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History of Dosimetry Audit in the UK

Andrew Nisbet

Department of Medical Physics
St Luke's Cancer Centre, Royal Surrey County Hospital NHS Foundation Trust, Guildford
& Department of Physics, Surrey University

What can we learn from audit results in the literature?

- What benefits have been derived?
- What is the currently achieved consistency in radiotherapy dosimetry?
- Can dosimetry audits be used to assure accuracy of advanced radiotherapy treatments?
- Do dosimetry audits benefit clinical trials?
- What should the methodology for future national dosimetry intercomparisons entail?

Timeline

- IAEA postal dosimetry service 1966/7 using (LiF) TLD. The WHO joined the programme in 1968
- RPC funded since 1968 by the NCI for QA of dosimetry of patients entered into clinical trials
- Worsnop B R 1968 Phantom thermoluminescent dosimeter comparison for a co-operative radiotherapy trial *Radiology* 91 541-53
- Almond P R, Law J and Svenson H 1972 Comparison of radiation dosimetry between Houston (USA),Edinburgh (UK) and Umea (Sweden) *Phys. Med. Bid* 17 64-70

Timeline

- Johansson K-A, Mattsson L 0 and Svensson H 1982 Dosimetric intercomparison at the Scandinavian radiation therapy centres *Acta Radiol. Ther. Phys. Biol.* 21 1-10

- Wittkimper F W, Mijnheer, B J and van Kleffens H J 1987 Dose intercomparison at the radiotherapy centres in the Netherlands. 1. Photon beams under reference conditions and for prostatic cancer treatment *Radiother. Oncol.* 9 33-44

Timeline

- Johansson K-A, Horiot J C, Van Dam J, Jepinoy D, Sentenac I and Sernbo G 1986 Quality assurance control in the EORTC co-operative group of radiotherapy. 2, Dosimetric intercomparison. Radiother Oncol. **7** 269-79

- Johansson K-A, Horiot J C and van der Scheuren E 1987 Quality Assurance Control in the EORTC co-operative group of radiotherapy. 3. Intercomparison in an anatomical phantom Radiother Oncol. *9* 289-98

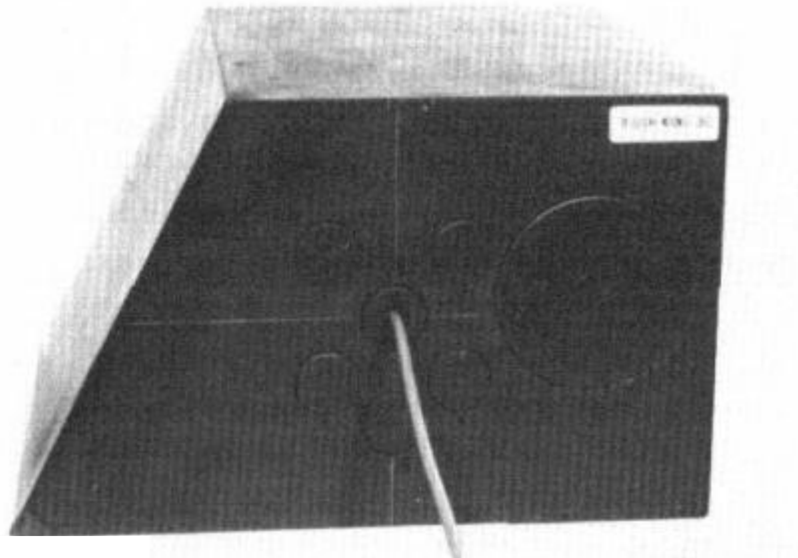
Timeline

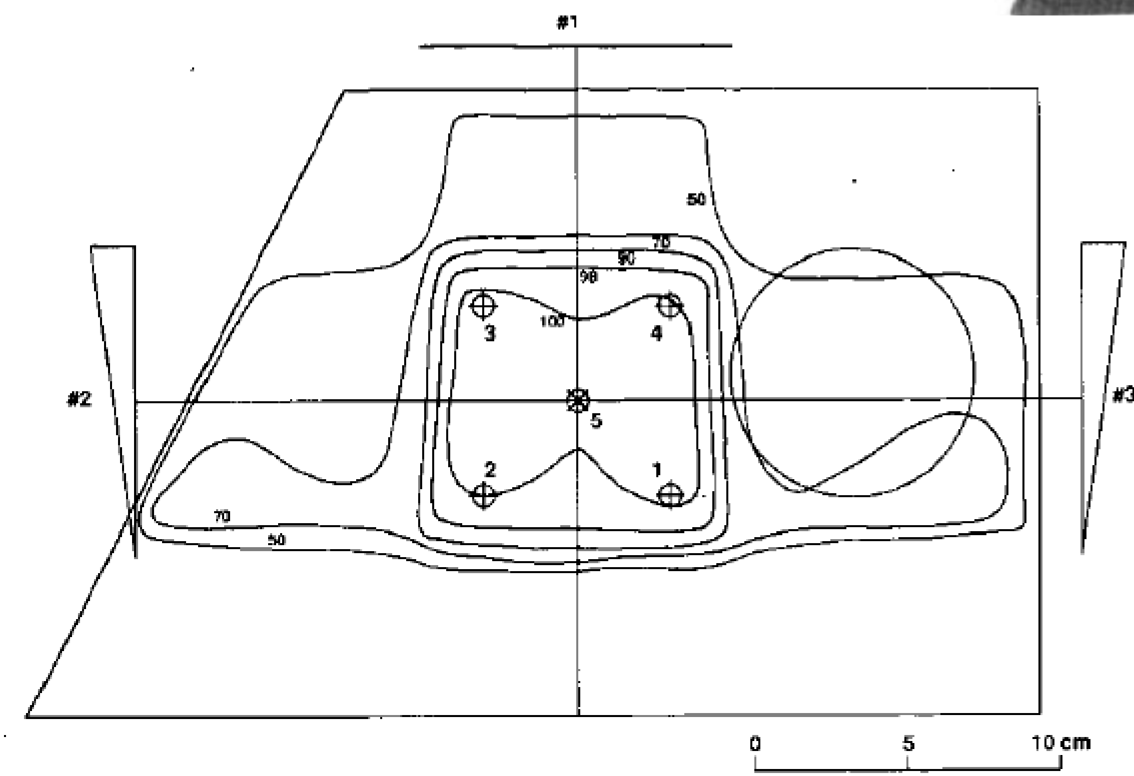
- Barrett J H, Davy T J, Dixan-Brown A, Goodman D, Lawson R C, Ormsby J E, Williams P C, Fowler J F and Wiemik G 1990 Dosimetric intercomparison in the British Institute of Radiology fractionation study of 3 F/week versus 5 F/week in radiotherapy of laryngo-pharynx cancer *Br. J. Rodiol. 63* 125-7

- 1st comprehensive national dosimetry intercomparison in the UK carried out in the late 1980s. (Thwaites et al. PMB 37, 445, 1992)

Thwaites et al 1992

- 15 regions
- Jan 1987-Jan 1991
- 63 centres





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Reference Dosimetry Results

Table 6. Summary of results (ratios of measured-to-stated dose) of recent photon dosimetry intercomparisons in reference conditions.

Reference	Region/study	No.	Av.	sd	Range
Johansson *et al* (1982)	Scandinavia				
	Co-60	22	1.001	0.014	0.05
	x-rays	50	1.017	0.023	0.10
Johansson *et al* (1986) (EORTC)	Europe				
	Co-60	59	1.001	0.019	0.10
	x-rays	16	1.024	0.033	0.14
Wittkämper *et al* (1987)	Netherlands				
	Co-60	11	0.994	0.006	0.02
	x-rays	40	1.008	0.020	0.10
Hanson *et al* (1991)	International (mainly USA)				
	Co-60 and x-rays	740	1.008	0.019	0.14
This work	UK				
	Co-60	61	1.002	0.014	0.08[a]
	x-rays	100	1.003	0.015	0.10

[a] Omitting centre 163.

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Multi Beam Situations

Table 7. Summary of results (ratios of measured-to-calculated dose at the centre of target volume) of *dosimetry intercomparisons in multi-beam situations* (with acknowledgements to Johansson 1987).

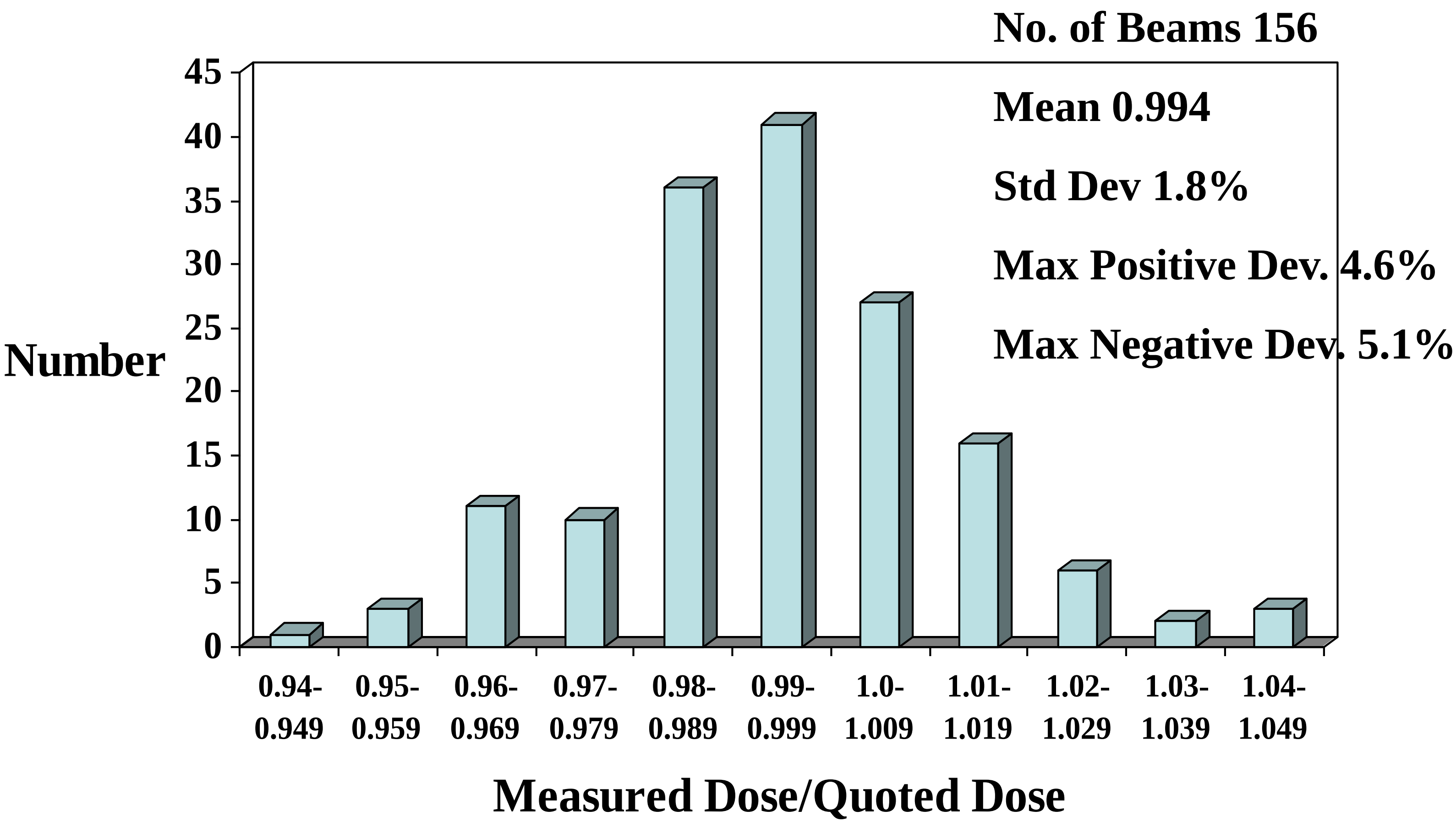
Reference	Region/study	Site	No.	Mean	sd
Worsnop (1968)	US 1968	lung	16	—	0.069
Johansson (1987)	Sweden 1984	bladder	15	1.002	0.031
Johansson *et al* (1987) (EORTC)	Europe 1982-1986	tonsil	19	1.035	0.032
Wittkämper *et al* (1987)	Netherlands 1985	prostate	18	1.015	0.015
SSRBMP (1984)	Switzerland 1984	lung	13	1.005	0.062
Present work	UK	3-field (homogeneous) (with lung inhomogeneity)	62 62	1.008 1.011	0.027 0.034

Timeline

- Dosimetry audit network evolved in the early 1990s (e.g. Bonnett et al BJR 67, 275, 1994)
  - UK national audit network established in 1993
  - Network co-ordinated by the IPEM and comprises eight co-operative regional groups
  - Basic audit methodology and phantom design followed that of the original national intercomparison

- National UK Electron Intercomparison carried out 1994-96 (PMB 42:2393-409, 1997)

Results for Electron Beam Calibrations

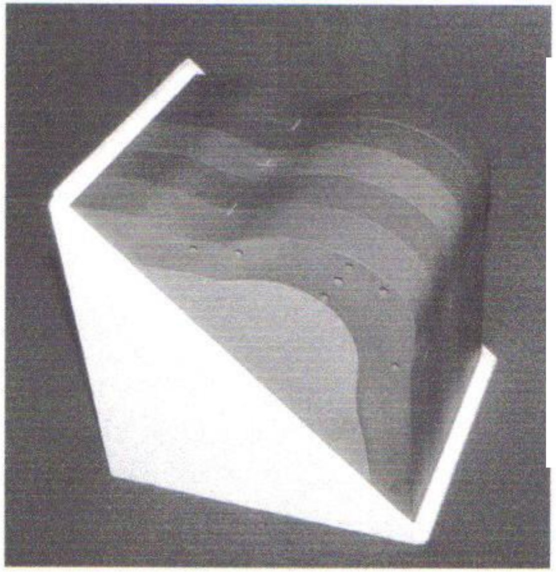
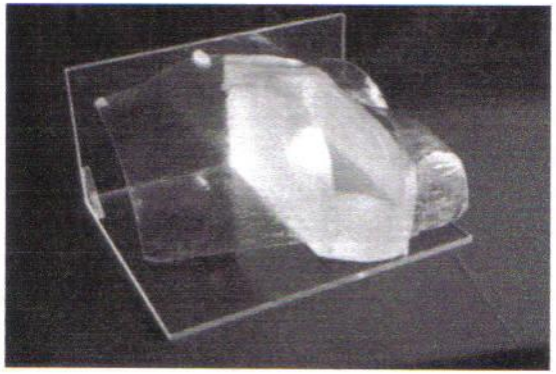
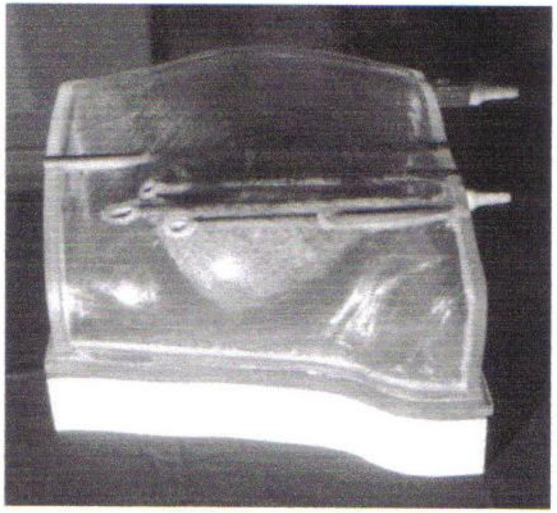


Timeline

- NPL, at the invitation of IPEM, started conducting reference dosimetry audits in 1995.
  - The NPL is involved in the network and carries out reference beam calibration audits to link the groups.

Circa 2000 NCRI Radiotherapy Clinical Trials: Quality Assurance Group

Start Breast Phantoms

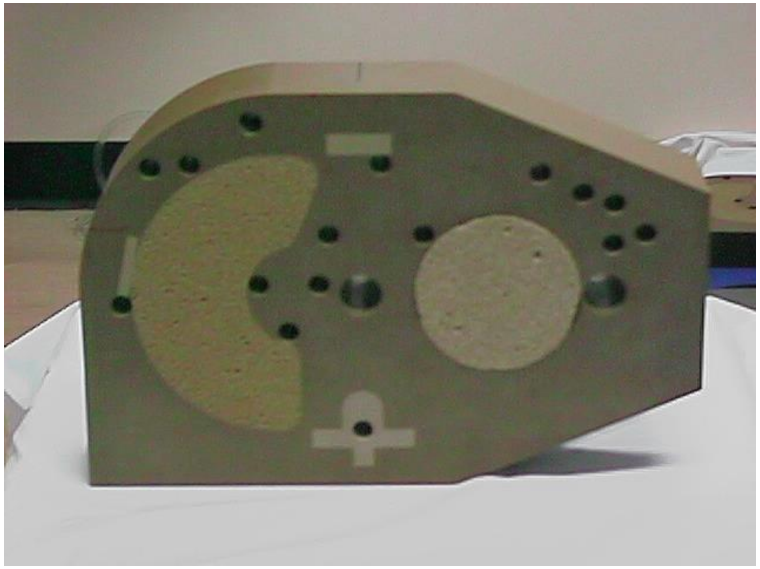




*Venables et al **Phys Med Biol. 2001 Jul;46(7):1937-48** The mean ratio of measured to calculated dose at the START reference point was found to be 0.981 for the breast phantom and 0.978 for the chest wall phantom. A number of departments had deviations of greater than 4%*

*Venables et al **Radiother Oncol. 2004 Jun;71(3):303-10** TLD measurements were performed on 429 patients from 33 hospitals. The average ratio of dose measured using TLD to that prescribed was 0.99+/-0.04. Eight patients had initial measurements more than 10% different to the prescribed dose.*

Semi Anatomic phantom Scottish+ audits(Thwaites et al 2003)

- MV calibration 1.001(SD 1.1%)
- Other single field parameters 0.998 (SD 1.5%)
- Geometric parameters 1.00(SD 1mm)
- e^- calibration 0.997 (1.8%)
- KV 1.001 (SD 1.6%)
- Breast 0.978(2.3%) 96% within 5% tolerance
- Thorax 0.991(1.1%) 100%
- H&N 0.993 (1.6%) 97% within tolerance



Timeline

- Dosimetry audit for a multi-centre IMRT head and neck trial. Clark et al Radiother Oncol 2009
- A national dosimetric audit of IMRT. Budgell et al Radiother oncol 2011
- A methodology for dosimetry audit of rotational radiotherapy using a commercial detector array. Hussein et al Radiother Oncol 2013
- A national dosimetry audit of intraoperative radiotherapy Eaton et al BJR 2013

Comparison between all results

2003		1996	
Number	22	Number	156
Mean	0.995	Mean	0.994
Std Dev	0.7%	Std Dev	1.8%
Max Pos Dev	0.5%	Max Pos Dev	4.6%
Max Neg Dev	2.0%	Max Neg Dev	5.1%

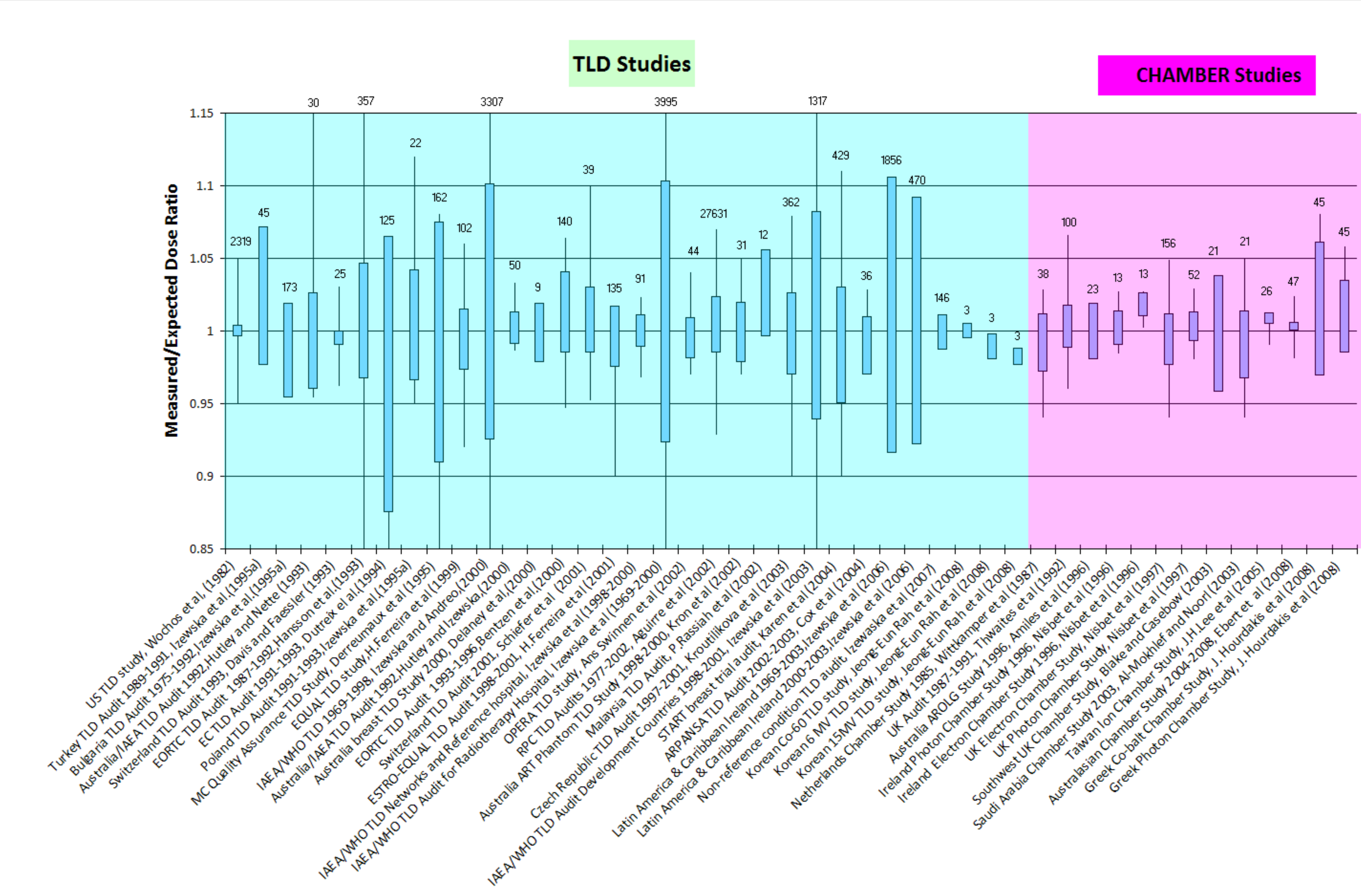
Comparison between relevant centres 1996 and 2003 results

	2003	1996
Number	22	15
Mean	0.995	0.995
Std Dev	0.7%	2.2%
Max Pos Dev	0.5%	2.6%
Max Neg Dev	2.0%	4.9%

EQUAL results >5% (Ferreira et al 2003)

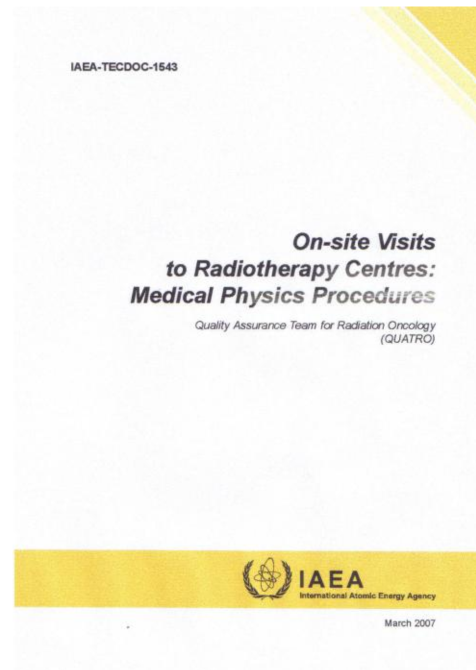
- Reference
  - 1998-1999 3.1%
  - 1998-2002 1.2%
- Beam output variations
  - 1998-1999 4.7%
  - 1998-2002 1.8%
- Wedge
  - 1998-1999 10.4%
  - 1998-2002 3.3%

Results from sample of audits



On site visits

- Clinically significant discrepancies in most studies
- Remote TLD audits less resource intensive –
- Site visits with ionisation chambers less uncertainty & more likely to find root cause



IAEA-TECDOC-1543

On-site Visits
to Radiotherapy Centres:
Medical Physics Procedures

Quality Assurance Team for Radiation Oncology
(QUATRO)

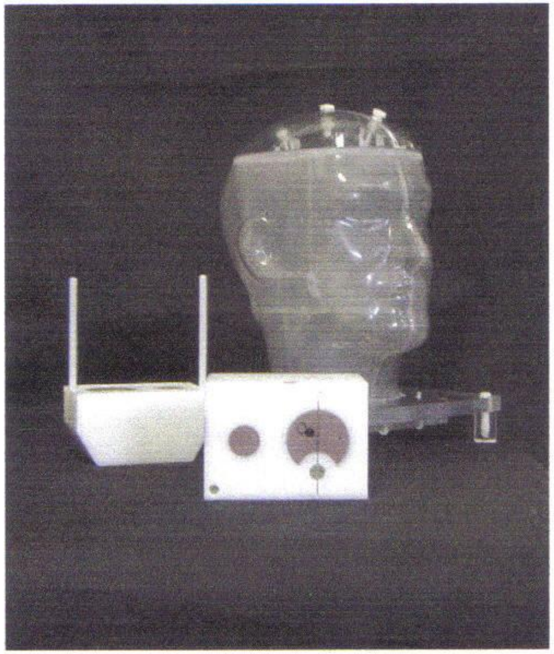
IAEA
International Atomic Energy Agency

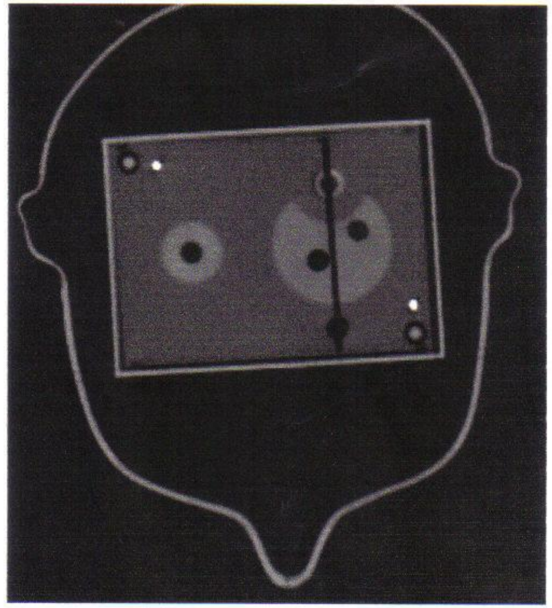
March 2007

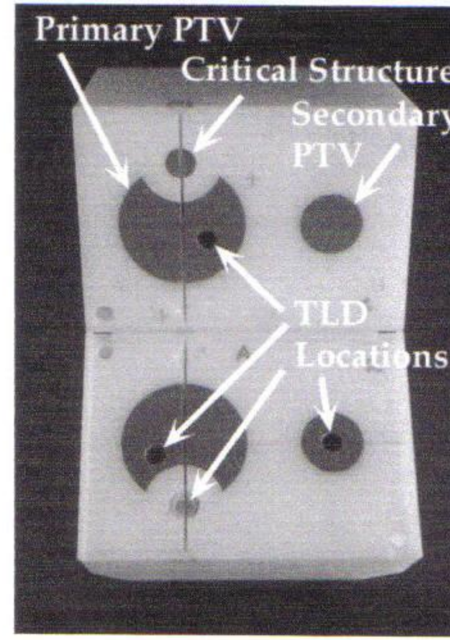
Cost Effective?

- **Radiotherapy and Oncology**
  Volume 86, Issue 2, Pages 195-99 Quality assurance of dosimetry and the impact on sample size in randomized clinical trials, Pettersen, Aird, and Olsen
- "The number of patients required in an Randomised Clinical Trial may be reduced by introducing appropriate dosimetry QA as the risk of under-powering the study is minimized. Dosimetry QA in clinical studies is therefore cost-effective".

RPC Head & Neck Phantom







Phantom	Head and neck	Prostate	Thorax	Liver
Irradiations	250	64	24	4
Pass	179	55	17	3
Fail	71	9	7	1
Year introduced	2001	2004	2004	2005

RPC Credentialing

- Voluntary credentialing study for head-and-neck IMRT. Out of 250 of the top US cancer treatment institutions, 71 failed, despite generous passing criteria (7% tolerance and 4 mm distance to agreement). (Ibbot et al Int.J.Radiat.Biol.Oncol.Phys. 2008)
- Gynae Ooncology Group 165, HDR cervix
  - Credentialed centres
    - major deviations 0, minor 15 (no 70)
  - Non -Credentialed
    - major deviations 57, minor 87 (no 275)

Benefits (&disadvantages) of credentialing

- Benefits
  - Primary role – reduce deviation rate for data submitted for clinical trials
  - Education
  - Reassurance
  - Some evidence deviations less in credentialed centres
- Disadvantages:
  - Resources needed
  - A deterrent to trial recruitment (Note: funds are available locally)

Conclusions

- Clinically significant discrepancies discovered in many (inter)national studies, particularly in developing world and under-resourced centres
- Clinically significant discrepancies discovered for advanced technologies in USA
- Deviations less in credentialed centres
- Cost effective

Conclusions

- Standard Deviations decrease with repeated intercomparisons
- Incidence of discrepancies decrease
- Standard deviations increase as complexity of intercomparison increase

- Results indicate consistency for photon and electron beam dosimetry at the level of beam calibration in the UK at tolerances applied (SD within 1.0%)

Options for Audit Groups

- Tighten tolerances for standard audits (diminishing returns)

- OR

- When it is observed that the tolerances for reference levels are met continually develop to include more complex treatments / modalities / levels of dosimetry chain /imaging /patient measurements.