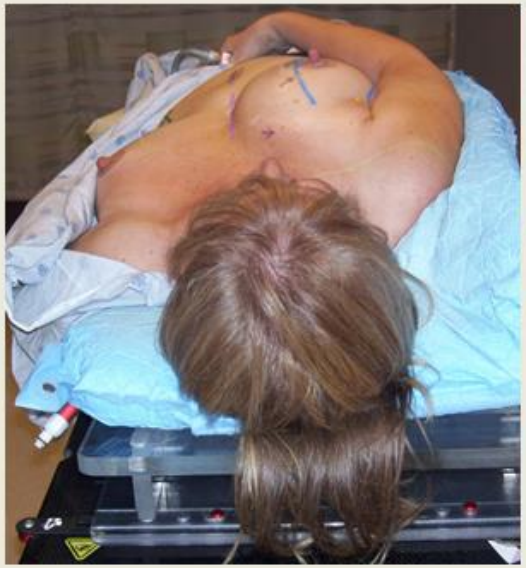
Proton Therapy

Patient 3





2 LAO fields

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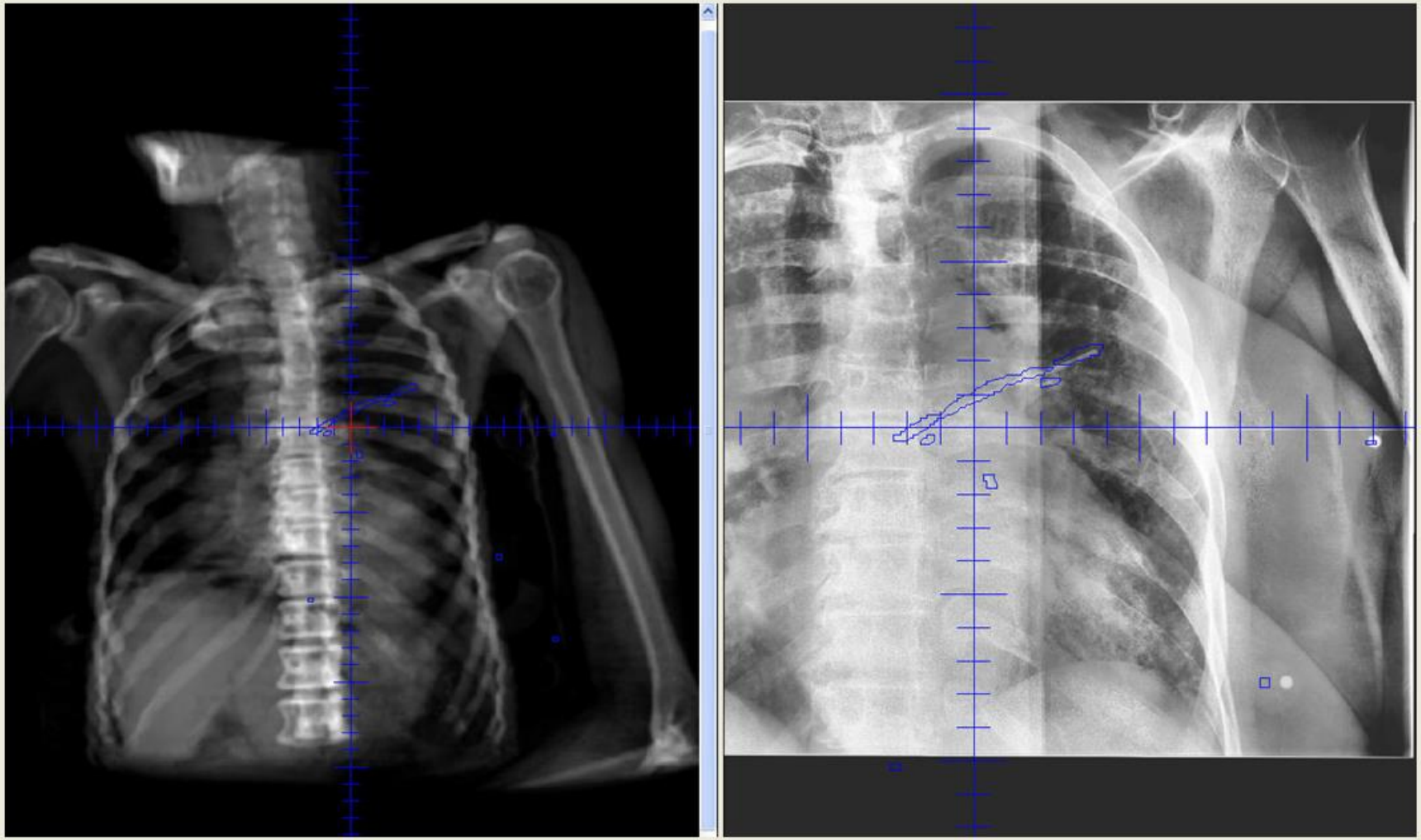
Proton Therapy

Image guidance: Patient 2



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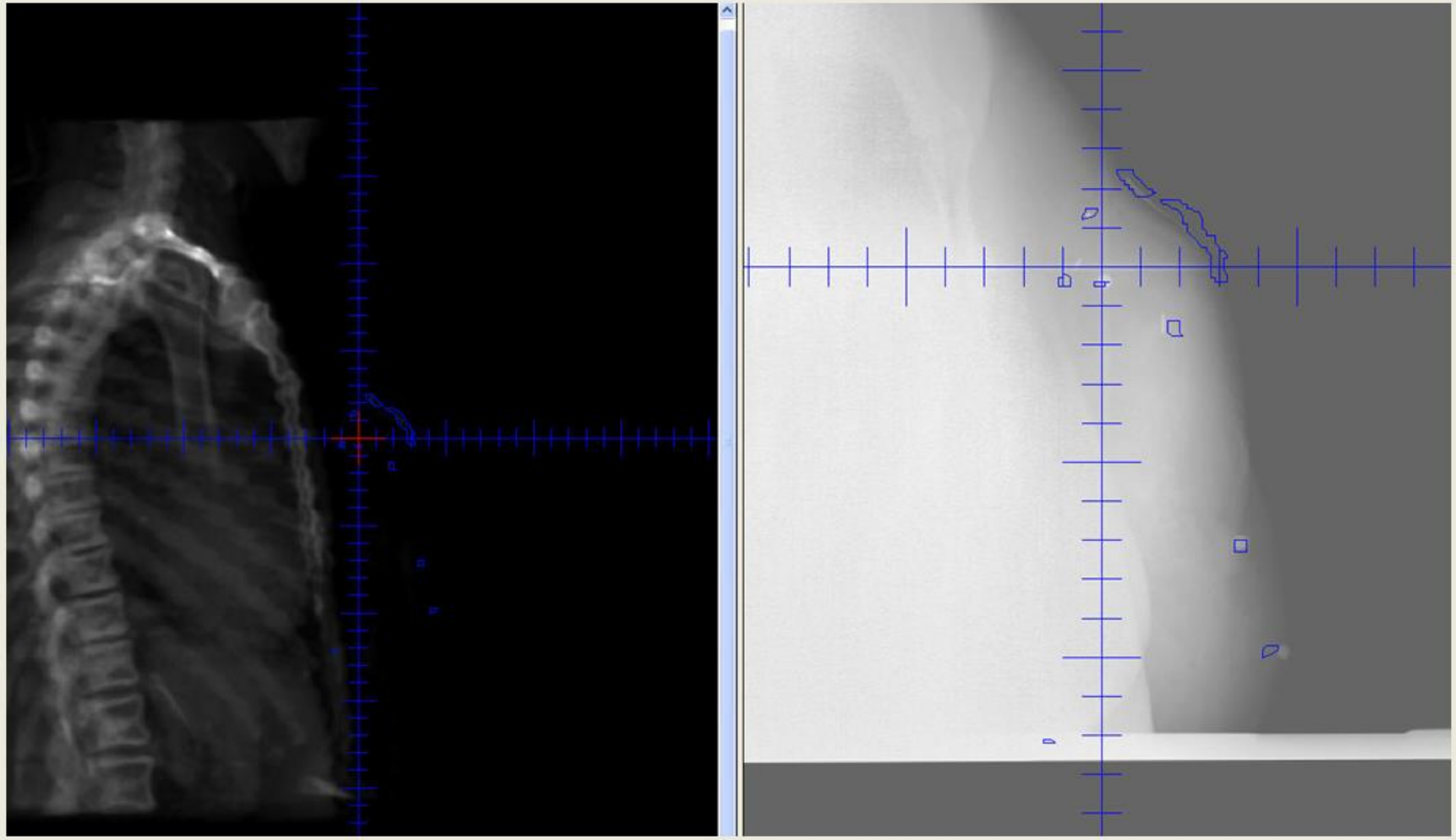
Proton Therapy

Image guidance: Patient 2



INTERNATIONAL JOURNAL of PARTICLE THERAPY

Cone-Beam Computed Tomography and Deformable Registration-Based "Dose of the Day" Calculations for Adaptive Proton Therapy

Catarina Veiga, MSc[1]; Jailan Alshaikhi, MSc[1,2]; Richard Amos, MSc[2]; Ana Mónica Lourenço, MSc[1,3]; Marc Modat, PhD[4]; Sebastien Ourselin, PhD[4]; Gary Royle, PhD[1]; Jamie R. McClelland, PhD[4]

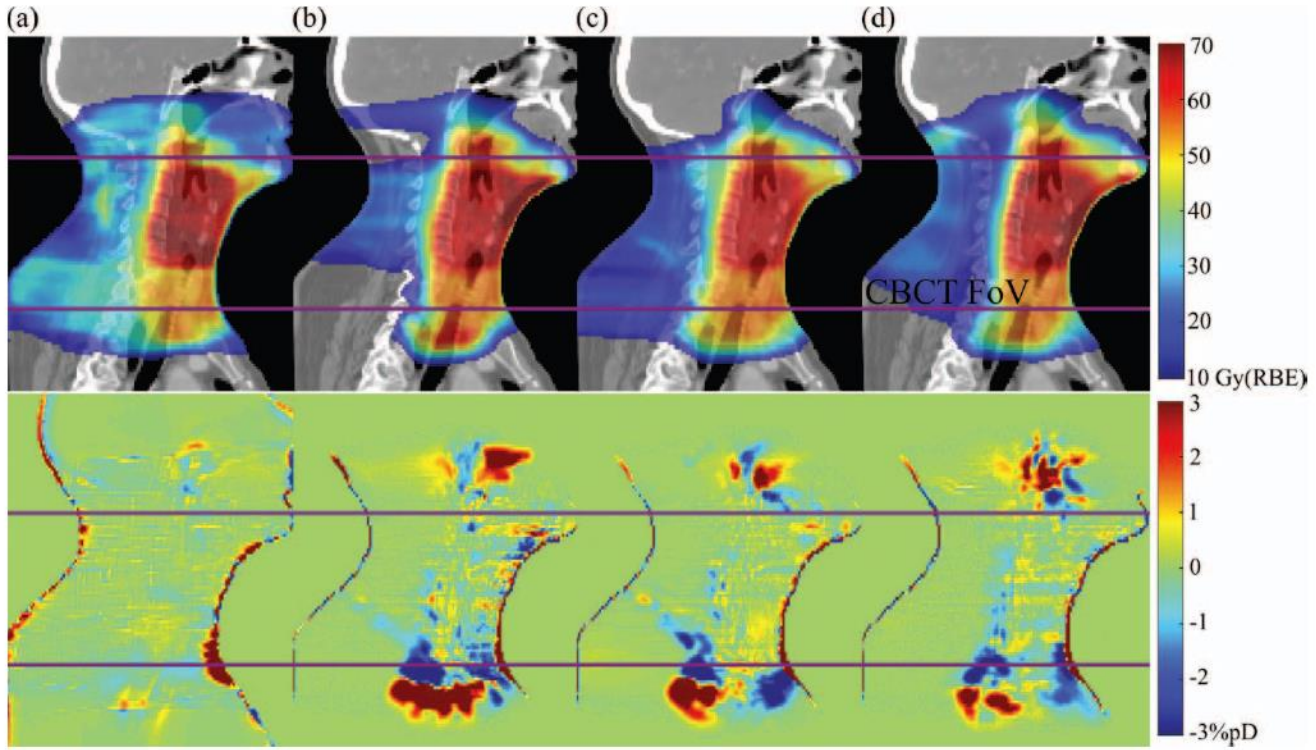
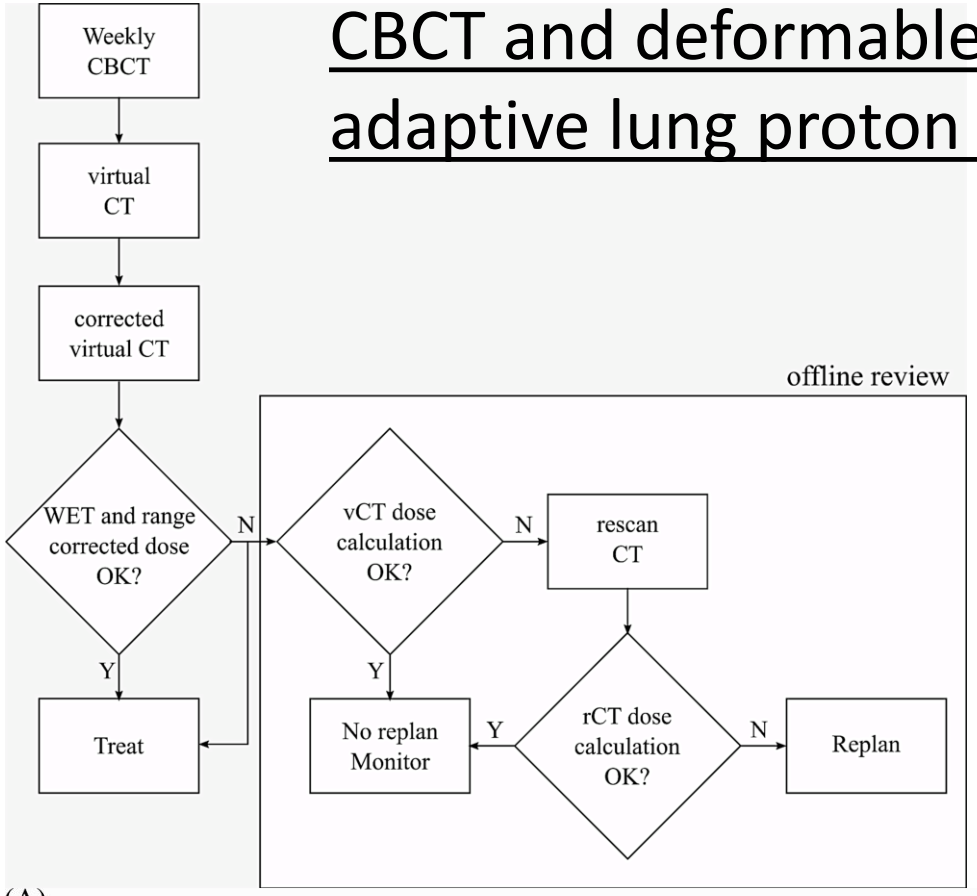
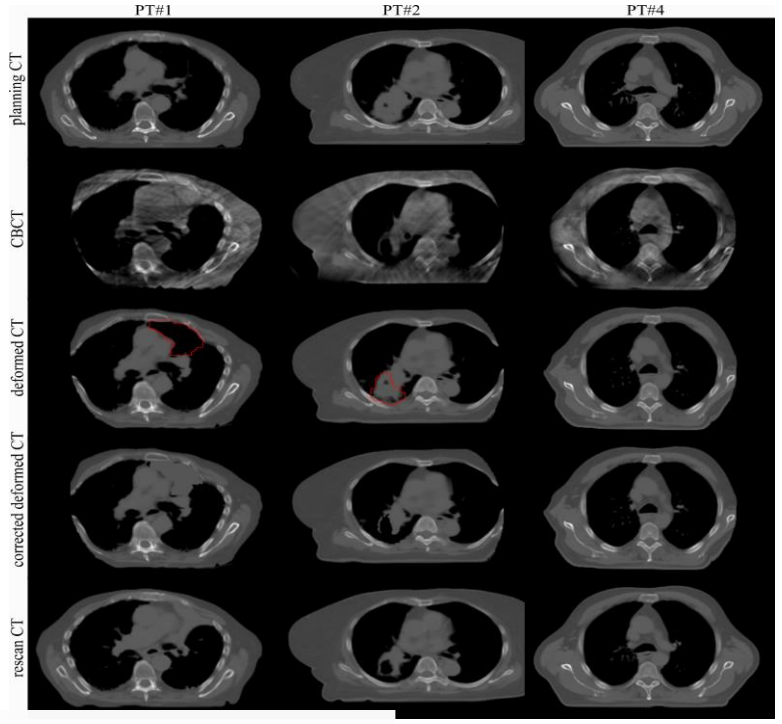


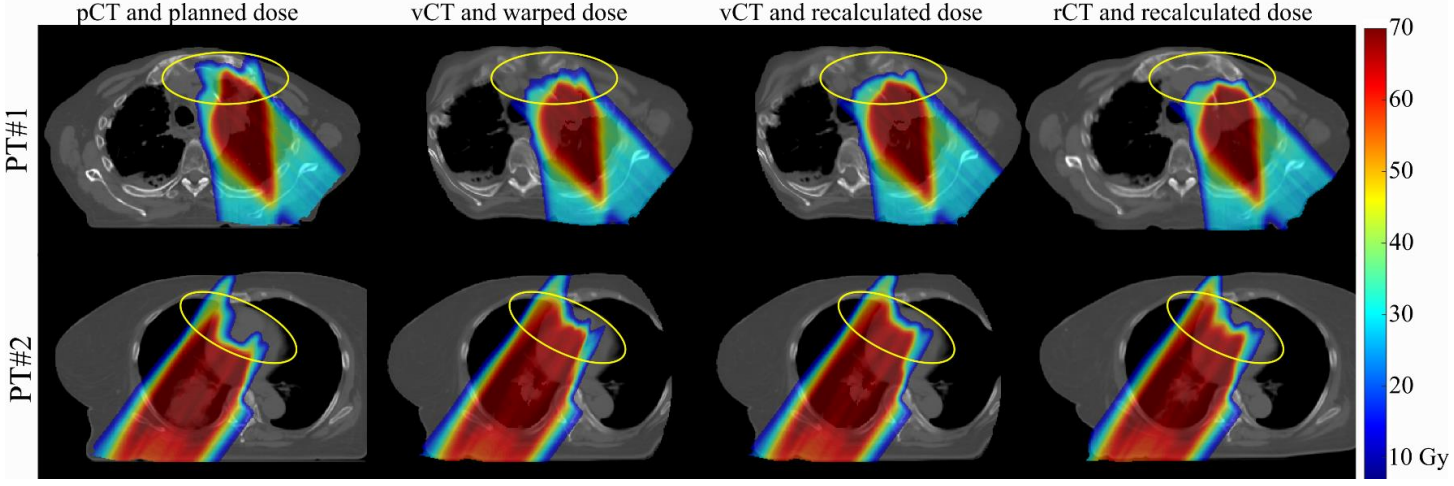
Figure 3. Dose color wash overlayed on the replan CT (top row) and difference in dose between replan CT and deformed CT (bottom row) for (A) the IMRT plan, (B) the $IMPT_{3B}$ plan, (C) the $SFUD_{3B}$ plan, and (D) the $IMPT_{5B}$ plan for one of the patients included in this study. The horizontal purple lines indicate the length of the CBCT FoV. Abbreviations: CBCT, cone-beam computed tomography; CT, computed tomography; FoV, field of view; IMPT, intensity-modulated radiation therapy; IMRT, intensity-modulated radiation therapy; SFUD, single-field uniform dose.

CBCT and deformable image registration for adaptive lung proton therapy - Catarina Veiga





(A)



Future work:

- Head and neck
- Experimental validation with prompt gamma

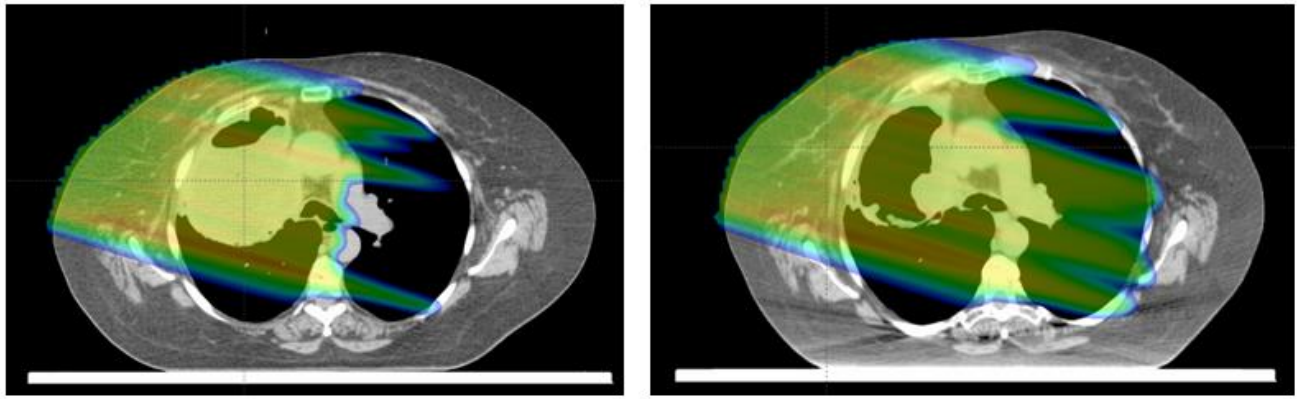


Fig.2 Comparison of dose distribution from single RAO field before and after tumor shrinkage as detected during third week of treatment. (This patient experienced the most dramatic tumor shrinkage).

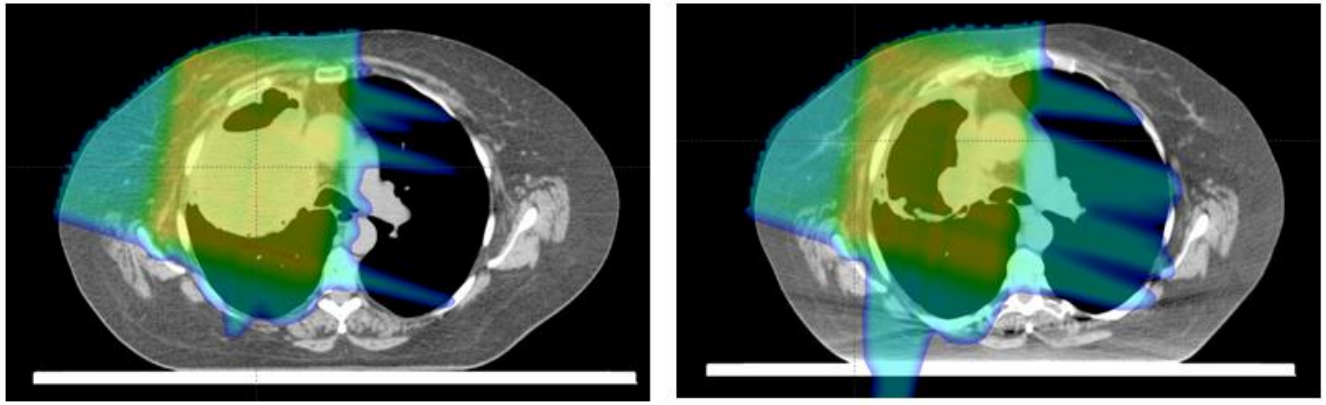
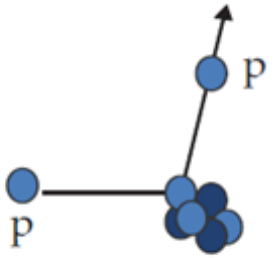


Fig.3 Comparison of total dose distribution before and after tumor shrinkage. (Same patient as Fig.2)

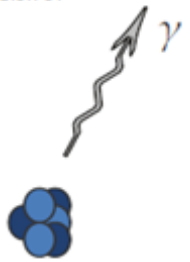
Amos R, *et al.* Variation in dose distribution with tumor shrinkage for proton therapy of lung cancer. Proceedings of PTCOG 46, Zibo, Shandong, China, 2007

In-vivo verification

Prompt gammas

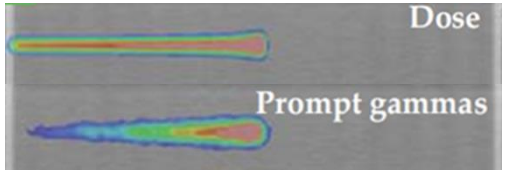


Nuclear scatter promote nuclei to excited states that decay through emission of single gamma

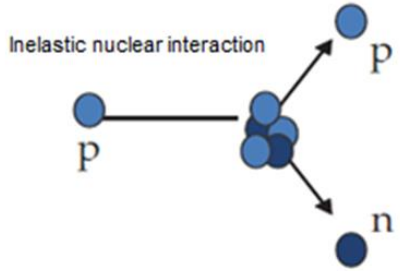


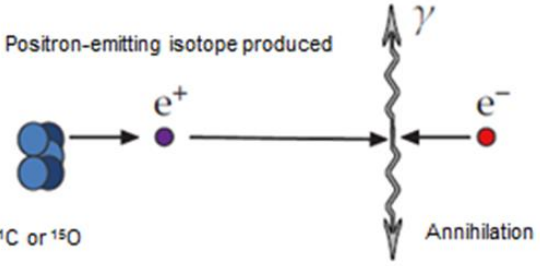
2 – 15 MeV gammas

(Existing imaging systems designed for gamma energies of a few hunded keV)

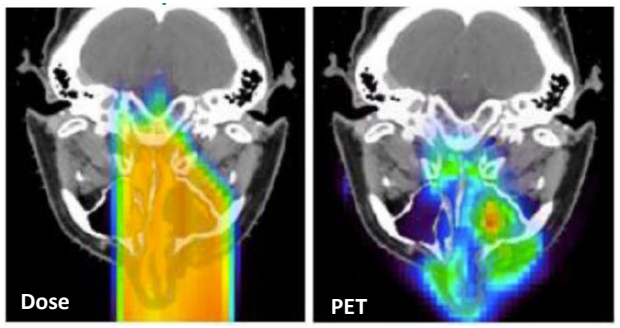


Positron-annihilation gammas

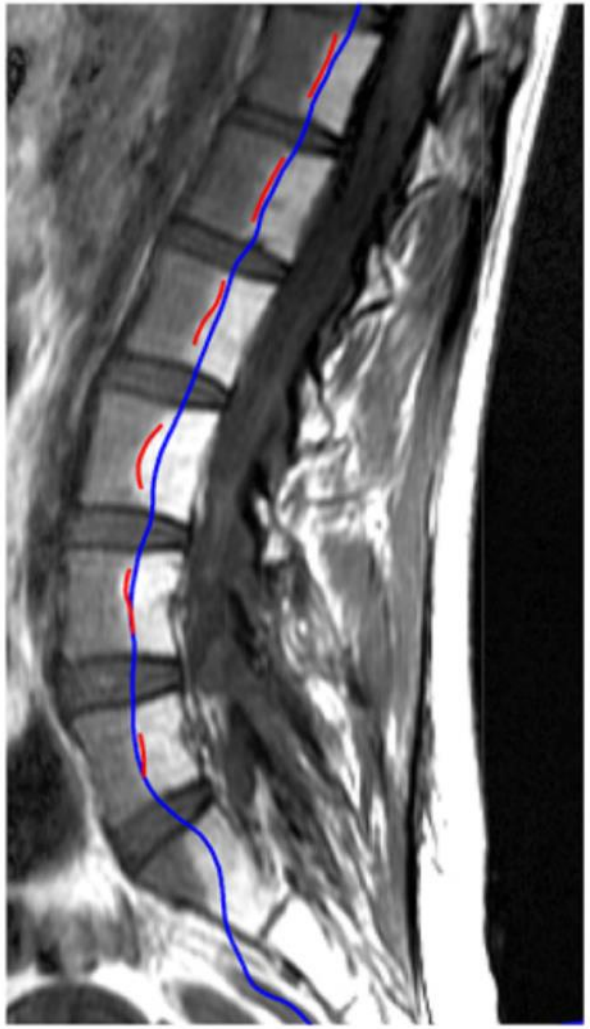




511 keV gammas



MRI



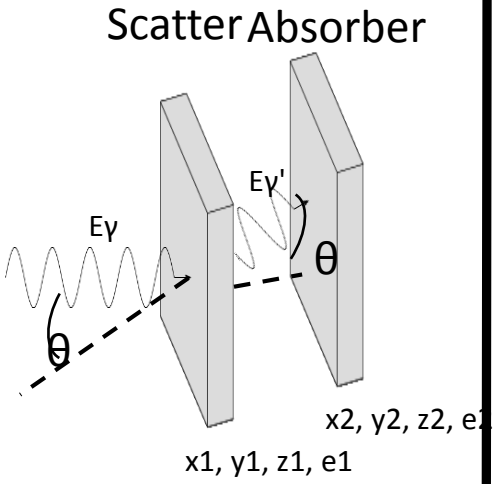
0 1 2 3cm

Pt. 5, 50.4 Gy (RBE)

Prompt gamma imaging for proton range verification during PBT

Andrea Gutierrez
Medical Physics and Biomedical Engineering Department, UCL

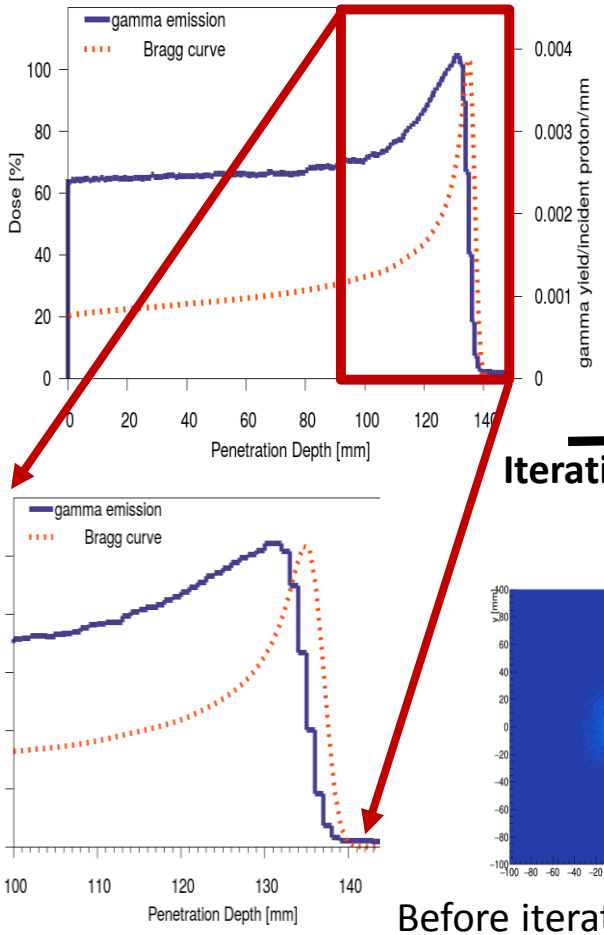
A Compton Camera for prompt gamma imaging



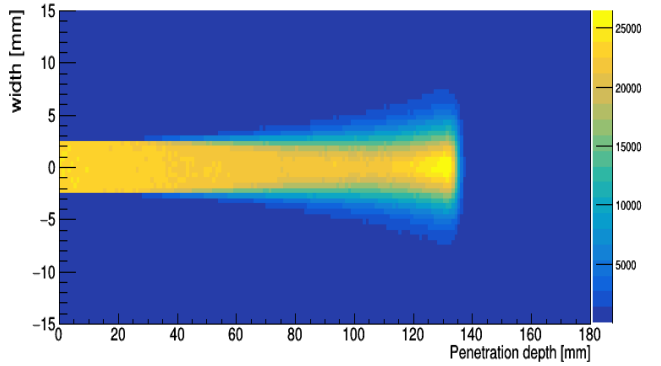
Collaboration:

University College London
University of Liverpool
The Clatterbridge Cancer Centre
The Royal Berkshire NHS Foundation Trust

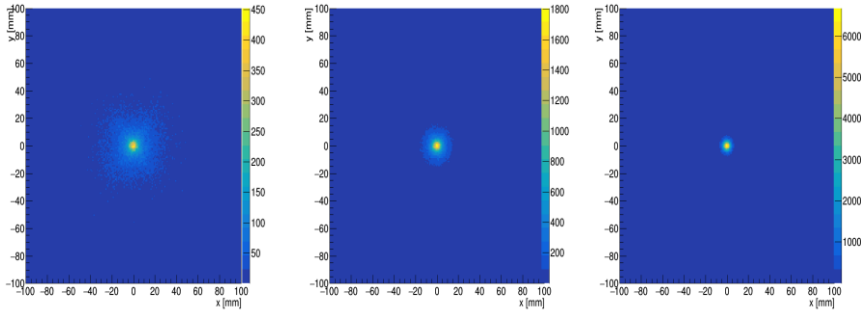
Geant4 simulations of prompt gamma emission



1D and 2D prompt gamma emission from 150 MeV proton beam irradiating a plastic phantom



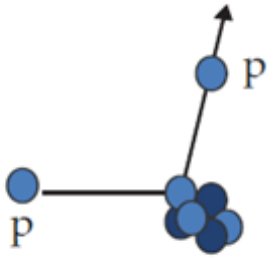
Iterative image reconstruction algorithms for Compton cameras (Stochastic Origin Ensemble)



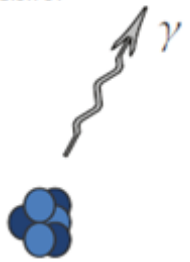
Before iterations After 10 iterations After 100 iterations

In-vivo verification

Prompt gammas

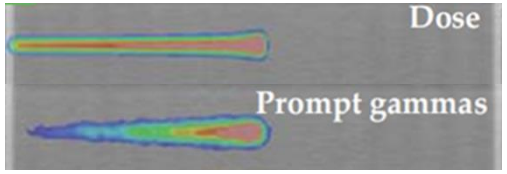


Nuclear scatter promote nuclei to excited states that decay through emission of single gamma

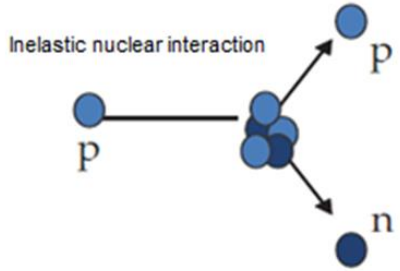


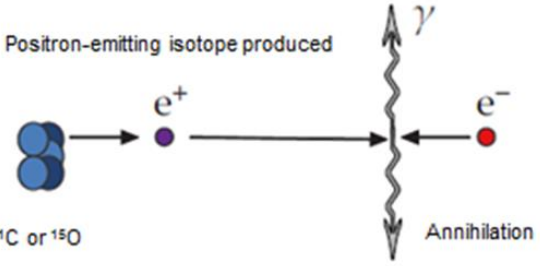
2 – 15 MeV gammas

(Existing imaging systems designed for gamma energies of a few hunded keV)

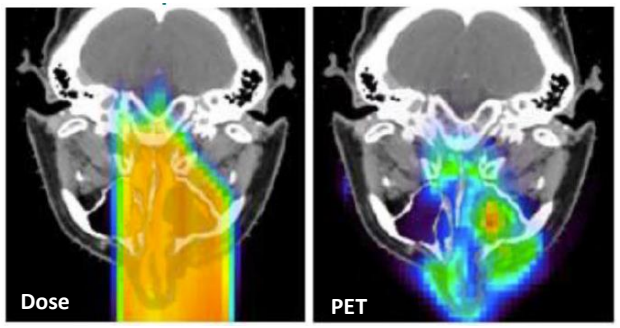


Positron-annihilation gammas

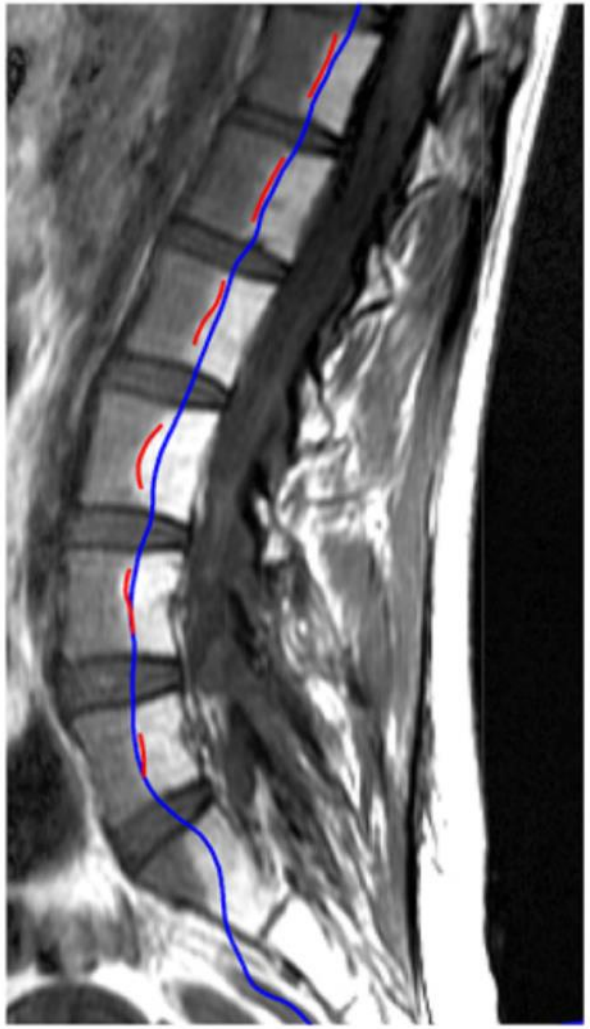




511 keV gammas



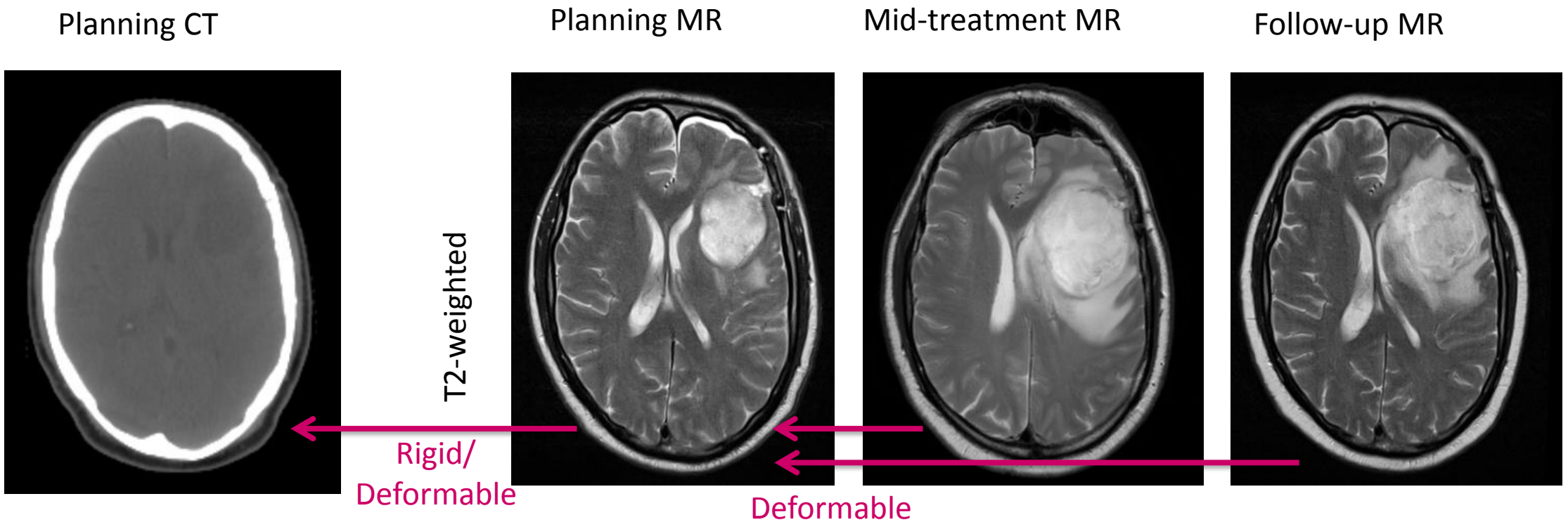
MRI



0 1 2 3cm

Pt. 5, 50.4 Gy (RBE)

MR image registration for radiotherapy applications



Summary

Improve range uncertainty
- Dual-energy CT (DECT)
- Proton radiography/pCT

In vivo range verification
- Prompt gamma imaging
- In-room PET

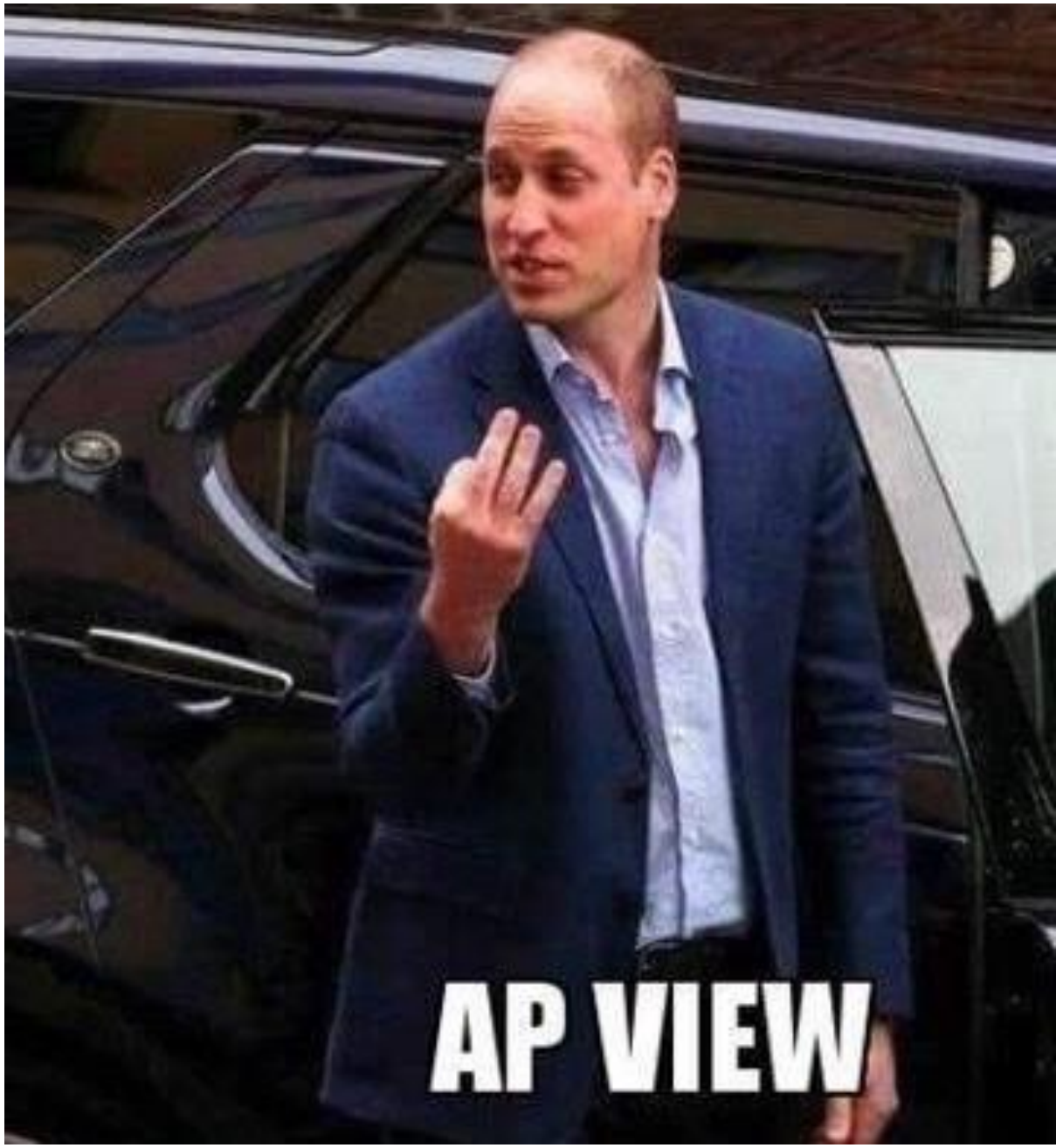
Volumetric image-guidance system
- Cone-beam CT (CBCT)

MRI

Imaging biomarkers
- Predict outcomes
- Adapt to response?

Adaptive therapy


LATERAL VIEW


AP VIEW

Thank you!