UK Brachytherapy Audit:

Origin, funding & collaboration

Tony Palmer

Portsmouth Hospitals NHS
NHS Trust

UNIVERSITY OF SURREY

IPEM

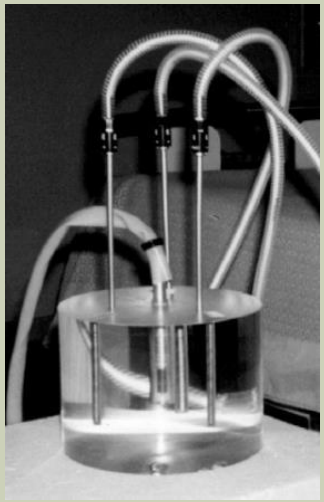
OVERVIEW

- Purpose
- From idea to implementation
- Methodology, results & reflection

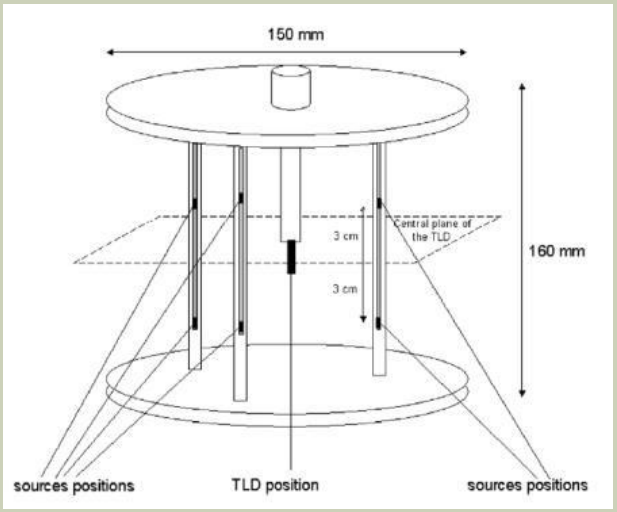
Proposal for a Brachytherapy Audit

- Modern brachytherapy is a complex process:
  - 3D imaging, volume prescribing, inverse planning optimisation
- Dosimetric verification for brachytherapy is challenging:
  - Dose gradient, dose range, small scales, applicator shapes
- Lack of brachytherapy audit:
  - Recent technology and clinical practice changes
  - More than source strength measurement
  - There have been errors
  - Required for clinical trials

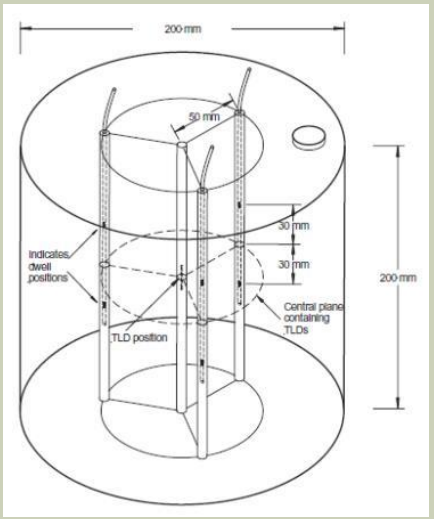
Non-UK Audits



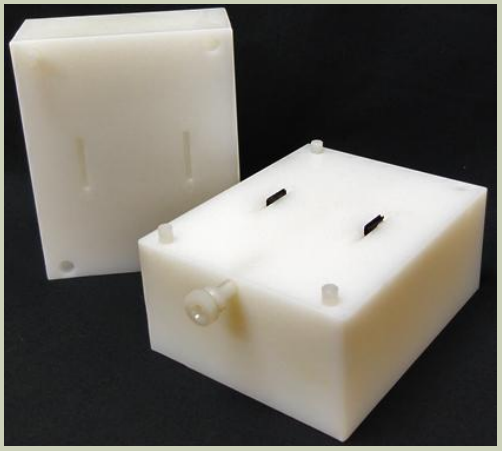
Elfrink *et al* (2001)
Ionisation chamber,
Netherlands and Belgium



Roue *et al* (2007),
TLD, EQUAL-ESTRO
mailed audit



Haworth *et al* (2013),
TLD, Australian audit

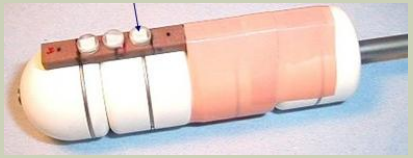


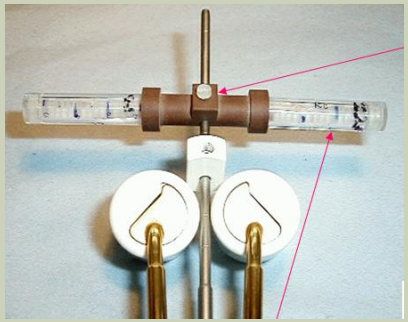
Casey *et al* (2011)
nanoDot optically stimulated
luminescence, mailed, USA

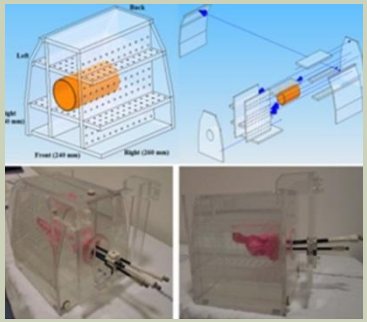
Tedgren *et a*l (2008)
Well chamber, Sweden

UK Regional and National Audits

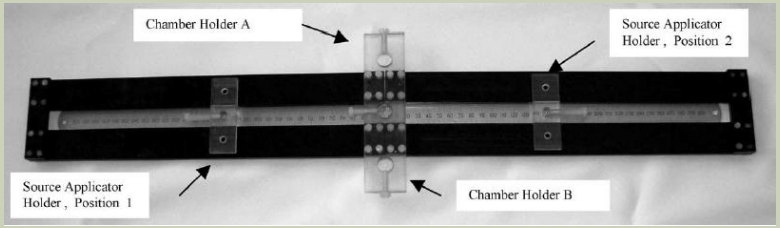
Ratcliffe *et al* (conference proceedings, 1996-2004), UK



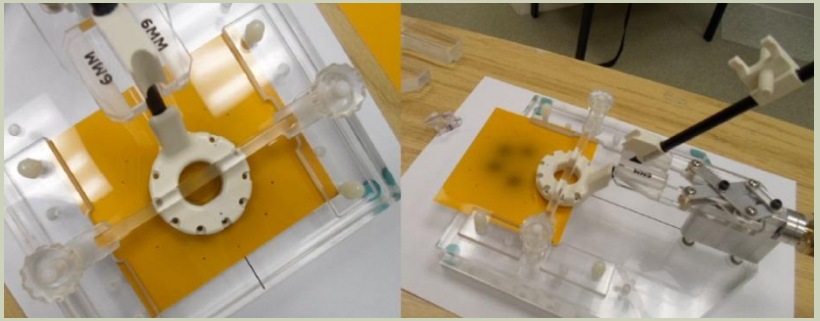




Heeney *et al* (2005)
Ionisation chamber,
Ireland, Scotland, N England



Lee *et al* (in progress)
Well chamber intercomparison, UK



Awunor *et al* (in progress)
Audit of ring applicator dwell positions, UK

Purpose

- Develop a comprehensive brachytherapy end-to-end system audit methodology
- Provide a QA process for the INTERLACE Clinical trial brachytherapy component
- Bring brachytherapy audit in line with external beam audit

Journey from Idea to Implementation

- *Feb 2012:*

  Audit Group E approved proposal.

  Not previously audited.

- *March 2012:*

  Presented at National Interdepartmental Audit Groups Meeting

- *A bit later in 2012:*

  Regional or national audit?

- *May-July 2012:*
  Advert in IPEM Newsletter Working Party.
  Gathering of people interested in a brachytherapy audit, at NPL:
  Regional Audit Groups E and C, RTTQA, NPL, others

- *Oct 2012:* Formed IPEM Working Party, £7.3k over 2 years
- *Nov 2012:* Emails to gauge interest, Working Party meeting
- *April 2013:* IPEM approved additional spend request of £3.1k

- Financial approval conditions:
  - Limit the number of members in the Working Party
  - IPEM virtual phantom library after the national audit

- *Possible objectives for the audit:*

1. System audit of
   intended and delivered dose distributions
   around clinical treatment applicators
   - *Comprehensive audit in near-clinical situation but challenging dosimetry and increased uncertainty*

2. Very accurate measurement of
   dose to a point & TPS point calculations
   for plastic catheter line source
   - *Somewhat removed from clinical complexity but increased accuracy and reduced uncertainty*

- Collaborative working between…
  - IPEM RT-SIG Working Party
  - NCRI Radiotherapy Trials Quality Assurance Group (RTTQA)
  - National Physical Laboratory

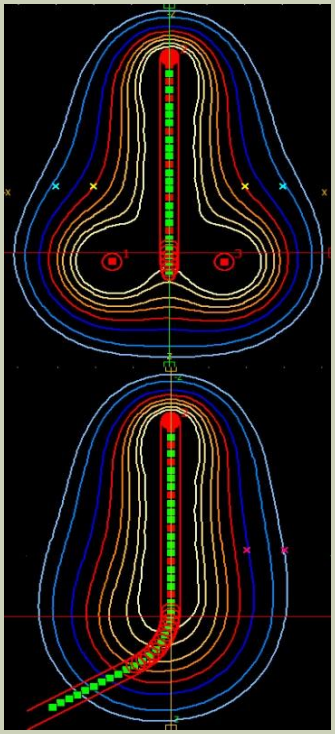
Trials assurance

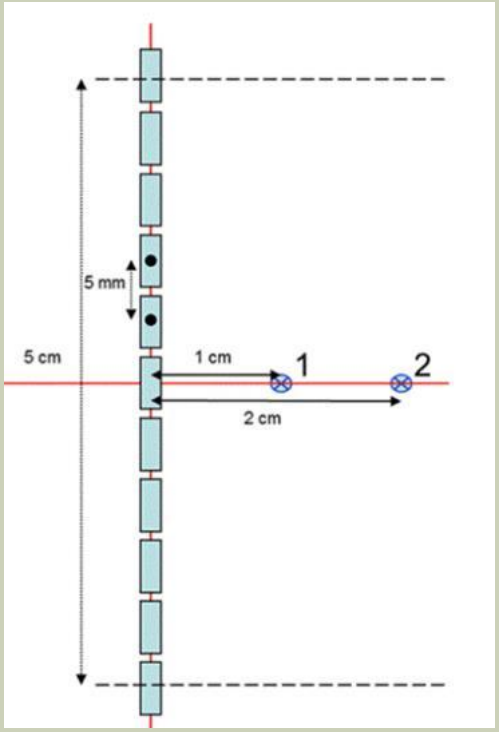
Clinical setting QA

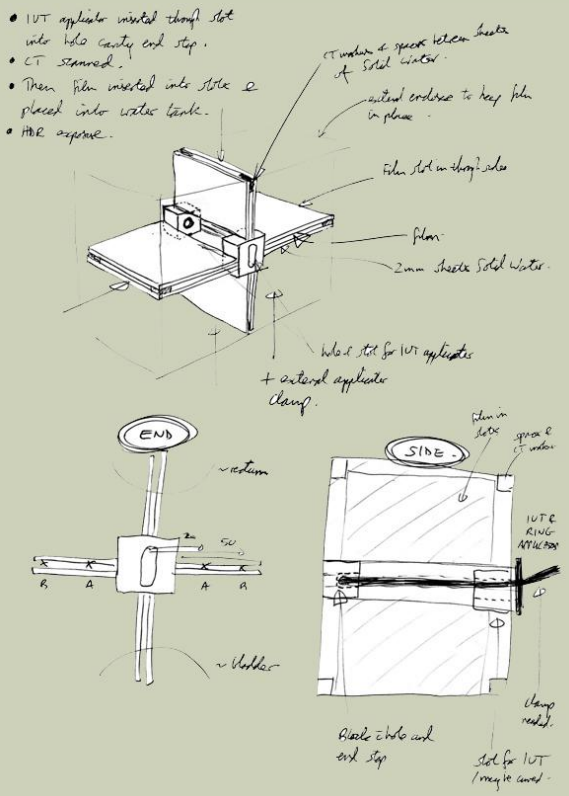
Dosimetric theory, alanine

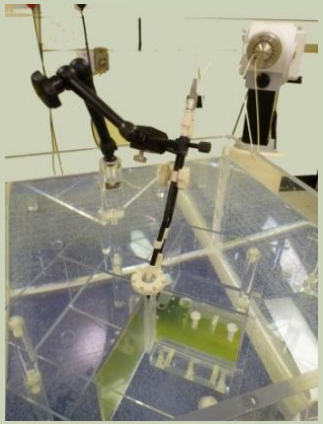
- *Outcome of collaboration:*
  - Two separate, complementary phantoms
  - Scheduling of joint audits
  - Sharing of data and collation of results

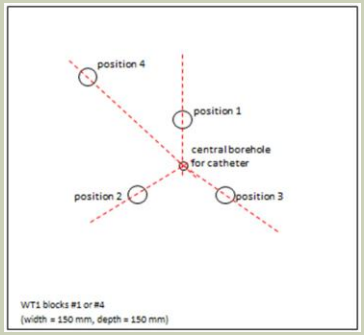
- *Two phantoms:*
  - IPEM WP: ‘System check’, clinical applicator dose distribution
  - RTTQA Interlace: Accurate point dose from linear series of dwells

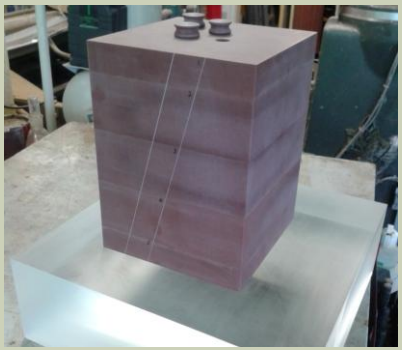






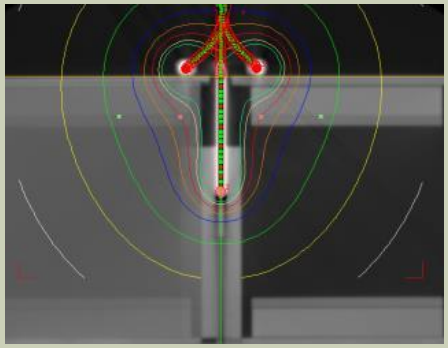


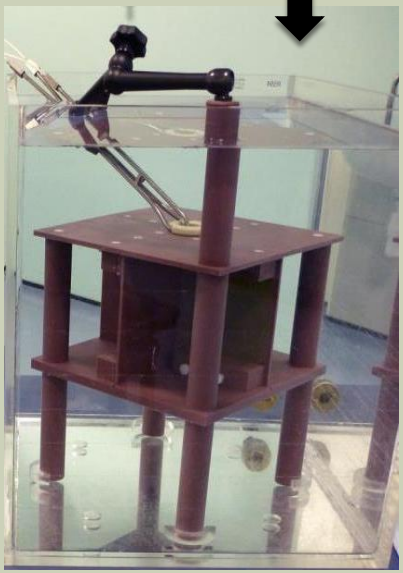




- *Feb to Aug 2013:* Develop and test methodology, design and construct phantoms. (Perspex mock-up and Solid Water final).
- *Aug 2013:* Pilot audits completed
- *Aug 2013 to May 2014:* National audit programme

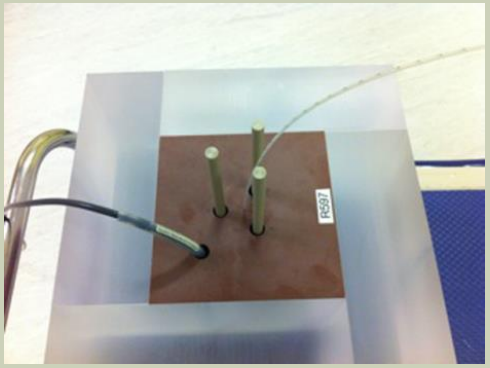
Methodology

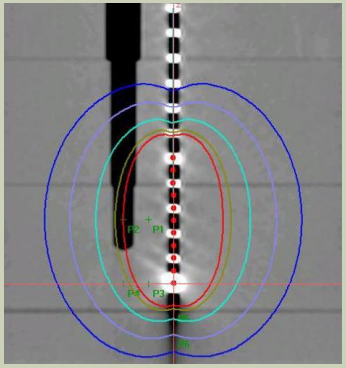


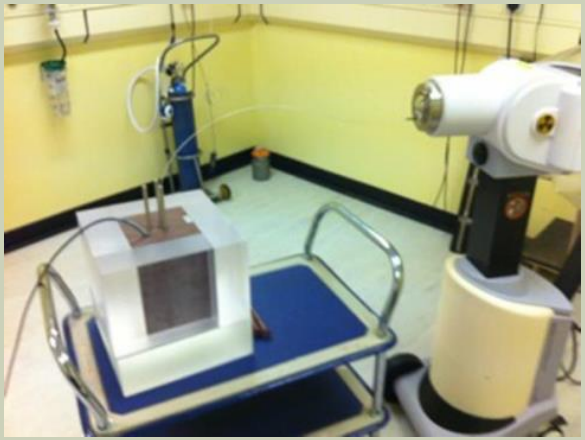


- ***IPEM WP Phantom***
  - Based on clinical applicator dose distribution
  - System check: CT scan, TPS plan, HDR/PDR irradiation
  - Gafchromic EBT3 film dosimetry

Methodology





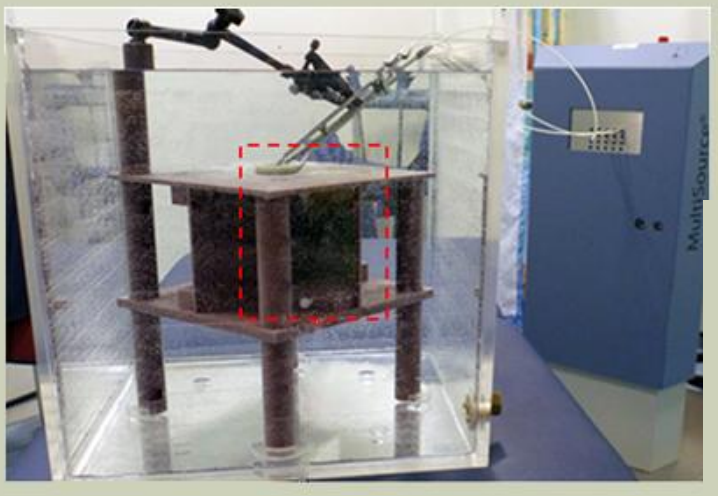


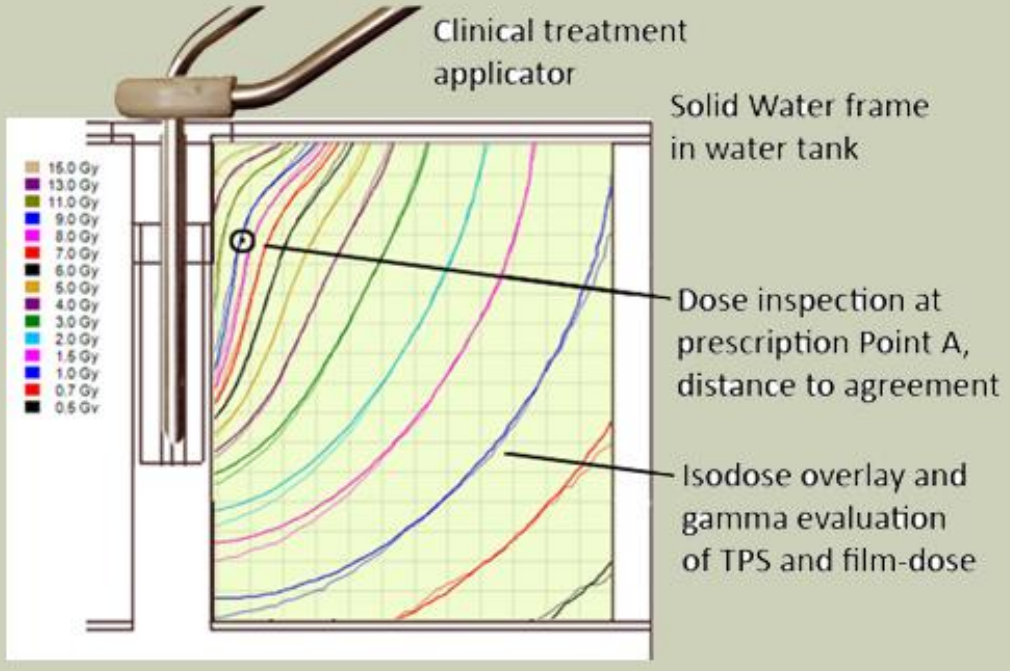
- ***RTTQA Interlace Phantom***
  - Based on linear series of dwells
  - Pre-audit TPS calculation check
  - Farmer-type ionisation chamber max response dwell position
  - Alanine irradiation, 3 stacks of 9 pellets at 20 mm radial

Audit Progress

- 14/45 audited (31%)
- Personally conducted and analysed all film measurements (Patty and Edwin the alanine work)
- ~3000 miles travelled so far
- Other auditors and/or self-administered postal audit in future ?
  - loan request form from IPEM

- Initial results from IPEM WP Phantom audit only





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HDR Brachytherapy Audit Report

Brachytherapy Applicator Dosimetry

[redacted] Hospital,
[redacted] NHS Foundation Trust

Audit by: Tony Palmer, Portsmouth Hospitals NHS Trust, 11th November 2013
Host centre lead: [redacted]

Summary

This audit was conducted using the brachytherapy applicator film dosimetry system (BRAD phantom) with an HDR treatment unit. The audit was conducted as a 'spot check' only and is not a comprehensive assessment of all possible treatment modes or equipment. This constitutes an assessment of one specific aspect of physics dosimetry alone, not any clinical aspects of treatment. The result is valid at the time of measurement only.

All results were satisfactory. Comparison of planning system calculated isodose distributions and the measured dose distributions from the HDR treatment unit and clinical treatment applicator showed acceptable agreement, with mean gamma passing rate of 96.5% at 3% (local), 2 mm criteria over a clinically relevant dose range. The treatment planning system (TPS) calculated dose for Manchester Point A was measured on the film dose maps within an average distance of 0.5 mm from the geometric position of Point A. Unusually, a locally defined 'Point C' is used in the TPS plan optimisation.

Method, materials and notes

The audit was conducted using the BRachytherapy Applicator Dosimetry ('BRAD') phantom utilising advanced radiochromic film dosimetry (Palmer *et al* 2013 *Phys. Med. Biol.* 58 6623-6640), for a UK national audit of brachytherapy dosimetry (funded by IPEM and under the auspices of IPEM RT-SIG), in combination with a supplementary measurement of source strength by RTTQA.

A Nucletron Interstitial Ring CT-MR applicator, 60 mm intrauterine (IU) tube, 30°, 30 mm ring (source to source diameter), was positioned within the BRAD phantom and CT scanned in approximate orientation for clinical use on a Philips Brilliance Big Bore scanner. CT scans were reconstructed at 1.0 mm slice width, consistent with local clinical brachytherapy protocols. A Nucletron Oncentra Brachy planning system (v 4.1.0.132) was used to manually locate dwell positions within the applicator using marker wire. No applicator library was available. Dwell positions were located along the centre of the applicator tubes in the ring and IU, with no path-corrections made for potential curvature-related displacements of the source. The local standard planning method was used. This includes a locally defined 'Point C', 7 mm lateral into tissue from the physical outside edge of the ring at the level of the centre of the source path, both left and right. All dwell positions in the IU were activated, and three dwells left and right each side of the ring. 7 Gy was prescribed to Point A, conventionally defined as 20 mm up from the physical ring surface and 20 mm lateral to IU, and then inverse planning used within the TPS to optimise dwells to deliver the prescription dose to Points A and Points C. An RTDose grid calculated at 1 mm resolution in each direction was exported and used for analysis. The plan was exported to the HDR treatment unit, Nucletron microSelectron HDR v2 with Ir-192 source, and four Gafchromic EBT3 films held within the BRAD phantom were irradiated through normal treatment delivery.

The measured film doses and exported planning system calculated RTDose matrix were compared using isodose overlay and gamma analysis. The dose at Point A was evaluated on each film and compared to TPS calculated dose for this point, and also the distance to agreement of the film measured dose to the TPS calculated dose at this point isodose was evaluated.

Results

Figure 1 shows isodose comparisons between TPS-calculated and film-measured doses for the four films held within the BRAD phantom. Table 1 provides gamma calculation passing rates for these situations.

The mean film measured dose at Point A was 6.85 Gy (at standard uncertainty estimate of 3.2%, k=1). The measured dose is therefore within 2.1% from the TPS calculated mean 7.00 Gy. Due to the sensitivity of the point dose to positional uncertainty (high dose gradients), it is suggested to use a distance to agreement indicator. The distance to agreement between the film measured dose and the TPS calculated dose at Point A was 0.5 mm for both lateral films (at a standard uncertainty of 0.6 mm, k=1).

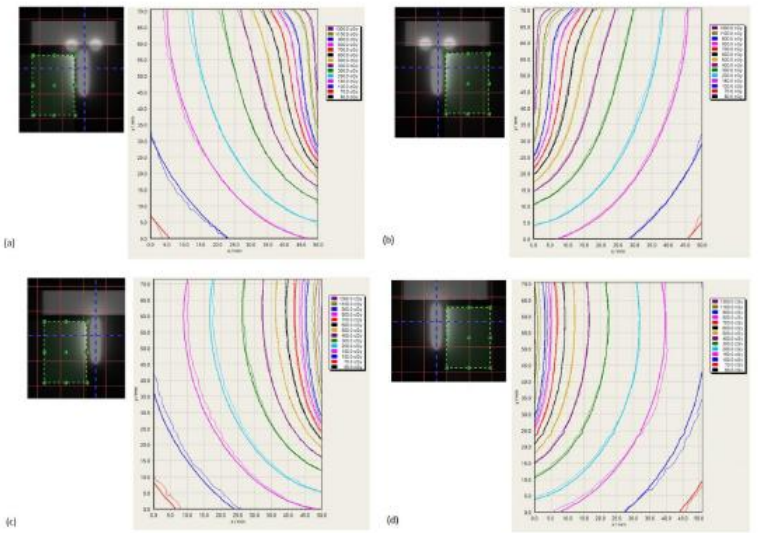
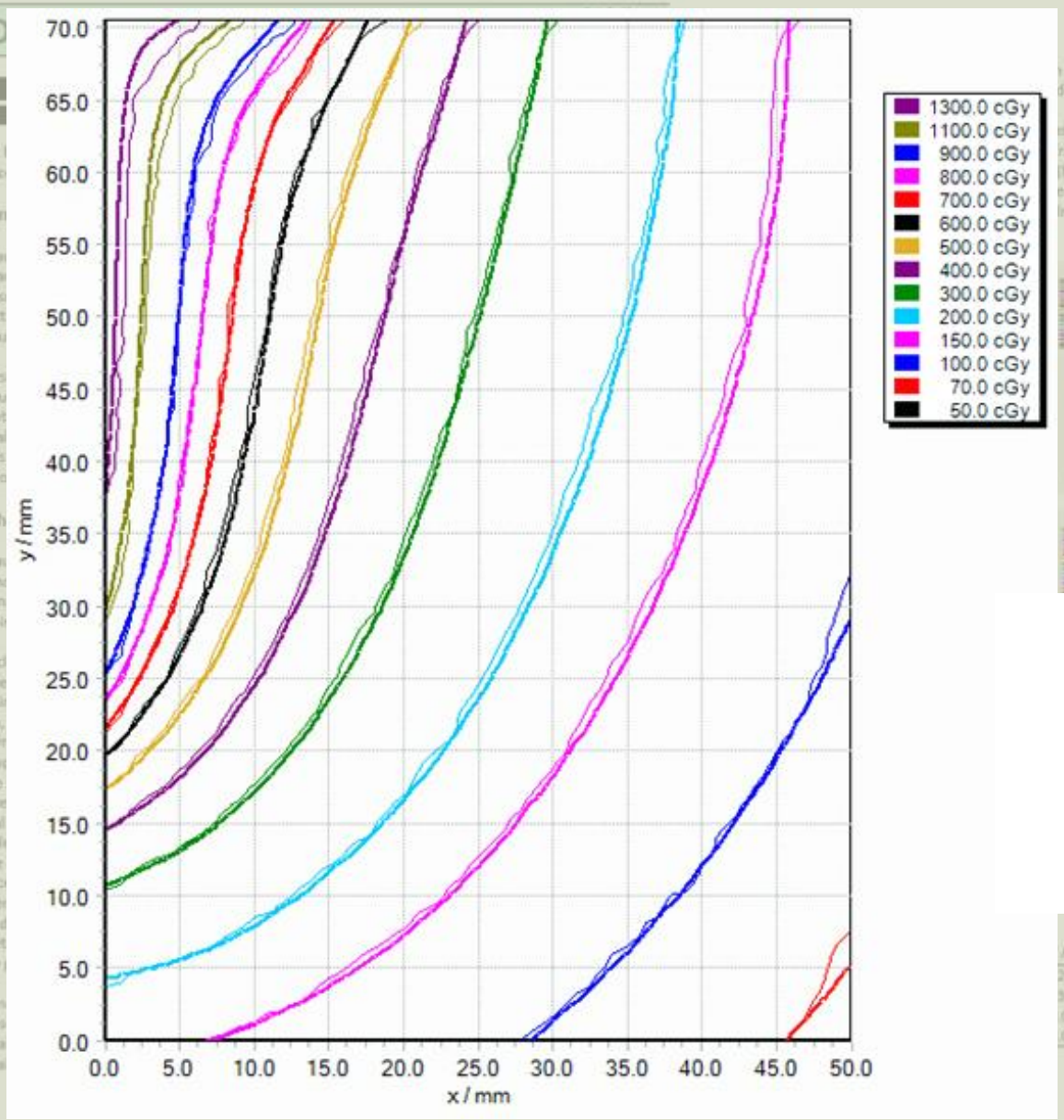


Figure 1. Isodose comparison between TPS-calculated and film-measured doses, over range 50 to 1300 cGy. RTDose plane and region of interest (50 x 70 mm) shown at left of isodose plot. (a) Right lateral through Point A, (b) left lateral through Point A, (c) anterior towards typical bladder, (d) posterior towards typical rectum.

Table 1. Gamma evaluation between TPS-calculated and film-measured dose distributions, over 50 x 70 mm regions of interest adjacent to the applicator, with 2 Gy lower cut-off. All percentage dose differences are locally normalised.

Film location in BRAD phantom	Gamma passing rate at:		
	5% (local) / 3 mm	3% (local) / 2 mm	2% (local) / 1.5 mm
Right lateral	99.2	97.3	87.8
Left lateral	99.3	96.2	89.6
Anterior	100.0	96.5	86.9
Posterior	100.0	95.8	80.7



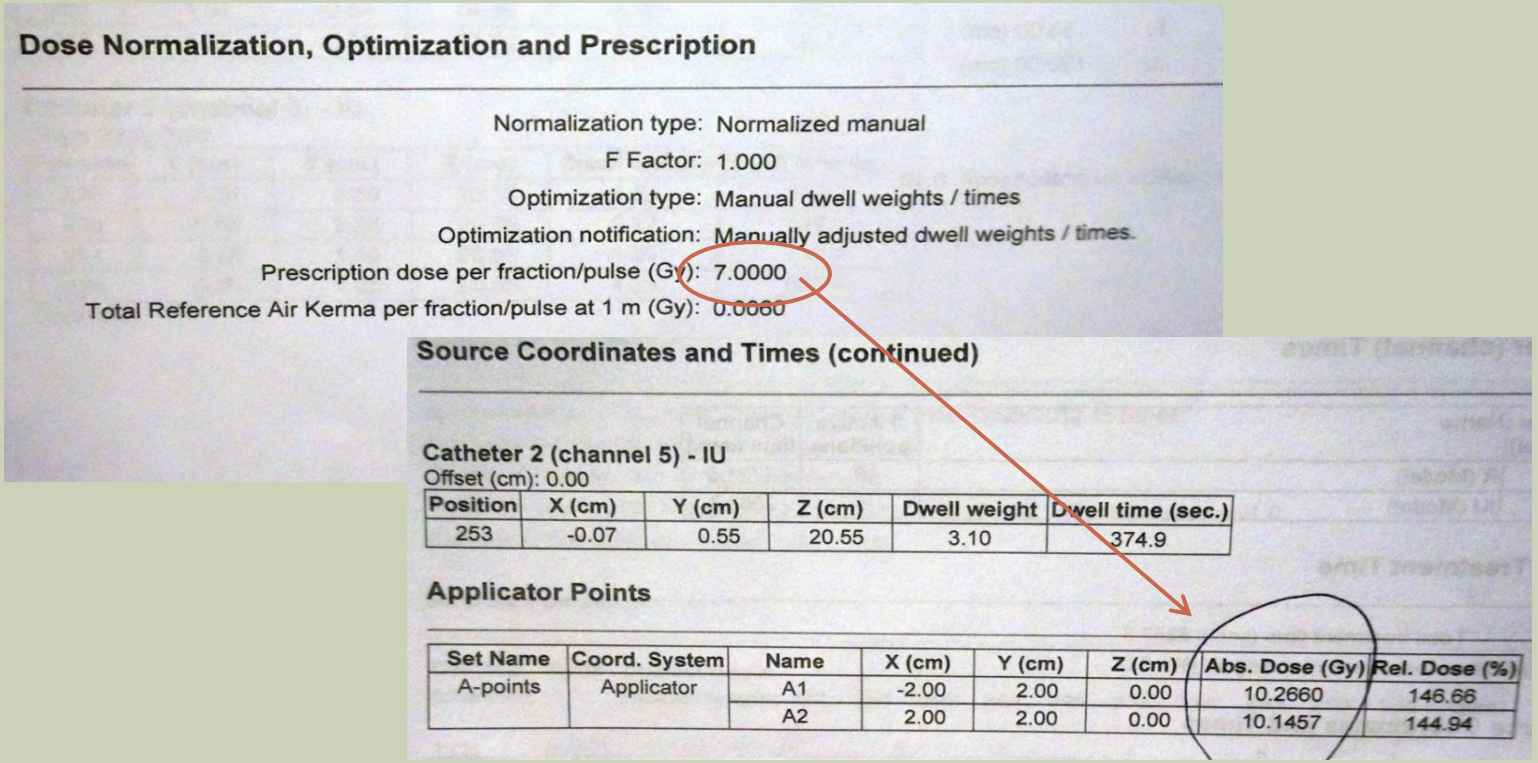
- Careful film methodology
- Triple-channel dosimetry via FilmQAPro®

First 10 UK centres,
comparing planned and delivered brachytherapy dosimetry

	Dose distribution, Gamma passing rate		Prescription Point A dose analysis	
	at 3%, 3 mm	at 2%, 2 mm	Dose difference	Distance to agreement
Mean	99.0%	92.3%	3.6%	1.0 mm
Interquartile range	97.8 – 99.7%	91.2 – 92.7%	2.5 – 5.7%	0.7 – 1.1 mm
Minimum, maximum	94.2, 99.8%	81.6, 97.5%	0.7, 8.5%	0.3, 1.8 mm

Standard uncertainty, 3.2% for point dose and 0.6 mm for distance to agreement at Point A.

- One out-of-tolerance result…



Dose Normalization, Optimization and Prescription

Normalization type: Normalized manual
F Factor: 1.000
Optimization type: Manual dwell weights / times
Optimization notification: Manually adjusted dwell weights / times.
Prescription dose per fraction/pulse (Gy): 7.0000
Total Reference Air Kerma per fraction/pulse at 1 m (Gy): 0.0060

Source Coordinates and Times (continued)

Catheter 2 (channel 5) - IU
Offset (cm): 0.00

Position	X (cm)	Y (cm)	Z (cm)	Dwell weight	Dwell time (sec.)
253	-0.07	0.55	20.55	3.10	374.9

Applicator Points

Set Name	Coord. System	Name	X (cm)	Y (cm)	Z (cm)	Abs. Dose (Gy)	Rel. Dose (%)
A-points	Applicator	A1	-2.00	2.00	0.00	10.2660	146.66
		A2	2.00	2.00	0.00	10.1457	144.94

…actually miscommunication on normalisation between auditor and local physicist….

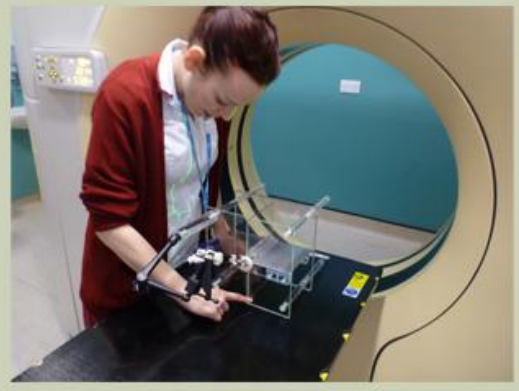
Reminder of the ‘human element’ most prone to error

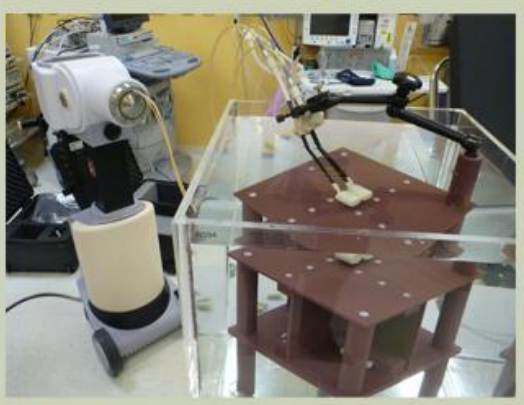
Response from Centres

- Feedback from audited centres to the IPEM WP film dosimetry audit
  - Purpose and process
  - Good and bad bits
  - When to audit
  - Future audits

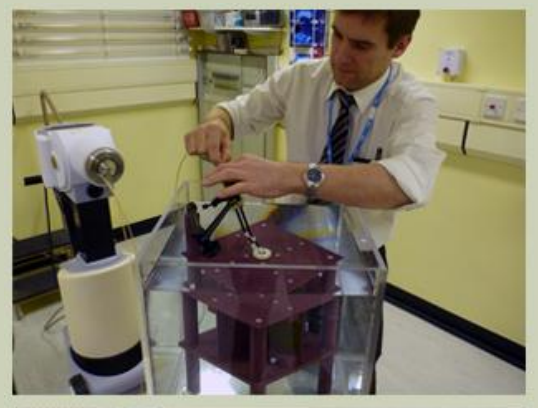


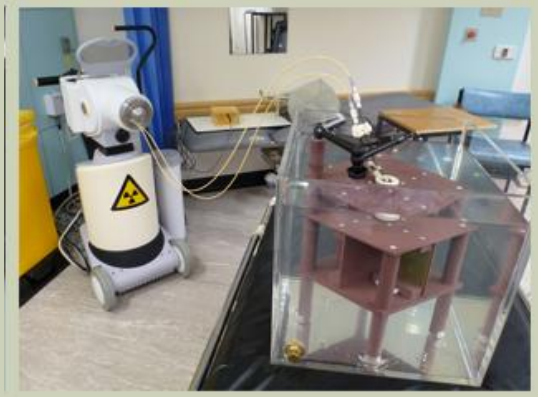

- **Purpose and process:**
  - "this is the first time we have been audited in this way and it complements the internal QA we do"
  - "very useful as it tested the whole treatment path … gave us access to a phantom and measurement technique not otherwise available"
  - "it confirmed that our planning and delivery system is within acceptable clinical tolerances"
  - "I liked that it involved the whole planning process including the CT scan"
  - "…found it very reassuring to have our full process audited"



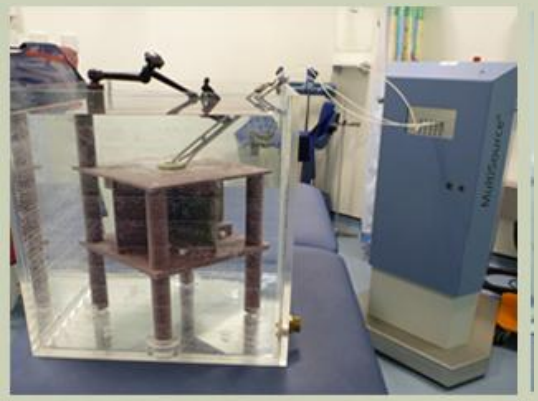


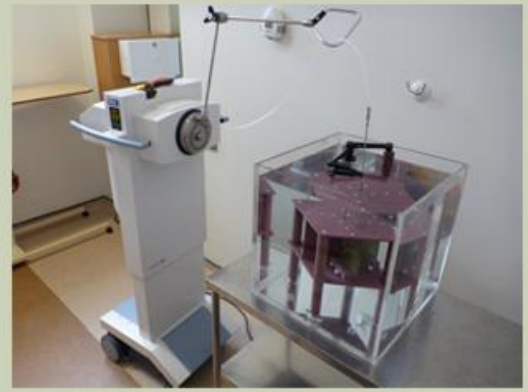
- **Good and bad bits:**
  - "Quick results and good spatial resolution. Also a very quick audit to perform"
  - "very well organised and protocols were easy to follow"
  - "the phantom is somewhat fragile and I'd be a little sorry to see it entrusted to a courier"
  - "It was teamwork, I made the tea while you did all the work"
  - "I am smiling broadly"
  - "I always believe any audit you pass is a very well set up and run audit"





- **When to audit**
  - "…offer the audit service to centres commissioning new equipment and/or implementing new brachytherapy techniques. This is the time when an external audit offers most benefit"
  - "I presume the phantom and procedure will be made available through IPEM for borrowing and individual use by departments"





Future audits

- "…HR-CTV is one huge area of confusion. Would be interesting to send an image set round the country and see if the patient would get the same treatment from different centres"
- "in a future version that all users with the same equipment could plan an identical plan for inter-dept comparison"
- "…audit in vivo dosimetry in brachy …non-TG43-based dosimetry…in the future"
- "small field dosimetry"

Conclusions

- Collaboration between IPEM, RTTQA, NPL
- Film dosimetry and alanine dosimetry for brachytherapy
- National brachytherapy audit implemented
- Initial results of ‘end-to-end’ dosimetry very good
- Supplementary benefits in discussing clinical practice

Further reading...

IOP Publishing — Physics in Medicine and Biology
Phys. Med. Biol. **58** (2013) 6623–6640 — doi:10.1088/0031-9155/58/19/6623

Design and implementation of a film dosimetry audit tool for comparison of planned and delivered dose distributions in high dose rate (HDR) brachytherapy

Antony L Palmer[1,2,6], Chris Lee[3], Ailsa J Ratcliffe[4], David Bradley[1] and Andrew Nisbet[1,5]

IOP Publishing — Physics in Medicine and Biology
Phys. Med. Biol. **58** (2013) 497–511 — doi:10.1088/0031-9155/58/3/497

Verification of high dose rate brachytherapy dose distributions with EBT3 Gafchromic film quality control techniques

Antony L Palmer[1,2,4], Andrew Nisbet[1,3] and David Bradley[1]

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