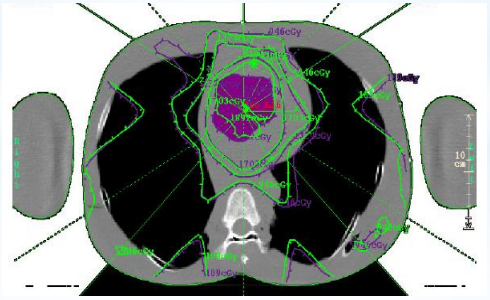
2nd UK and Ireland Dosimetry Check User Meeting Symposium

Clatterbridge Cancer Centre, 24th October 2012

Introduction to Dosimetry Check



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Introduction

My experience with Dosimetry Check:

- Beta testing of the system's transit dosimetry module and installation of pre-treatment module – Edinburgh Cancer Centre May 2010
- MSc thesis – reproducibility, sensitivity, phantom measurements, new kernels, clinical results
- September 2011, Dosimetry Check installed at Royal Surrey County Hospital; clinical pre-treatment and in-vivo results for 47 IMRT/RapidArc patients

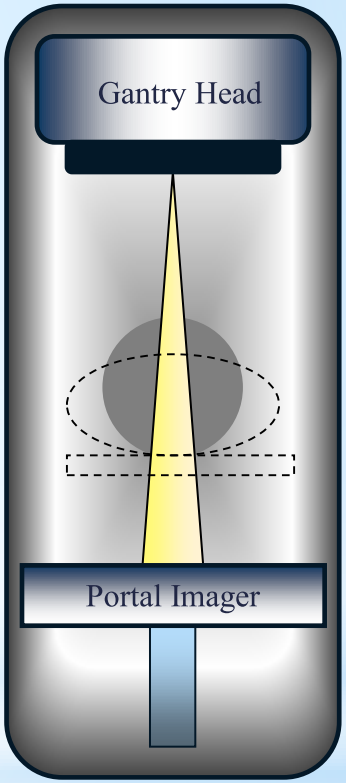
Dosimetry Check

What is Dosimetry Check?

- Dosimetry Check is software which uses the portal images acquired during treatment (through the patient) to calculate **absolute dose** to the patient
- Dose Guided Quality Assurance (DGQA) system which provides dosimetric reconstruction and verification
- Provides **full 3D volumetric** information throughout the patient contour
- Suitable for IMRT and VMAT
- Vendor independent
- Developed by Math Resolutions LLC[2], distributed in the UK by OSL

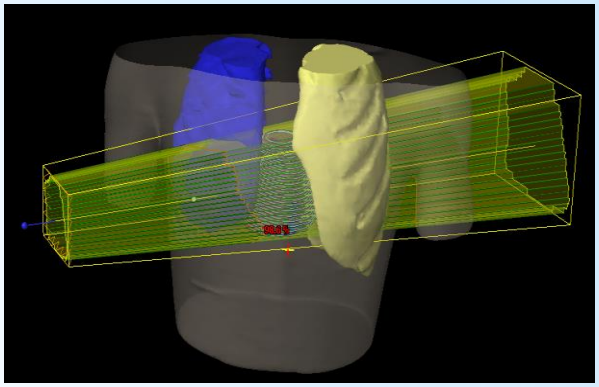
The System

- It has been widely adopted that EPID dosimetry is the future for performing patient specific QA[3,4]
- Dosimetry Check is a well established system used in many centres worldwide
- **Pre-treatment QA** is performed by exposing the treatment plan directly to the EPID, in the absence of the patient or phantom
- "**Transit dosimetry**" allows in-vivo measurements of patient dose using the portal images acquired during the patient treatment[6]
- The system reconstructs patient dose based on in-air fluences calculated from the EPID images to produce a 3D dose distribution projected on the patient CT[5]



How does it work?

* Images are acquired of the beam exiting the patient, in integrated mode for static gantry treatments and continuous/cine mode for dynamic arc therapies



* Incident beams are divided up into multiple small beamlets and assigned an intensity weighting from the measured fluence map
* A 10x10cm 100MU calibration image is used to map each pixel on the fluence image to a **Relative Monitor Unit** (RMU)
* The RMU relates the exposure level of each pixel to that at the centre of the calibration image in order to compute absolute dose using a pencil beam algorithm

Setup Requirements

* **Existing data**: PDDs, Output Factors, MU definition, CT density values
* **Measured data**: Calibrate EPID, collect a series of integrated images of square fields
* **Transit measured data**: Collect square field images through increasing thicknesses of water

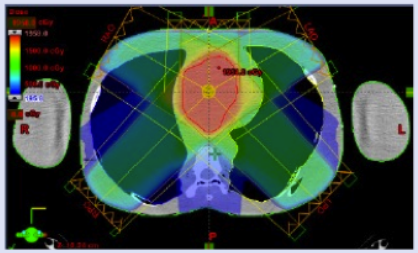
This data is used to create the measured source model

* The deconvolution with the point spread function (psf) of the EPID gives in-air fluence
* A downhill search algorithm minimises the variance between reconstructed dose from images and dose to water until a sufficiently small step size is achieved (~1%)
* The psf is modelled using the sum of five exponentials

$$p.s.f. = \sum_{i=0}^{i=5} A_i e^{B_i *}$$

* The in-air off-axis ratio restores the beam horns removed during calibration

* The Clinical Pathway



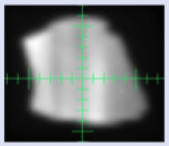
TPS plan, dose matrix, structures and CT/CBCT

Portal image for each field

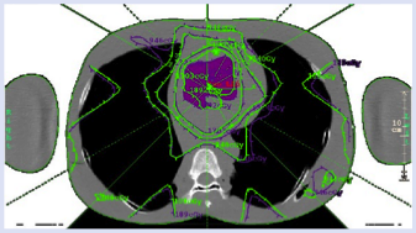
Calibration file

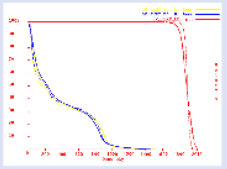
Dosimetry Check

- Measured source model
- Calibration file
- Deconvolution kernel
- Image mapped to RMU
- Weighted fluence map determines dose to patient



Report generated directly comparing dose generated by Dosimetry Check with that computed by the TPS





Isodose overlay and DVH

The Report

- Points Summary
  - Points Summary generated in seconds
  - Shows dose contribution from each beam
  - Quick comparison between TPS/DC doses at defined reference points
  - pdf format

Total Dose cGy	1946.3
Plan Dose cGy	1891.7
Difference %	2.88% of 1891.7

Specific Points

CPU ID 37952771536794 By leila
Version 3, Release 1, 12 May 2010
Patient Name: , DEMO_LN

Page 1
02-Sep-2010-10:37:16(hr:min:sec)

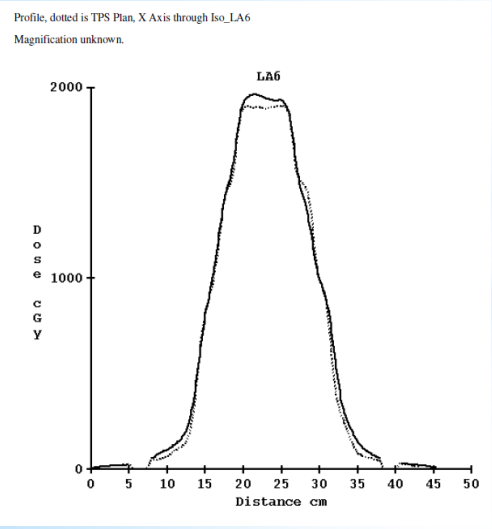
Plan: LA6
EXIT: Evaluation only, not for Clincal Use
Number of Fractions/Normalization Factor: 10
CT to Density File Name: Varian_UK
External Contour Name: BODY

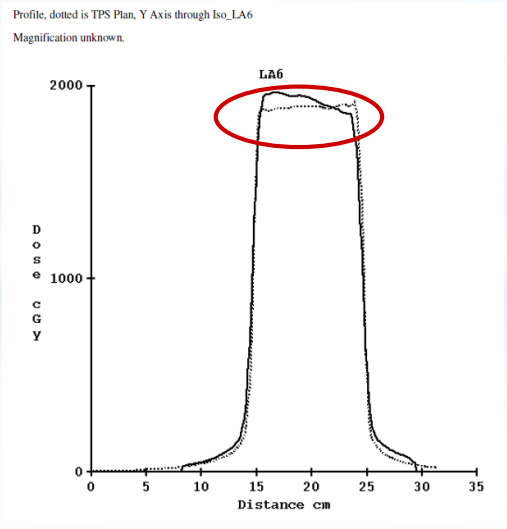
Specific Points LA6, ID=7

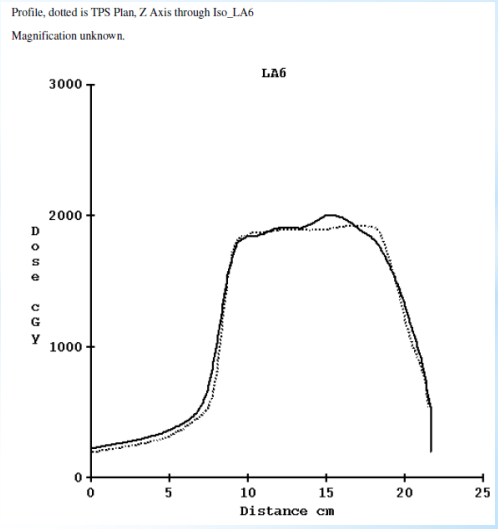
Point Name:	**Iso_LA6**
	x, y, z cm
Coordinates	-0.8, 1.1, 7.6
	Dose cGy
AP	466.8
Machine Name	LA6
Check Type	Exit-Integration
BEV Coordinates	-0.0, -0.0, 0.0
LAO	393.7
Machine Name	LA6
Check Type	Exit-Integration
BEV Coordinates	-0.0, -0.0, -0.0
LPO	355.2
Machine Name	LA6
Check Type	Exit-Integration
BEV Coordinates	-0.0, -0.0, -0.0
RAO	392.5
Machine Name	LA6
Check Type	Exit-Integration
BEV Coordinates	0.0, -0.0, 0.0
RPO	338.1
Machine Name	LA6
Check Type	Exit-Integration
BEV Coordinates	0.0, -0.0, 0.0
Total Dose cGy	1946.3
Plan Dose cGy	1891.7
Difference %	2.88% of 1891.7

The Report

- Full Report
  - User select what to include: 2D dose profiles, isodose overlays, gamma analysis, dose volume histograms, gamma volume histograms, beam statistics and more…
  - ~5-30 minutes
  - pdf

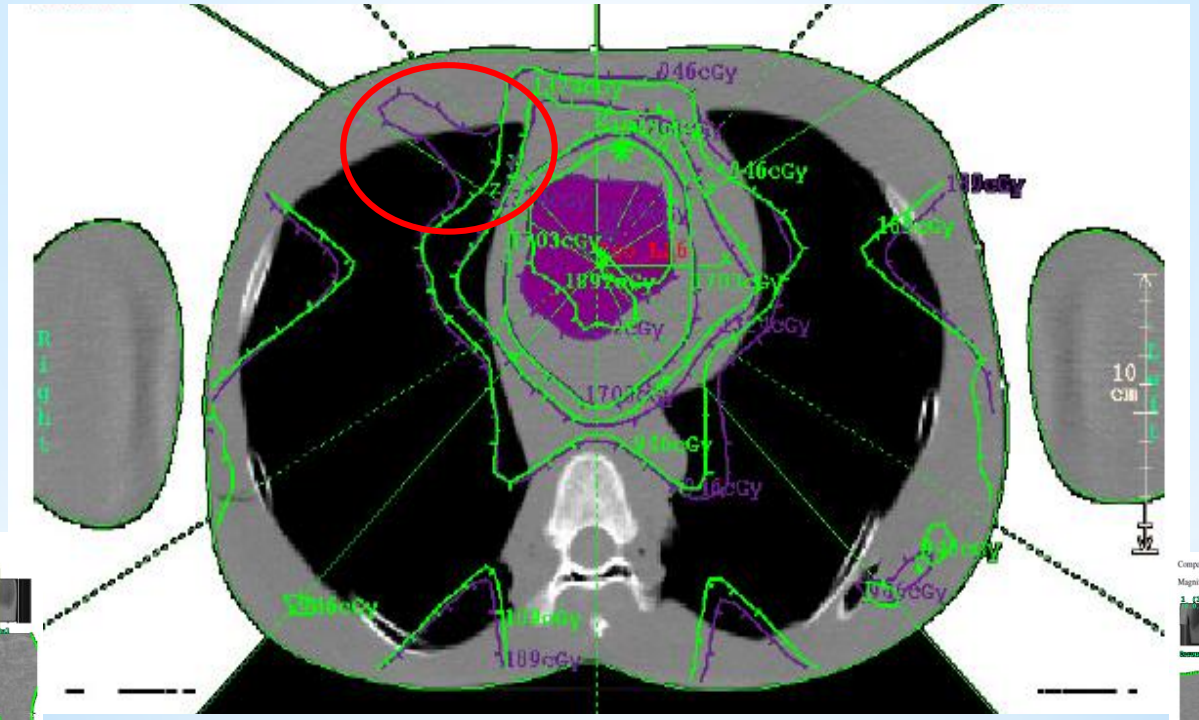


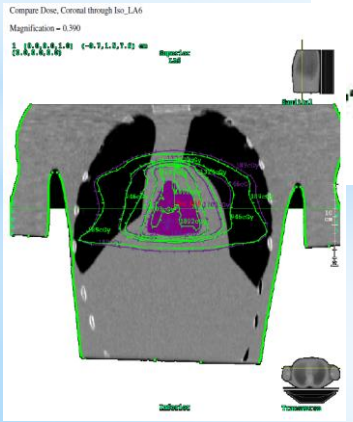


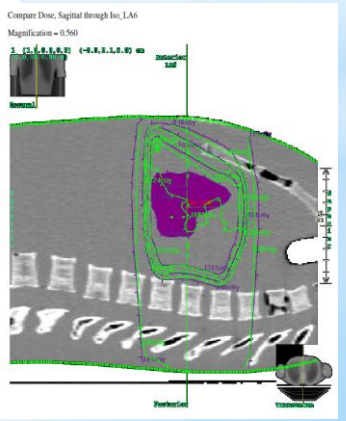


* The Report

* Full Report – Isodose Overlays



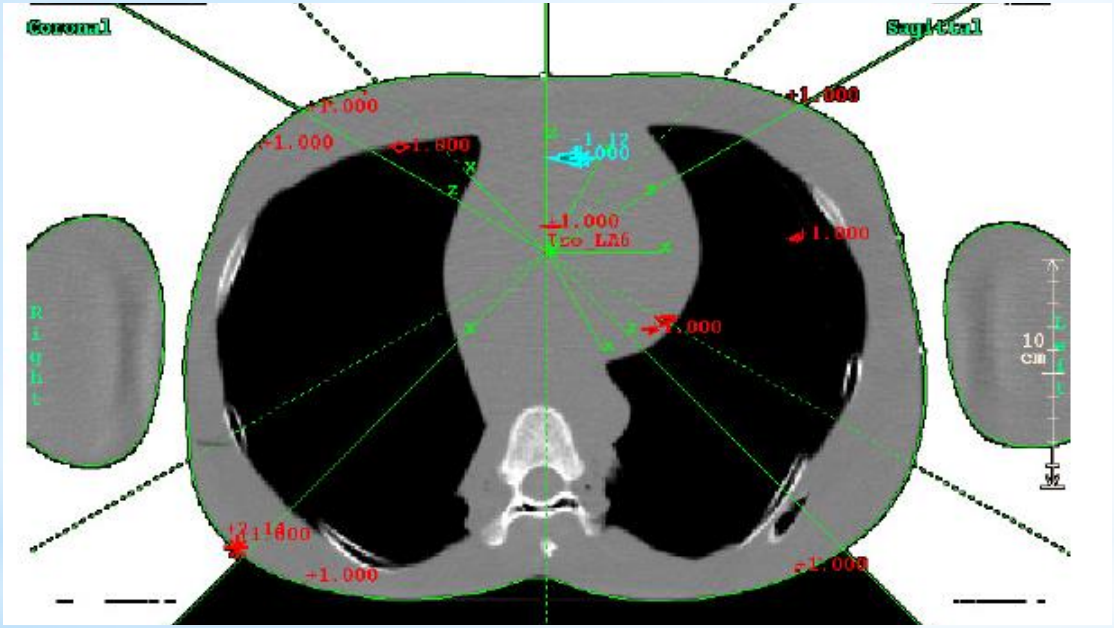




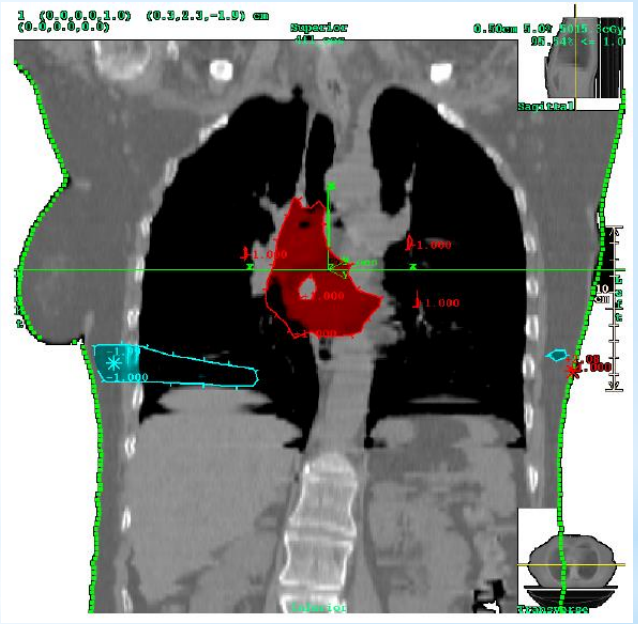
--- Eclipse TPS --- Dosimetry Check

The Report

* Full Report – Gamma Analysis



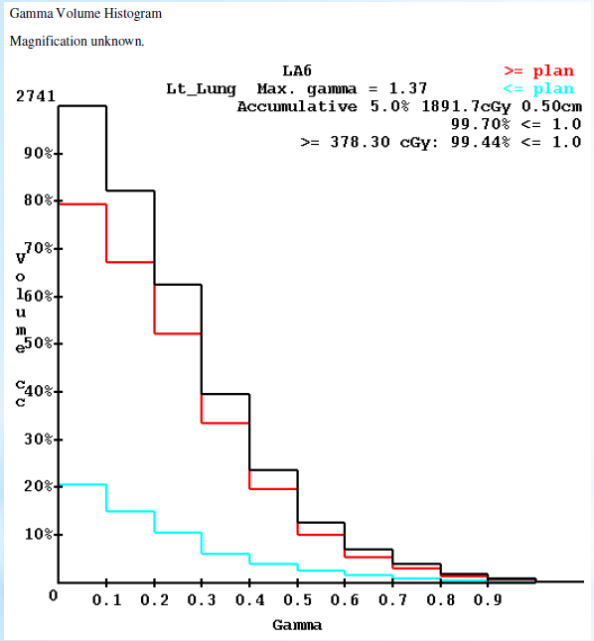
0.3cm, 3%
99.30% ≤ 1.0



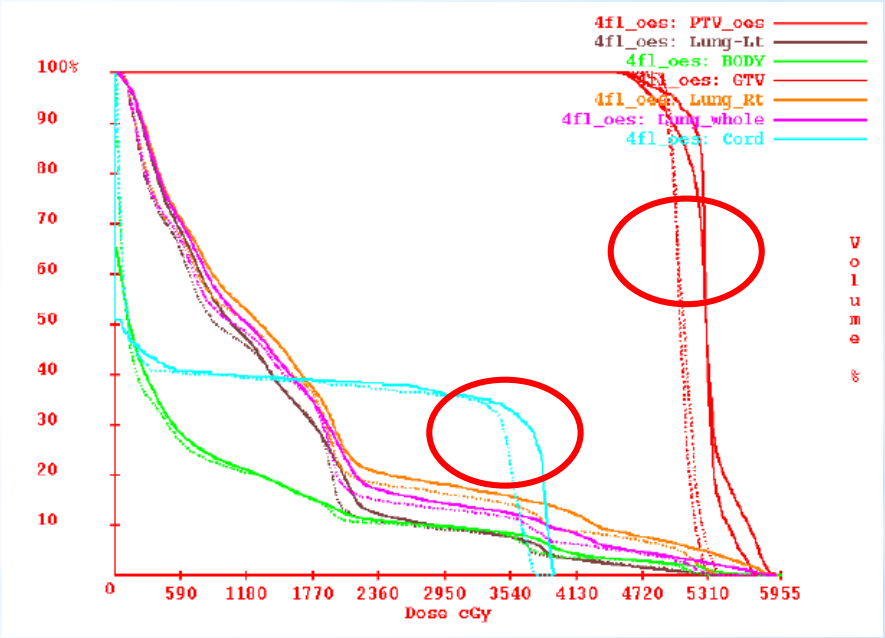
0.5cm, 5%
95.54% ≤ 1.0

The Report

* Full Report – 3D Gamma Volume Histogram & Dose Volume Histogram



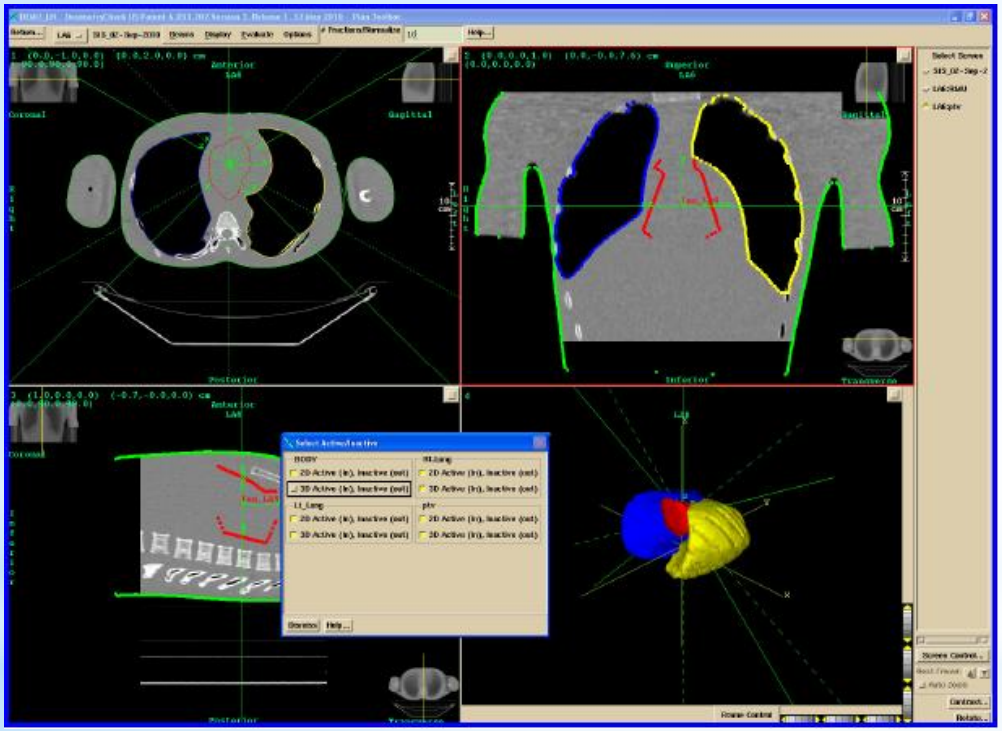
GVH – Left Lung
(0.5cm, 5%) 99.70% ≤ 1.0

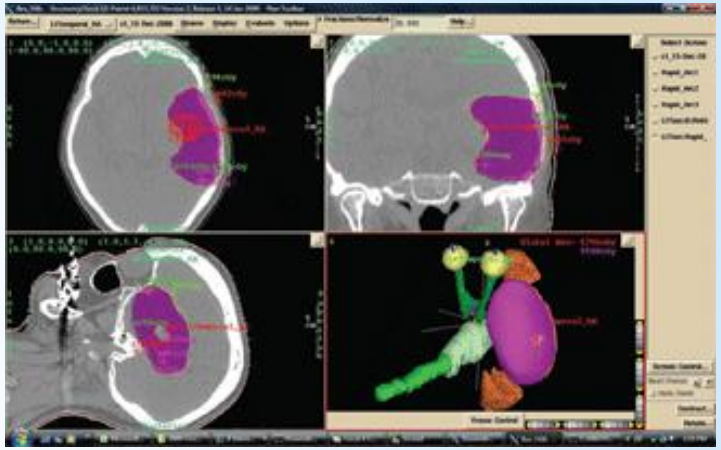


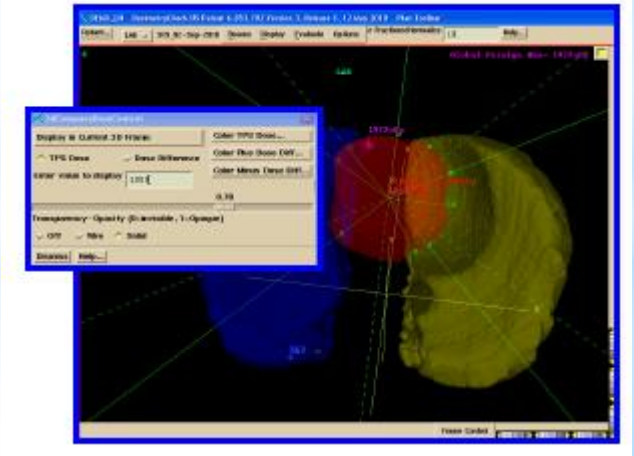
DVH – Shows differences for cord and PTV doses

* The Report

* Many more features

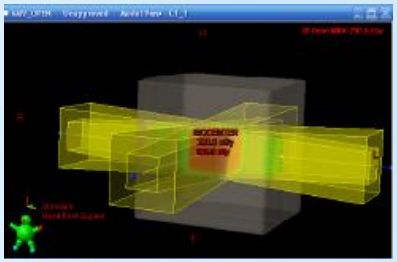






* Beta Testing

* Edinburgh Cancer Centre – May 2010



1) Testing the system: Dosimetry Check vs TPS vs ionisation chamber

- Four orthogonal 10x10cm fields on solid water phantom, open/EDW, 200cGy to isocentre

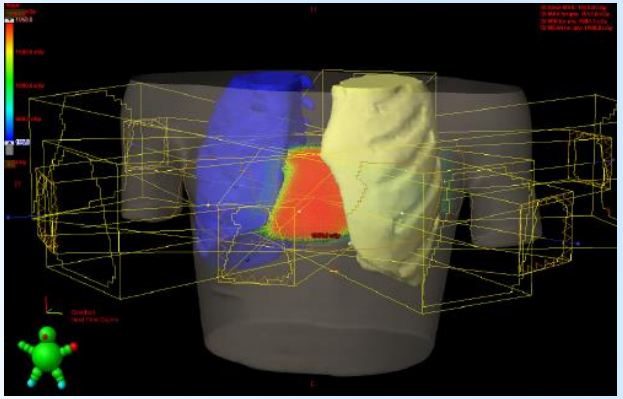
	TPS (cGy)	Chamber	Dosimetry Check (Pre-Treatment)		Dosimetry Check (in-vivo)	
			Golden Beam Kernel	**Measured Kernel**	Golden Beam Kernel	**Measured Kernel**
Open	200	-0.003%	-1.19%	**-1.25%**	4.94%	**1.98%**
EDW	200	-0.005%	-0.98%	**-0.95%**	4.85%	**2.12%**

<u>Conclusion:</u> Accuracy determined by comparison with calibrated ionisation chamber is within ± ~2%

* Dosimetry Check

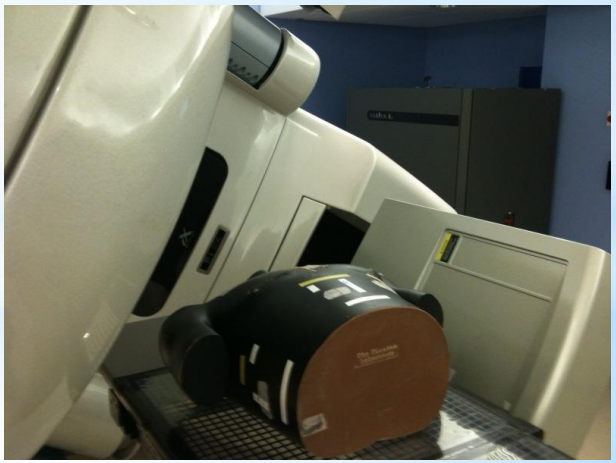
2) Testing the system: IMRT verification

- System reproducibility analysed using a five static field dynamic MLC IMRT plan on an anthropomorphic thorax phantom
- Dose to isocentre examined using initial golden beam kernel
- Pre-treatment ~20 datasets: +2% (± 0.4%)
- Transit/in-vivo ~60 datasets: +2% (± 0.6%)



3) Testing the system: AAA algorithm assessment

- The same 5-field IMRT thorax phantom plan was recalculated using AAA algorithm
- This plan was imported into Dosimetry Check and compared with 5 pre-existing pre-treatment and transit datasets
- Pre-treatment : **1.2%,** Transit: **0.6%**
- Closer agreement with AAA plan



* Dosimetry Check

4) Sensitivity

- During reproducibility study, sensitivity also examined by shifting phantom by a known amount
- 2cm shift: additional 2.0% ± 0.5%
- 5cm shift: additional 6.6% ± 0.8%

5) Testing the system: Patient IMRT QA (pre-treatment)

- 4xHead & Neck 7 field IMRT plans and 2xProstate 5 field IMRT plans verified using pre-treatment module and compared against current method, MapCheck

Site	DC vs TPS (PB)	Map Check
H&N	1.64%, **2.48%**	-5.0% @ Central axis*
H&N	**-1.05%**, -1.04%	-5.8% @ Central axis*
H&N	0.39%, 0.51%	-
H&N	0.12%, 0.98%	-
Prostate	0.38%, 0.24%	0.4% @ Central axis
Prostate	0.54%, -0.21%	-1.02% @ Central axis

* Dosimetry Check

6) Clinical Testing: Pre-treatment and In-vivo patient dose verification

- 15 patients assessed pre-treatment and in-vivo over 3 consecutive fractions where possible (43 datasets)
- 3D conformal lung/oesophagus patients planned using Pencil Beam Algorithm
- Worst case scenario: lung inhomogeneities, respiratory motion, no gating
- **Sample results:**

Site	Pre-Treatment	In-vivo/transit
Lung	1.41%	-2.93%, **-7.09%**, 1.09%
Lung	**0.20%**	**7.68%**, 1.91%, 6.00%
Lung	1.85%	5.72%, 7.08%, 7.53%
Lung	**4.73%**	2.61%, -1.61%, 0.77%

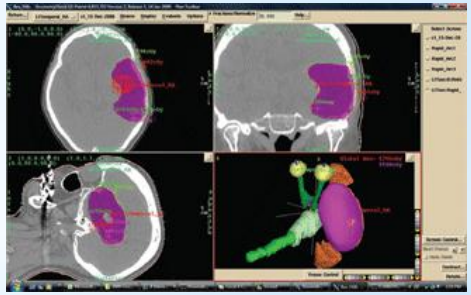
- Pre-treatment: 1.9% (±1.7%)
- In-vivo: 1.5% (±4.2%)
- Tolerances would probably be set to ±10% for lung and ±5% for fixed anatomy

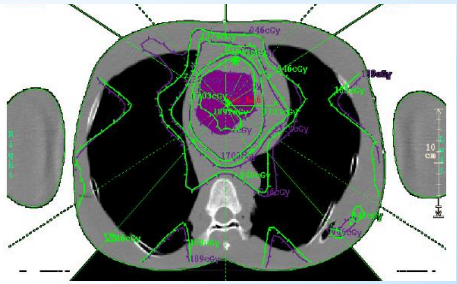
Clinical Results - RSCH

* RSCH trialling the system from September 2011 on Varian iX linac
* All new IMRT and RapidArc patients analysed using DC over 3 fractions close to start of treatment where possible
* Images acquired by radiographers during treatment

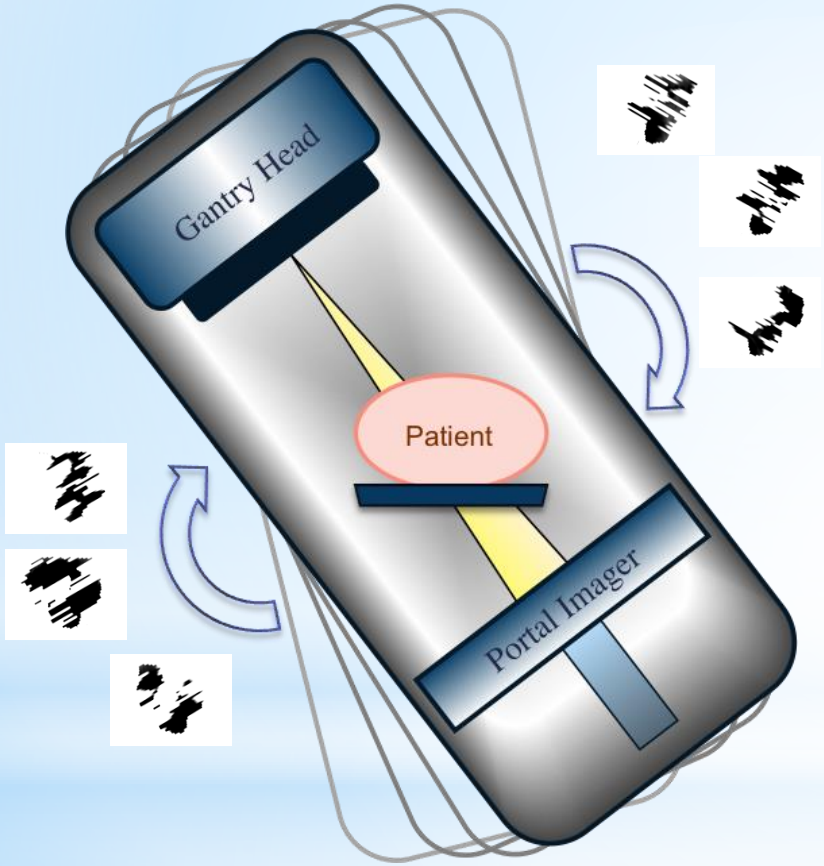
Analysis

* 47 patients, 3 fractions each where possible,
* Head & Neck, Prostate & Nodes, Prostate, Gynae
* Mean dose to primary PTV from DVH data[7]
* Options: points summary, 1D profiles, isodose overlays, gamma analysis, gamma volume histogram, DVH and more

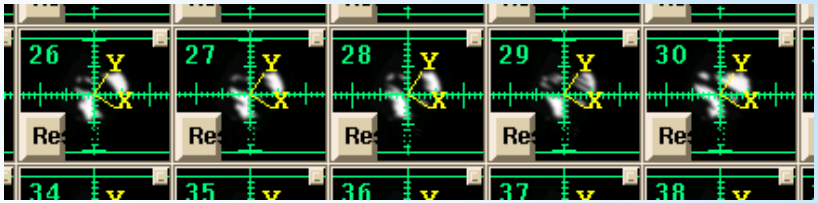




Case study - VMAT



* RapidArc Prostate & Nodes patient prescribed 74 Gy in 30 fractions
* Pre-Treatment verification showed mean volume to PTV to be within **2.7%** of the TPS value
* Transit measurements were performed on fractions 2,5 and 6 and were found to be **-0.5%, 1.1%, -0.4%** respectively



* Case study - VMAT

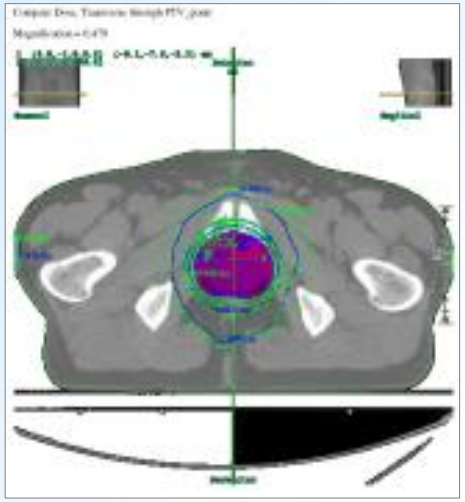
Plan: A1
EXIT: Some beams or all are exit (transit)
Number of Fractions/Normalization Factor: 37
CT to Density File Name: GuildfordHUDCurve
External Contour Name: Body

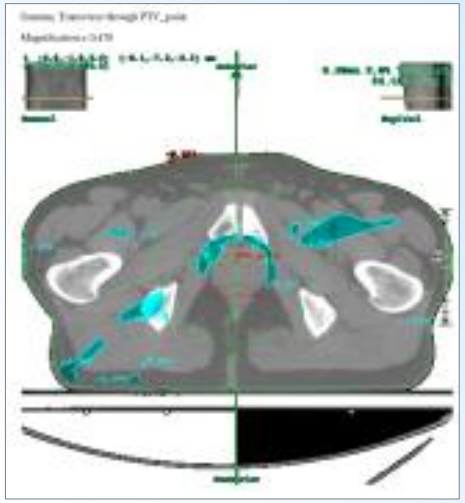
Specific Points A1, ID=1

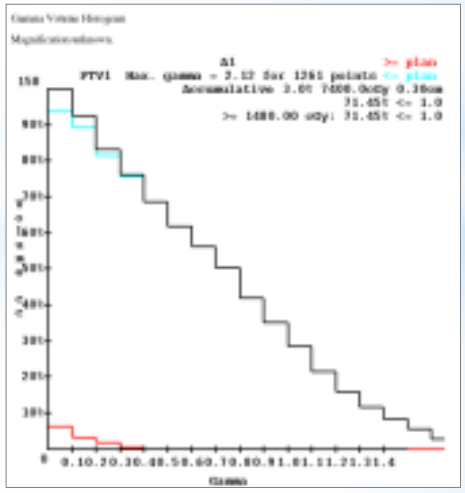
Point Name:	Iso_A1			PTV_point		
	x,	y,	z cm	x,	y,	z cm
Coordinates	-0.1,	-3.4,	-1.8	-0.1,	-7.8,	-1.8
			Dose cGy			Dose cGy
ARC1_CCW			2528.1			3859.3
Machine Name		LA2_2010			LA2_2010	
Check Type		Exit-Integration			Exit-Integration	
Beam at Gantry Angle (degrees) - Dose cGy	2		48.6	2		56.3
	9		55.7	9		104.7
	13		48.1	13		89.1
	18		72.3	18		93.3
	22		93.2	22		97.6
	26		80.0	26		82.7
	33		72.9	33		82.6
	38		48.1	38		90.3
	41		31.5	41		80.0
	47		50.7	47		79.5
	53		33.1	53		81.6
	58		35.2	58		76.6
	61		33.3	61		68.7
	66		35.1	66		73.5
	70		41.9	70		62.1
	77		54.7	77		62.2
	81		53.2	81		59.6
	88		39.6	88		60.6
	91		27.1	91		62.4
	95		20.2	95		58.4
	102		26.5	102		60.8
	106		32.3	106		63.5
	112		27.5	112		46.1
	115		31.6	115		43.3
	120		41.0	120		41.6
	127		41.3	127		46.8
	132		42.8	132		51.7
	137		42.7	137		60.3
	140		64.6	140		69.2
	145		78.0	145		71.8
	151		76.5	151		72.6
	157		70.0	157		51.9
	161		51.2	161		45.0
	165		36.4	165		45.3
	172		28.7	172		41.6

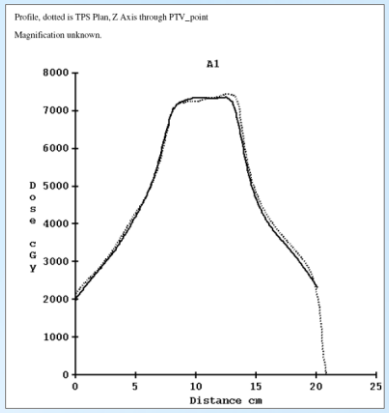
Specific Points A1, ID=1

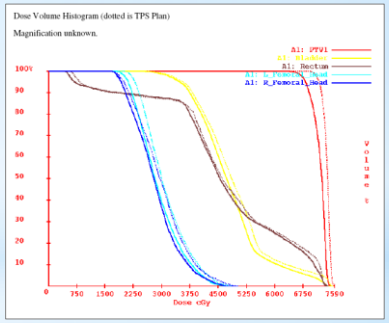
Point Name:	Iso_A1		PTV_point	
	302	41.8	302	75.4
	307	34.9	307	76.9
	313	18.5	313	85.1
	316	35.5	316	84.3
	322	44.0	322	83.4
	326	39.3	326	83.9
	332	40.8	332	78.0
	336	43.4	336	87.1
	341	28.7	341	91.6
	344	19.5	344	82.8
	351	12.0	351	76.0
	357	9.1	357	65.8
BEV Coordinates	0.0, 0.0, -0.0		-2.2, -3.8, -0.0	
Total Dose cGy		4347.5		7324.8
Plan Dose cGy		4416.5		7341.1
Difference %		-1.56% of 4416.5		-0.22% of 7341.1
Difference %		-0.93% of 7400.0		-0.22% of 7400.0

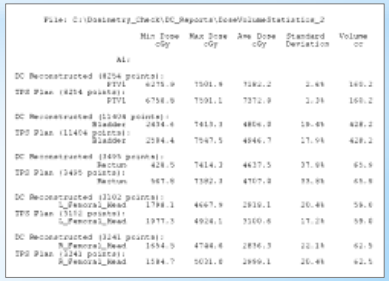




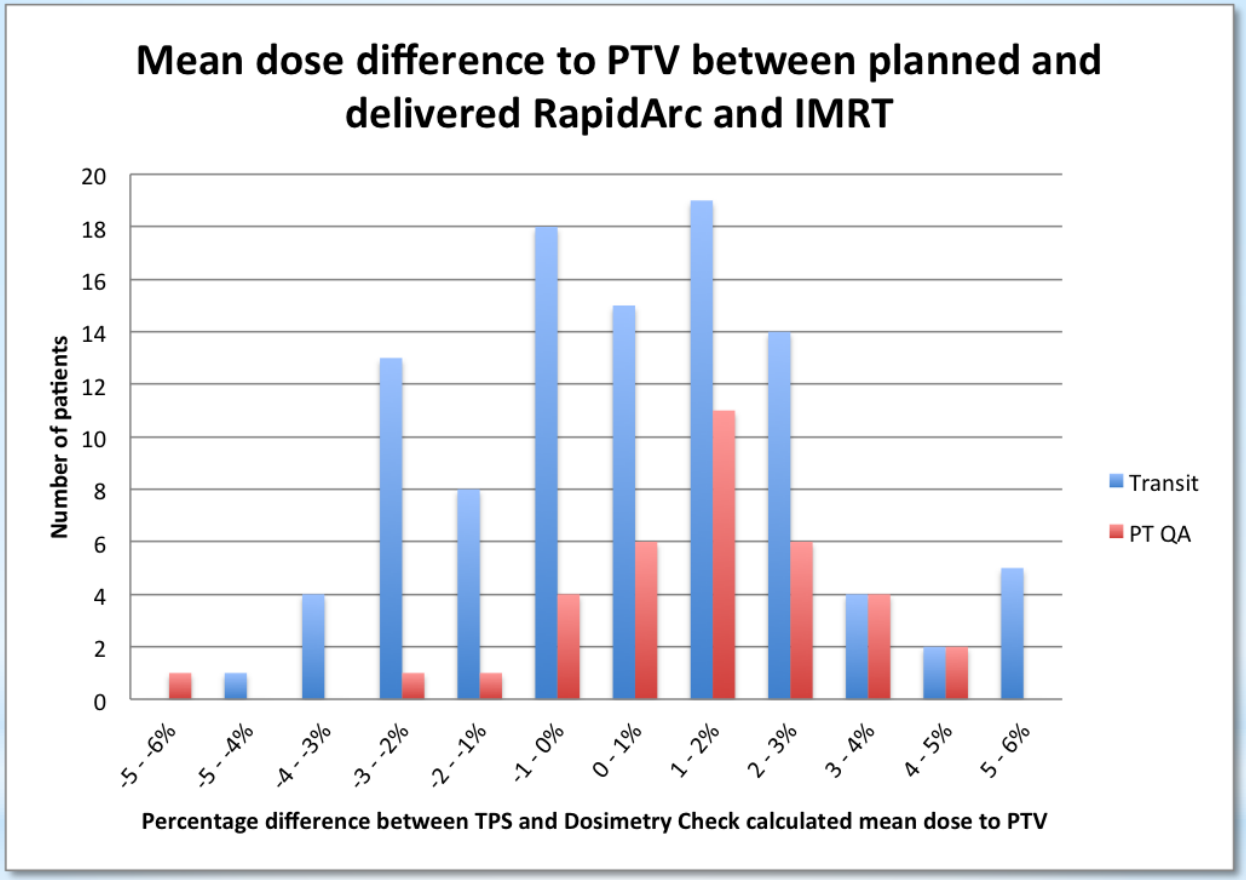








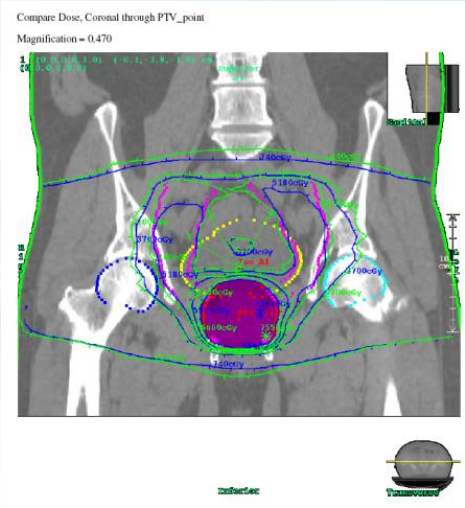
Our Results



* Mean pre-treatment QA agreement: **1.3% (±2.1%)**
* Mean transit agreement: **0.5% (± 2.3%)**

Conclusions

* **Reassurance** - Safe, efficient and effective method of performing IMRT QA as well as in-vivo confirmation of dose delivery
* **Independent** – Uses measured source model rather than existing models
* **Speed** - No impact on treatment time, only requires the extension of the EPID
* **Capacity** - Once implemented, no significant impact on physics resources. Would be routinely run off-line by radiographers similar to standard portal images, maximising machine capacity
* **Unique** - in the fact that it measures absolute in-vivo dose in **cGy** which can be viewed in **3D** on the patient contour
* **Simulates the full clinical situation** - Transit option measures the actual delivered dose, providing confidence that no significant error has occurred, and allowing you to visualise exactly what is being treated relative to the plan



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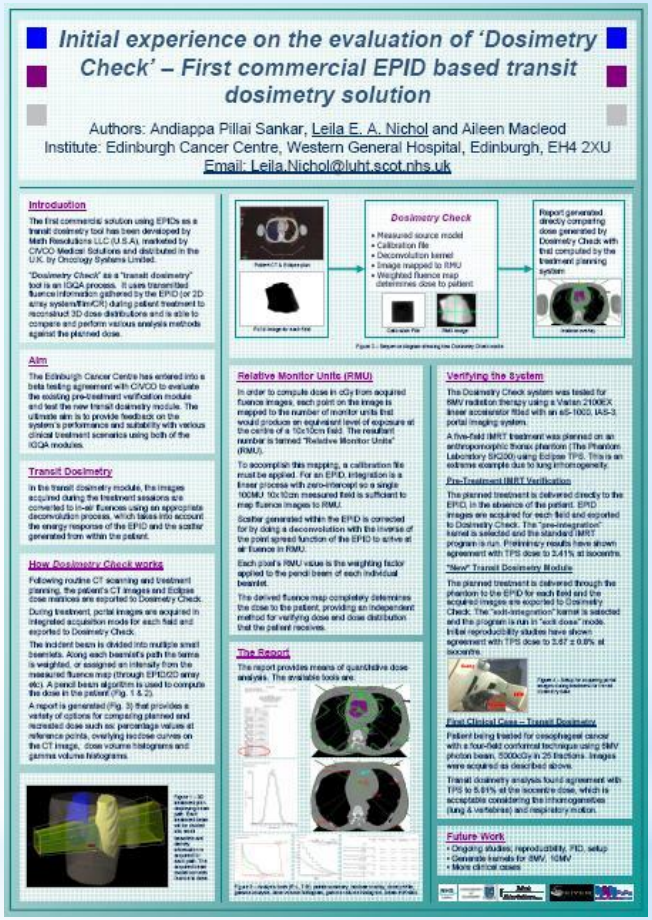
*Thank you!

Questions?



Initial experience on the evaluation of 'Dosimetry Check' – First commercial EPID based transit dosimetry solution

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Introduction

The first commercial solution using EPIDs as a transit dosimetry tool has been developed by Math Resolutions LLC (U.S.A), marketed by CIVCO Medical Solutions and distributed in the U.K. by Oncology Systems Limited.

"*Dosimetry Check*" as a "transit dosimetry" tool is an IGQA process. It uses transmitted fluence information gathered by the EPID (or 2D array system/film/CR) during patient treatment to reconstruct 3D dose distributions and is able to compare and perform various analysis methods against the planned dose.

Aim

The Edinburgh Cancer Centre has entered into a beta testing agreement with CIVCO to evaluate the existing pre-treatment verification module and test the new transit dosimetry module. The ultimate aim is to provide feedback on the system's performance and suitability with various clinical treatment scenarios using both of the IGQA modules.

Transit Dosimetry

In the transit dosimetry module, the images acquired during the treatment sessions are converted to in-air fluences using an appropriate deconvolution process, which takes into account the energy response of the EPID and the scatter generated from within the patient.

How *Dosimetry Check* works

Following routine CT scanning and treatment planning, the patient's CT images and Eclipse dose matrices are exported to Dosimetry Check.

During treatment, portal images are acquired in integrated acquisition mode for each field and exported to Dosimetry Check.

The incident beam is divided into multiple small beamlets. Along each beamlet's path the fluence is weighted, or assigned an intensity from the measured fluence map (through EPID/2D array etc). A pencil beam algorithm is used to compute the dose in the patient (Fig. 1 & 2).

A report is generated (Fig. 3) that provides a variety of options for comparing planned and recreated dose such as: percentage values at reference points, overlying isodose curves on the CT image, dose volume histograms and gamma volume histograms.

Relative Monitor Units (RMU)

In order to compute dose in cGy from acquired fluence images, each point on the image is mapped to the number of monitor units that would produce an equivalent level of exposure at the centre of a 10x10cm field. The resultant number is termed "Relative Monitor Units" (RMU).

To accomplish this mapping, a calibration file must be applied. For an EPID, integration is a linear process with zero-intercept so a single 100MU 10x10cm measured field is sufficient to map fluence images to RMU.

Scatter generated within the EPID is corrected for by doing a deconvolution with the inverse of the point spread function of the EPID to arrive at air fluence in RMU.

Each pixel's RMU value is the weighting factor applied to the pencil beam of each individual beamlet.

The derived fluence map completely determines the dose to the patient, providing an independent method for verifying dose and dose distribution that the patient receives.

The Report

The report provides means of quantitative dose analysis. The available tools are:

Verifying the System

The Dosimetry Check system was tested for 6MV radiation therapy using a Varian 2100EX linear accelerator fitted with an aS-1000, IAS-3 portal imaging system.

A five-field IMRT treatment was planned on an anthropomorphic thorax phantom (The Phantom Laboratory SK200) using Eclipse TPS. This is an extreme example due to lung inhomogeneity.

Pre-Treatment IMRT Verification

The planned treatment is delivered directly to the EPID. In the absence of the patient, EPID images are acquired for each field and exported to Dosimetry Check. The "pre-integration" kernel is selected and the standard IMRT program is run. Preliminary results have shown agreement with TPS dose to ±1.1% at isocentre.

"New" Transit Dosimetry Module

The planned treatment is delivered through the phantom to the EPID for each field and the acquired images are exported to Dosimetry Check. The "exit-integration" kernel is selected and the program is run in "exit dose" mode. Initial reproducibility studies have shown agreement with TPS dose to 0.67 ± 0.8% at isocentre.

First Clinical Case – Transit Dosimetry

Patient being treated for oesophageal cancer with a four-field conformal technique using 6MV photon beam. 5000cGy in 25 fractions. Images were acquired as described above.

Transit dosimetry analysis found agreement with TPS to 0.81% at the isocentric dose, which is acceptable considering the inhomogeneities (lung & vertebrae) and respiratory motion.

Future Work

- Ongoing studies: reproducibility, PID, setup
- Generate kernels for 8MV, 10MV
- More clinical cases