Future upcoming technologies and what audit needs to address

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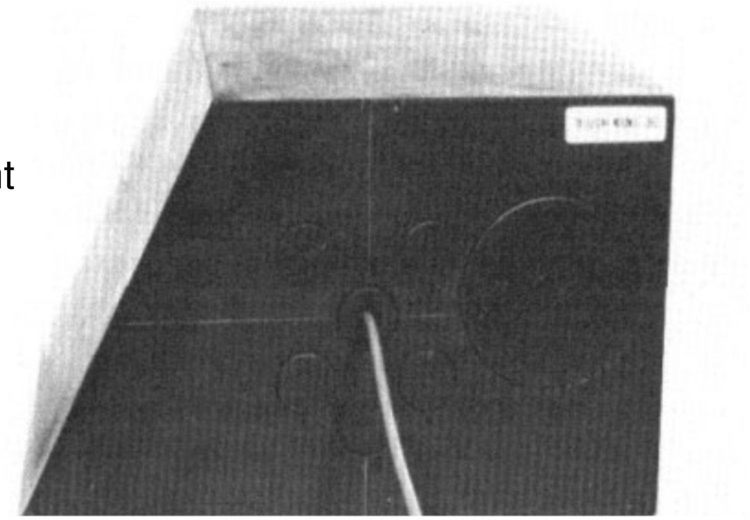
History of audit

- Absolute dose
  - Simple phantom standard dose measurement
- Point doses in beams
  - Phantoms of relatively simple geometry
  - Several points in beam
- Treatment simulation
  - Point doses
  - Semi anatomical phantom
  - Realistic treatment technique
  - Scan – Plan - Treat
- IMRT
  - Absolute dose and dose distribution
  - More complex treatment protocol
- Rotational Audit
  - Challenging geometry
  - Test of planning system and dose delivery
- Advanced techniques
  - SABR



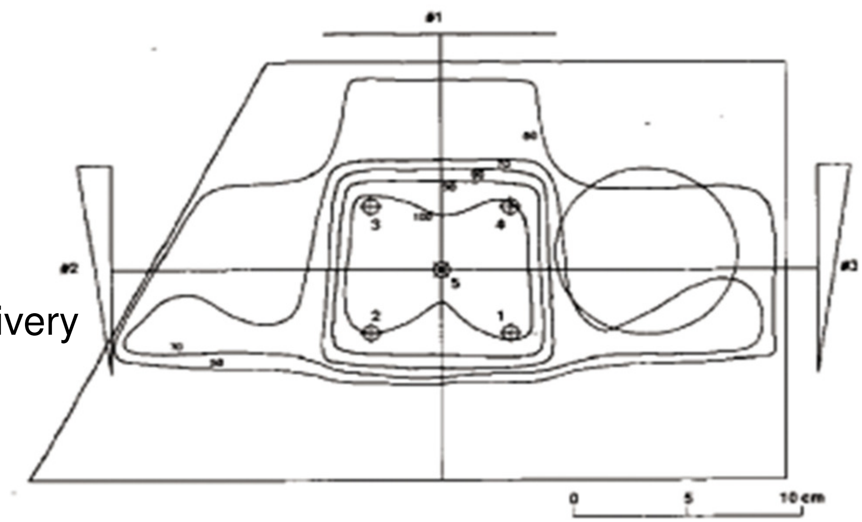


Figure 2. The field arrangement and a typical dose distribution for the planned irradiation showing the positions of the five measurement points.

Advanced Radiotherapy

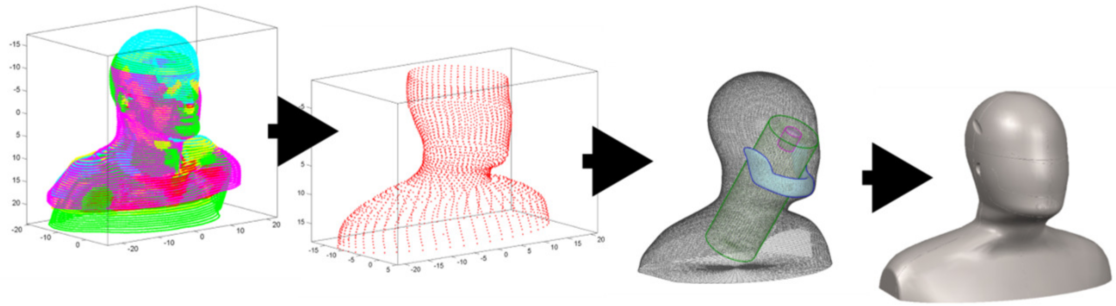
Modality	Small field	High Intensity Modulation	Adaptive Radiotherapy	Imaging	High dose rate	Gating/Tracking
Protons		√	√	√		?
Flattening Filter Free		√	√	√	√	
VMAT		√	√	√	√	
Cyber Knife	√	√		√		√
Tomotherapy		√	√	√		
SRS Linac	√			√		
MR linac		√	√	√		√

Challenges in new technology

- Technology is making dose delivery more diverse
- New technology is a combination of advanced delivery techniques
- Audit is traditionally quite rigid
  - We design the audit for the technique
- Does this fit our model of regional audit
  - Collaborative approaches between those with similar technology
- Can we make the measurement system more flexible

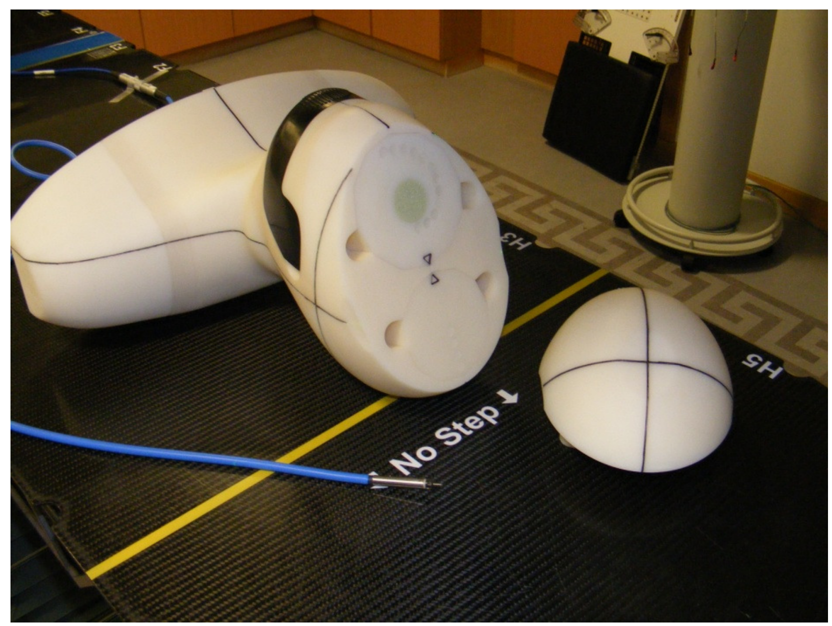
Marvin: Overview

- **M**odel
  Anatomy for
  Radiotherapy
  Verification and Audit
  In the Head and
  Neck



- Average geometry from patient CT scans (4 male, 4 female):
  - Body
  - Mandible
  - Sinuses
  - Spinal cord (location only)

- Mandible and cavity can be swapped for ABS versions to make a homogeneous phantom



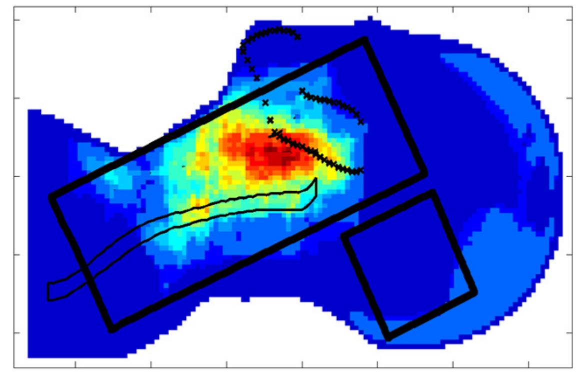
Marvin: Detector module

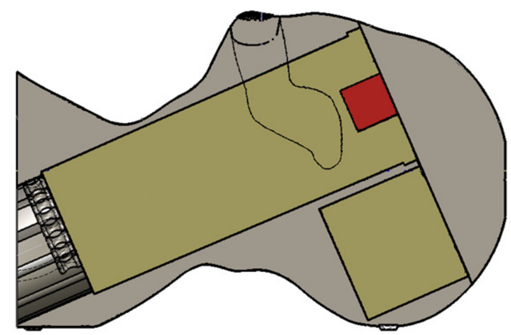
- Cylindrical detector module
  - Location maximises coverage of typical PTV locations and spinal cord
  - Can be designed for any type of detector (film, gel, diode array…)

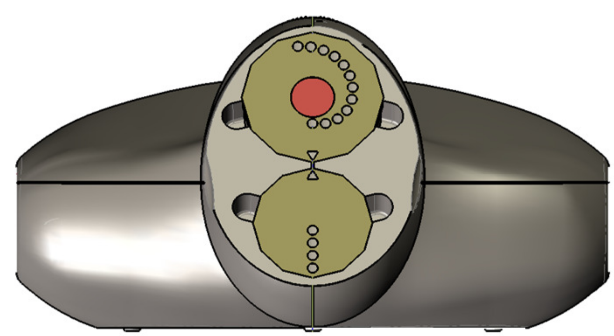
- Prototype module designed for pinpoint ionisation chamber
  - Absolute dose measurements

- Simple chamber positioning system
  - 15 chamber holes from centre to edge
  - Module rotates to 12 fixed positions
  - Depth of chamber set using spacer rods

    Chamber can be positioned almost anywhere within the cylinder

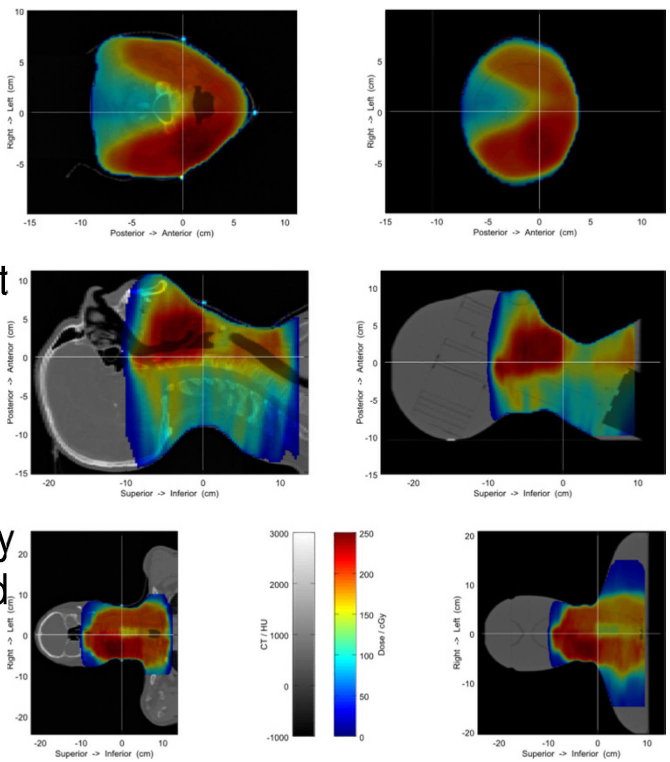






Chamber positioning code

- Need to be able to position chamber:
  - Within the PTV or spinal cord
  - Avoid steep dose gradients
- Detector module has >1500 possible chamber positions
  - Selecting suitable points manually can be difficult
- Software automates point selection
  - PTV located as a percentage of the max dose point (typically 90 or 95 %)
  - Cord position known from average cord geometry
  - Chamber positions lying within these regions and with low dose gradients identified
  - Code currently based on Pinnacle file format



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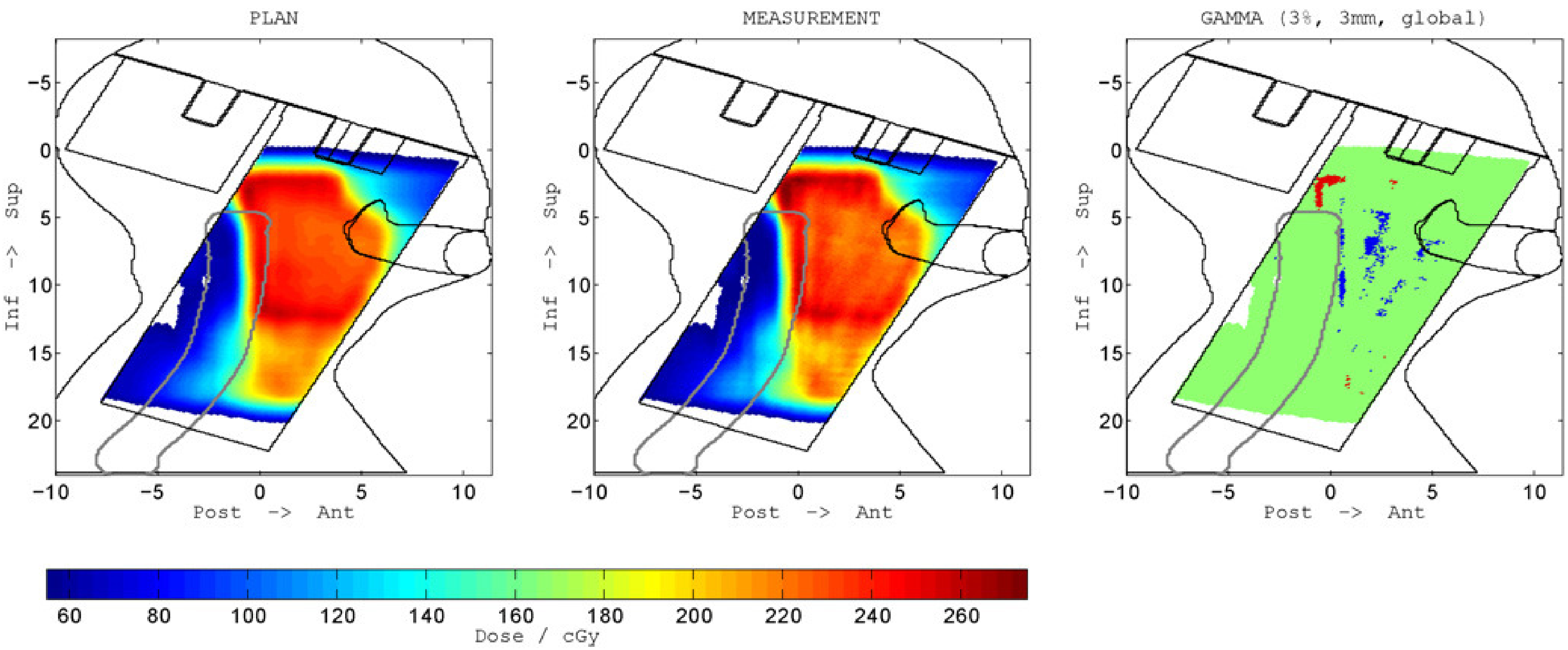
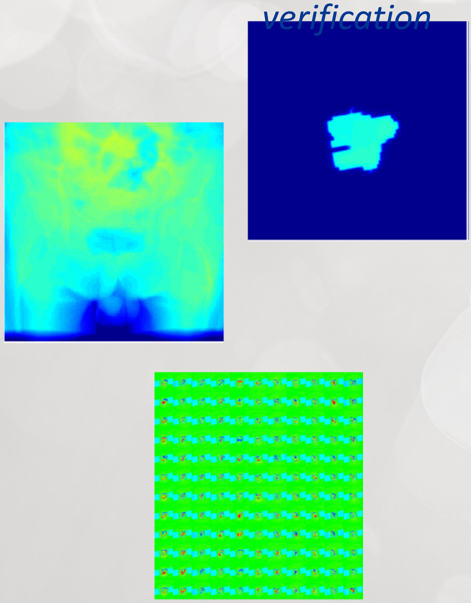
Example audit results

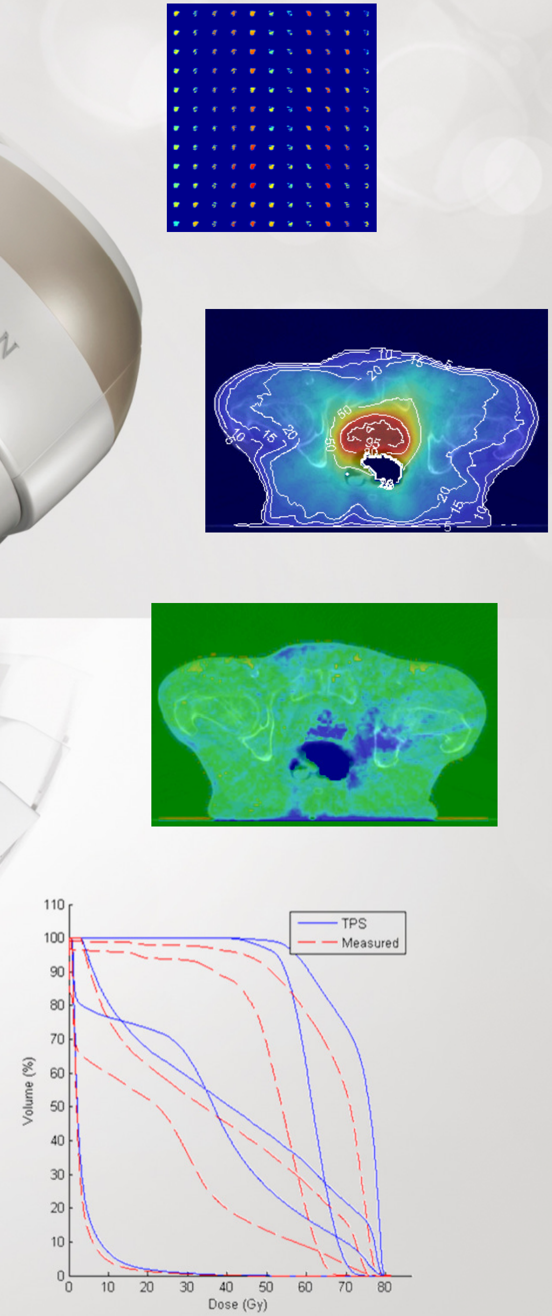


•Phantom Free Audit ?

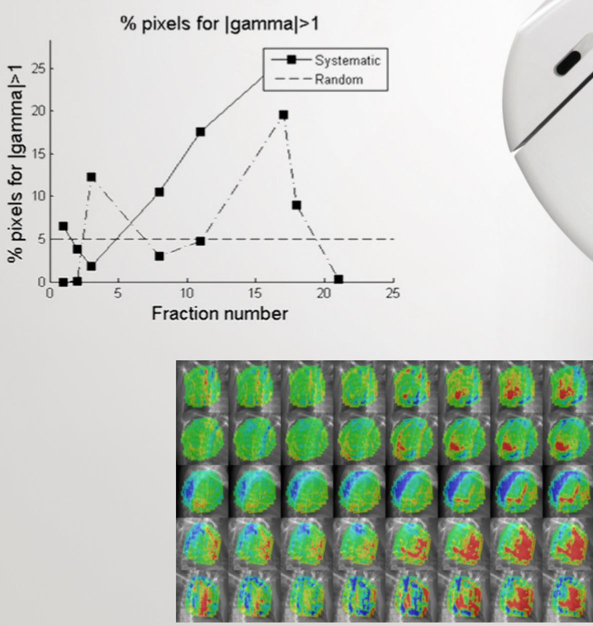
•*2D DGRT – VMAT verification*



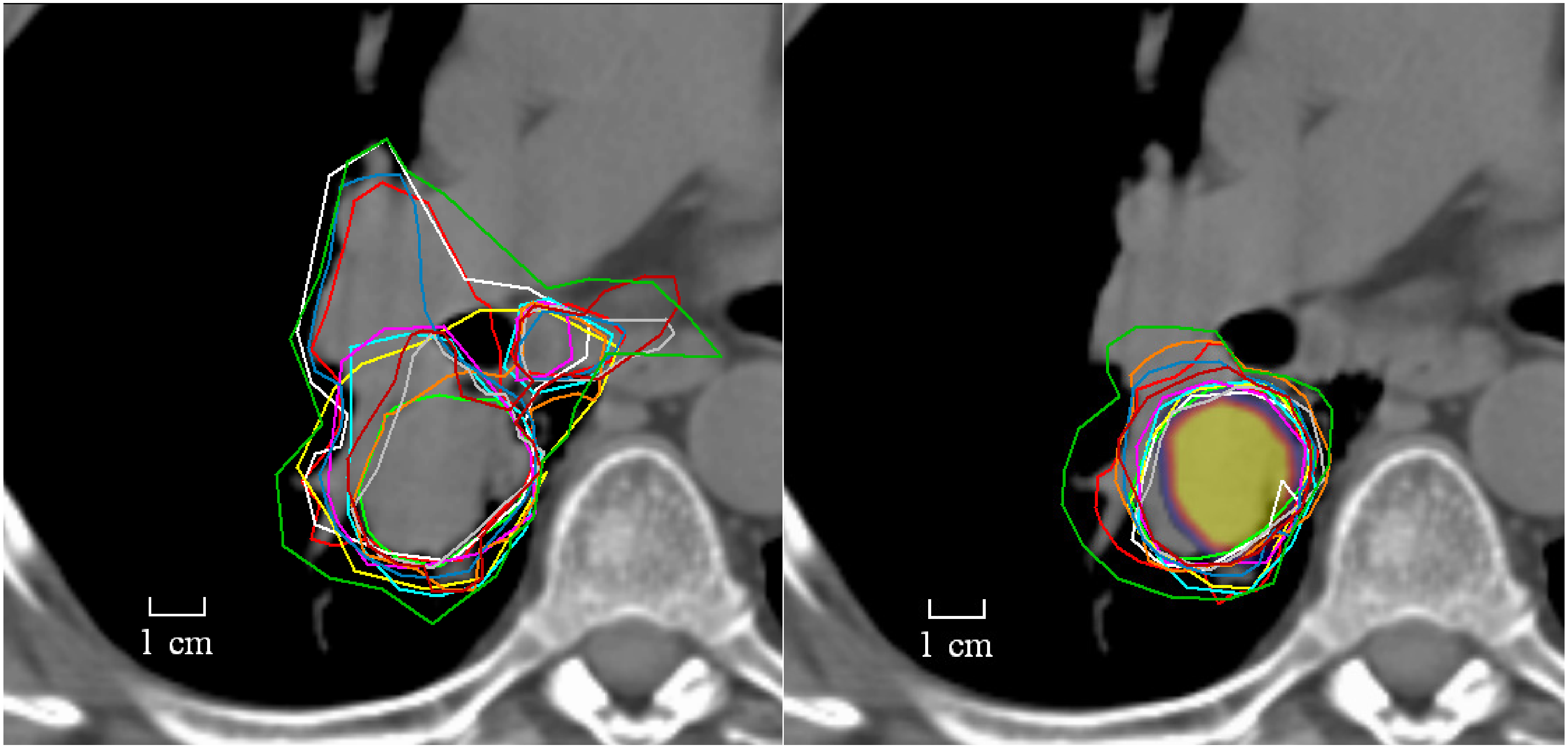
•*3D DGRT – Dose reconstruction*



•*2D DGRT – Trend analysis*



Delineation variation: CT versus CT + PET



•Steenbakkers et al, IJROBP 2005

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Potential uses of PET in RT planning

1. Improved diagnosis and staging of disease
   - Improved sensitivity and specificity of FDG-PET
   - Can detect distant metastasis and advanced disease

TABLE 1
Comparison of CT and ^{18}F-FDG PET for Staging of Lymph Node Involvement

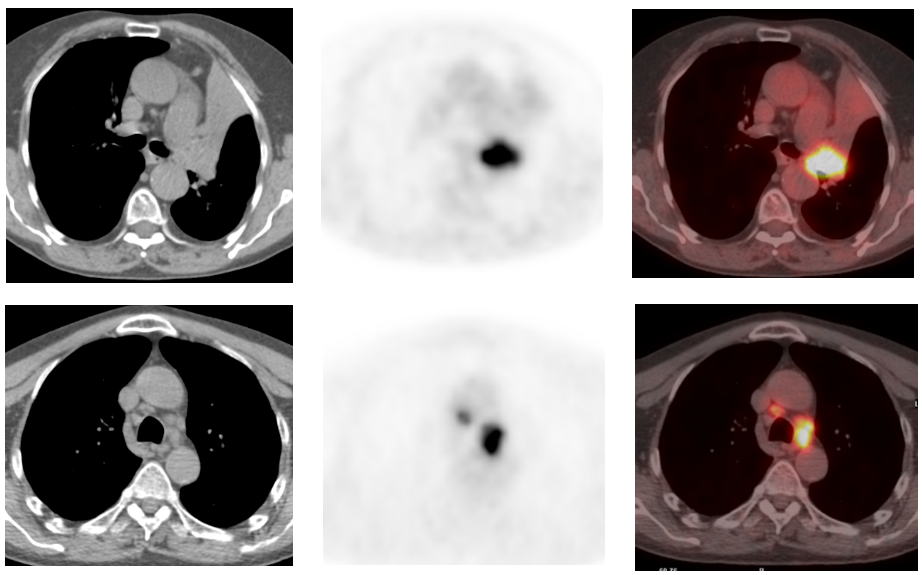
Cancer (reference[s])	% Sensitivity		% Specificity	
	CT	^{18}F-FDG PET	CT	^{18}F-FDG PET
Head and neck (*19–25*)	36–86	50–96	56–100	88–100
NSCLC (*27–31*)	45	80–90	85	85–100
Cervical carcinoma (*34–36*)	57–73*	75–91	83–100*	92–100
Esophageal (*32*)	11–87	30–78	28–99	86–98

*CT or MRI.

- Gregoire et al, J Nuc Med 48(1)S, 2007

Potential uses of PET in RT planning

2. Tumour delineation

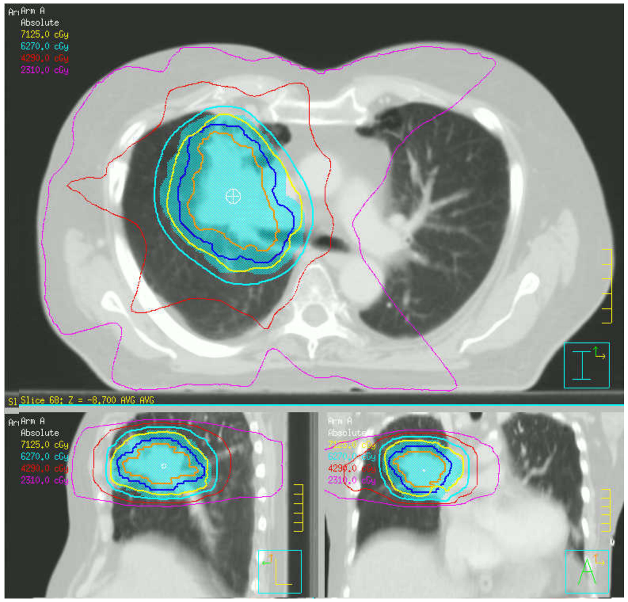


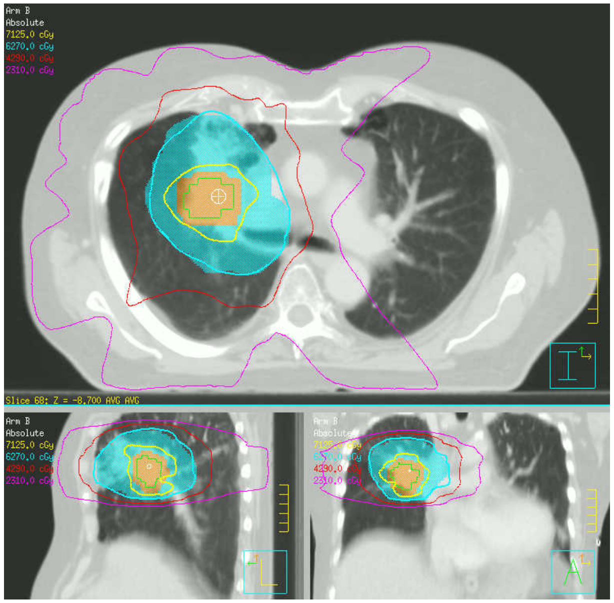
- Tumour boundary

- Involved lymph nodes (10-25%)

Potential uses of PET in RT planning

3. Dose modulation

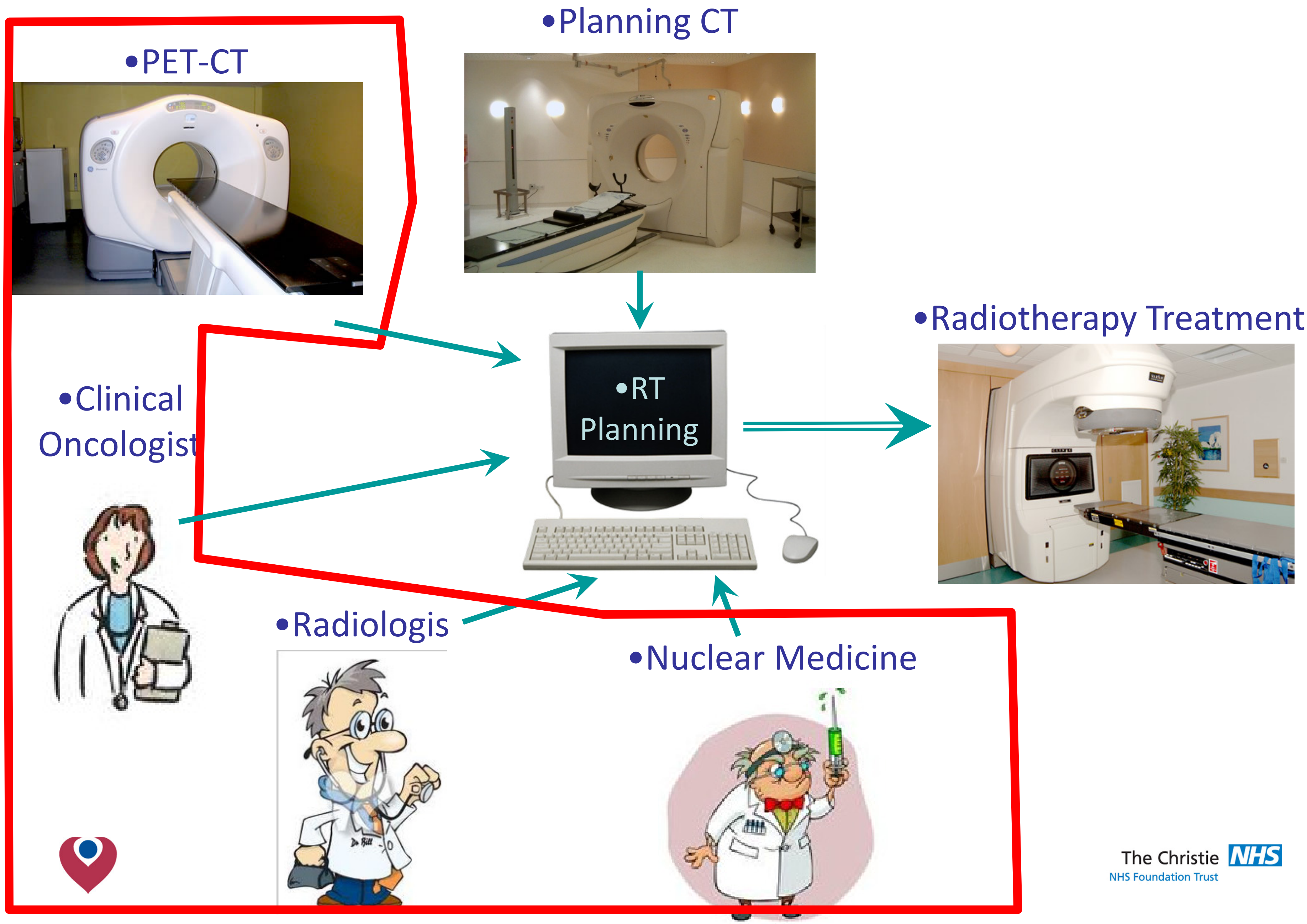




- Targeted conformal high dose
- Isotoxic dose escalation
- Improved local control with no increase in toxicity?

4. Prediction / monitoring treatment response

Transfer of Information



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•www.ncri-pet.org.uk

Site Approval

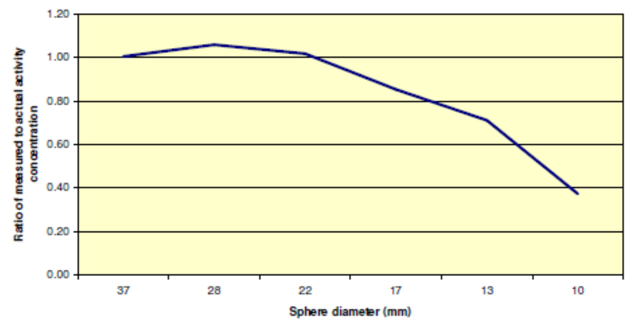
PET Centre:	**WMIC**
Scanner Manufacturer and Model:	**Siemens Biograph TrueV6**
Analysis performed by:	**LP**
Date of Phantom Analysis:	**06/04/2011**

Qualitative Analysis:

Image Quality	Acceptable	~~Not acceptable~~
PET/CT alignment on core centre reporting system	Acceptable	~~Not acceptable~~
Comments	**analysed on Hermes Gold 3 hybrid viewer.**	
Sphere activity concentration at scan start time:	21.60	kBq/ml
Background activity concentration at scan start time:	4.45	kBq/ml

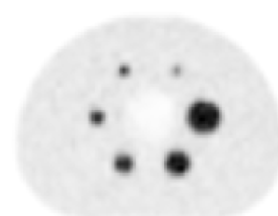
	Activity Concentration		
	Measured (M)	**Actual (A)**	**Ratio**
Sphere diameter (mm)	**kBq/ml**	**kBq/ml**	**M/A**
37	21.72	21.60	1.01
28	22.88	21.60	1.06
22	22.00	21.60	1.02
17	18.43	21.60	0.85
13	15.36	21.60	0.71
10	8.05	21.60	0.37
Background	4.03	4.45	0.90

A recovery curve should be generated from the tabulated data:



Average SUV for a large ROI positioned over the background: **0.91** (1±0.1)

Recovery Curve:	Acceptable	~~Not acceptable~~

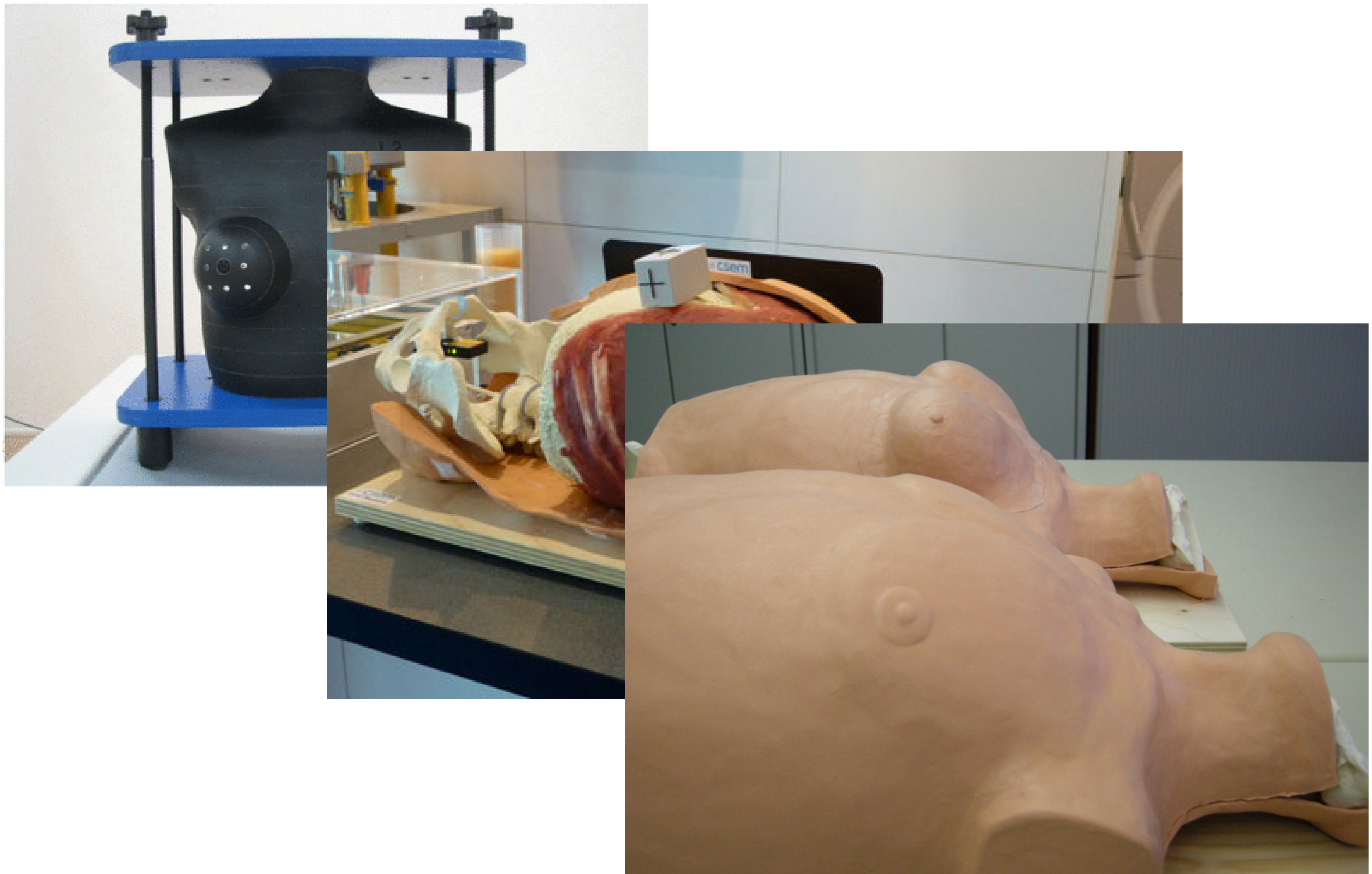


Protons

- Uncertainties in proton therapy are greater
  - Uncertainty in proton stopping power
  - Inhomogeneities
  - Set up uncertainties have a greater effect
  - Changes in patient anatomy
- Dose delivery for scanned beams is highly intensity modulated using very small delivery fields

  -Motion is a well known problem in scanning proton therapy
- Dose delivery for IMPT is not in itself robust
- Require dosimetry for protons at same level of photons

Audit for proton therapy



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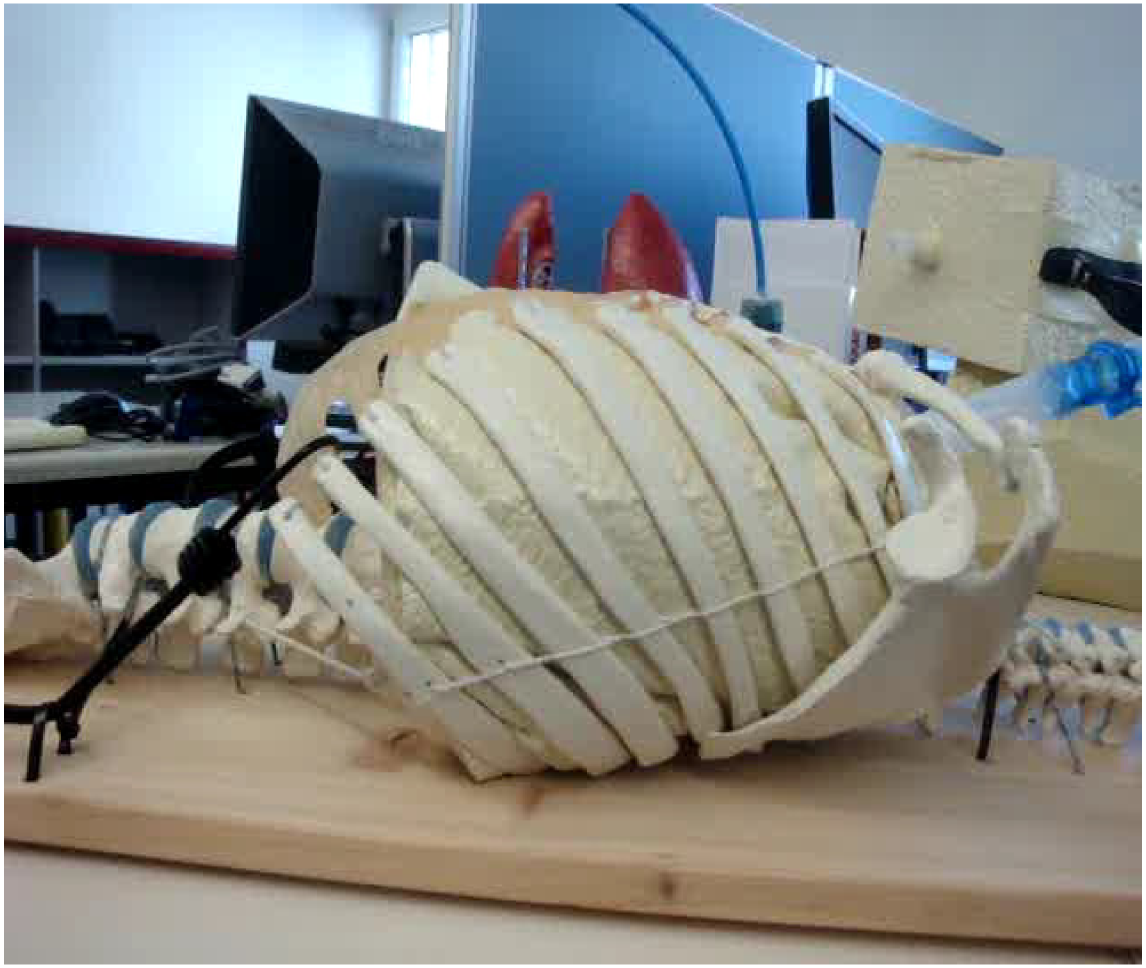
•Validation (4D dosimetry)

csem

• Introducing 'Oscar' – a 4D, anthropomorphic phantom



•Zakova et al, P142, PTCOG 52

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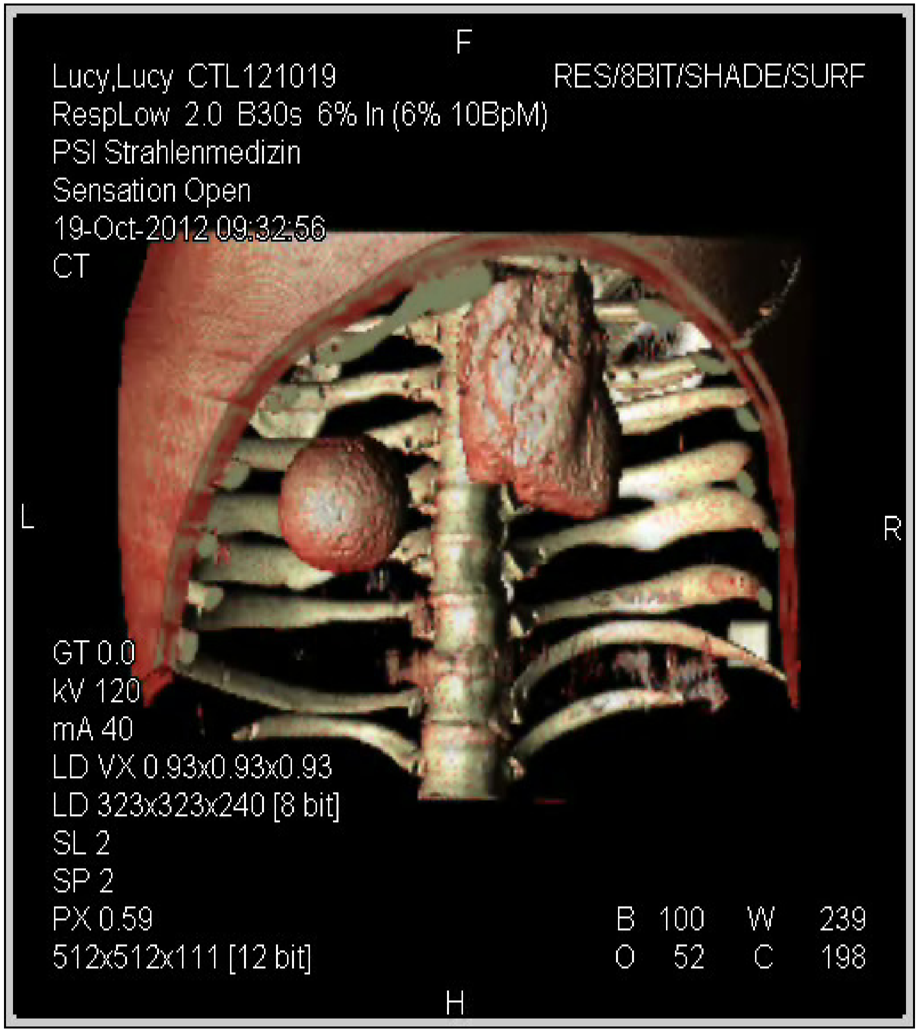
•Validation (4D dosimetry)

•4D CT of ‘Oscar’



•Zakova et al, P142, PTCOG 52

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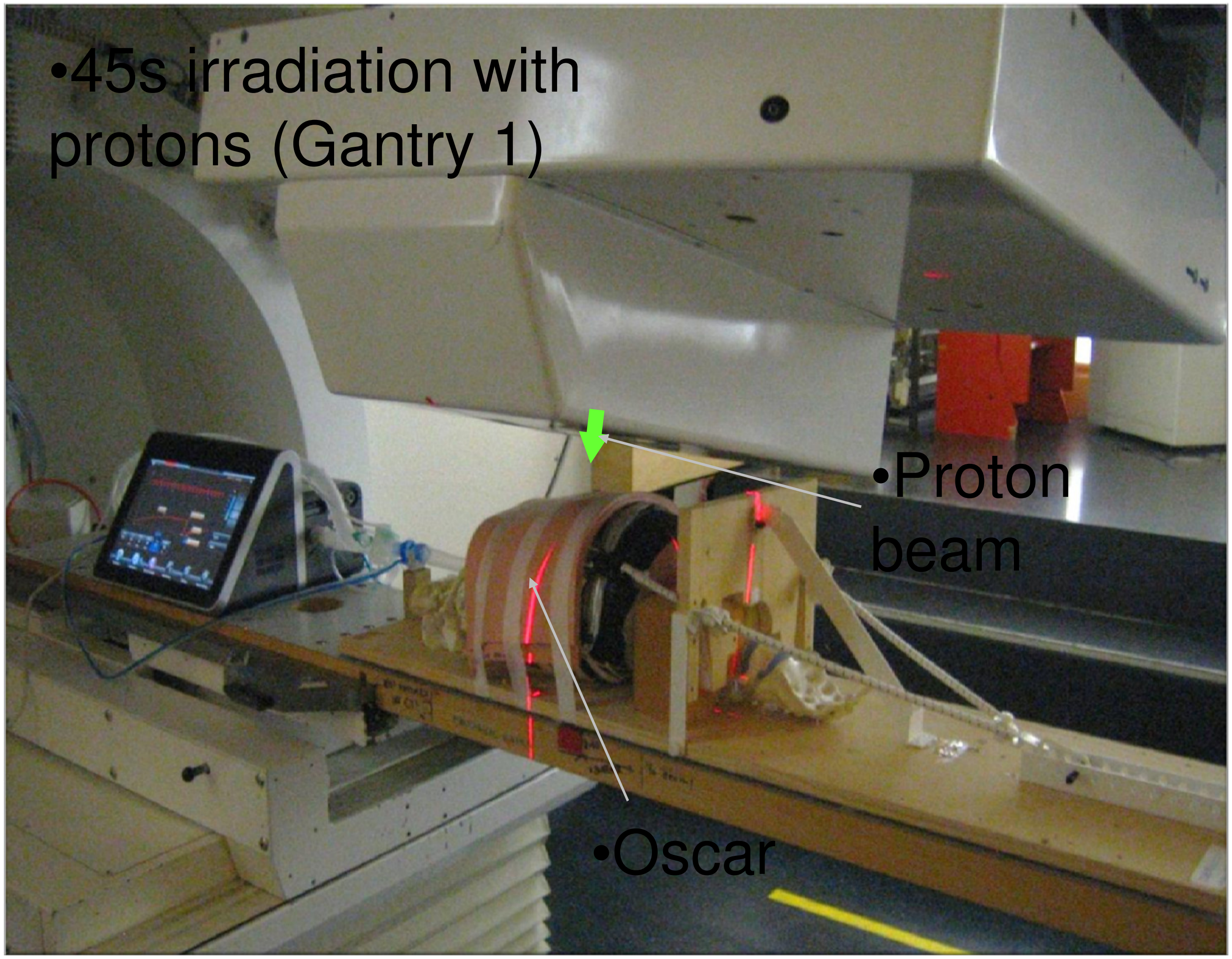
•Validation (4D dosimetry)

•'Oscar' has been irradiated



•Zakova et al, P142, PTCOG 52

Where will it end?

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Summary

- Dosimetric audit is a powerful tool and has served radiotherapy well
- Treatment techniques become more diverse as technology progresses and audit must become more flexible
- Greater collaboration between users of particular delivery systems
- Need to extend the audit process to include additional information that will increasingly affect how we deliver radiotherapy
  - Particularly functional imaging
- Require dosimetry for protons at same level of photons.

  - New tools for audit required

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