

Interdepartmental Dosimetry audits – the UK experience

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AAPM Spring Meeting
Denver, Co



Great Staff - Great Care - Great Future

Hull and East Yorkshire Hospitals
NHS Trust



Declaration

- I am a Founder, owner and Director of a company that exists to produce and market the VERT system
 - A Flight Simulator for Radiation Therapy training

Vertual Ltd
www.vertual.co.uk

Acknowledgement

- Several people have contributed slides, material and advice for this talk
 - Steve Bolton - IPEM audit
 - Catharine Clark – UK trials and NPL
 - Russell Thomas – NPL
 - Una Findlay - PHE
- I am representing the UK Radiation Oncology Physics Community

My department in Hull



SAM

- It is early in the morning for me!
- This is a SAM course
- So we will have a practice SAM

- **VOTE BY RAISING YOUR HANDS FOR THIS PRACTICE QUESTION.....**

Practice-SAM

vote by raising your hands only

What is the role of a National Inter-departmental audit?

- a. To fulfil, where necessary, a legislative requirement
- b. To identify departments that don't have quality staff
- c. To identify departments that should be closed down
- d. To aim for best practice and consistent treatments
- e. To ensure expensive Physicists have enough work to do

Don't press your buttons!!

Practice-SAM

you didn't press your buttons did you?

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UK Safety Culture

Legislation

IR(ME)R / IRR99

Professional

Registration

Reporting & Learning

Systems

Professional Guidance

- TSRT

Dosimetry Audits

MDT Working

Quality Management

Systems

Training & CPD

Independent or Peer

Review

Multi-disciplinary collaboration

Outline of talk

- Will present various audits and lessons learnt from them
- Try to build a picture that explains the current national philosophy and 'audit culture'
 - Multi-disciplinary approach to patient safety
 - Collegiate approach by all to help all with safety issues
 - How trials have benefited from peer review audit
 - Have dosimetry audits impacted consistency over the UK?
 - Have dosimetry audits helped improve quality of radiotherapy?

<http://www.scopeonline.co.uk/pages/articles/radaudit.shtml>

1987-1991 audit

- First comprehensive UK audit was between January 1987 and January 1991
- Intercomparison between all 64 centres in the UK
 - 161 sets of reference point measurements and 62 distributions returned
 - CAX at 5cm depth for 5x5, 10x10, 15x15 sq cm fields
 - Distribution = doses at five points
- Organised by a group of 15 regional coordinators, who took the equipment and made measurements with a local physicist
 - Hand-over between regions aided consistency

Thwaites et al, PMB 1992 **37** 445-61

Auditor Reference point measurements testing locally calculated value

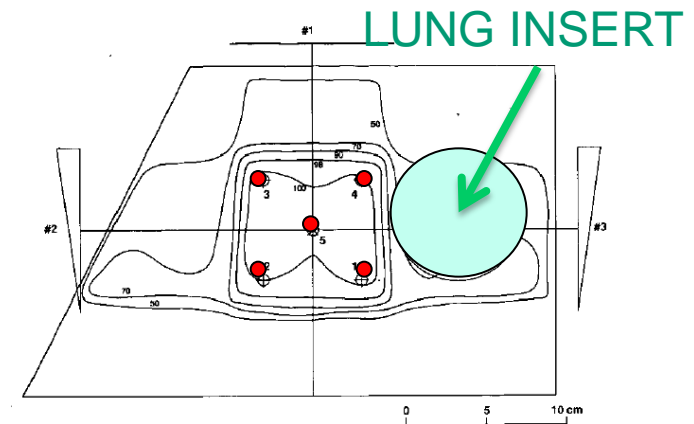


Figure 2. The field arrangement and a typical dose distribution for the planned irradiation showing the positions of the five measurement points.

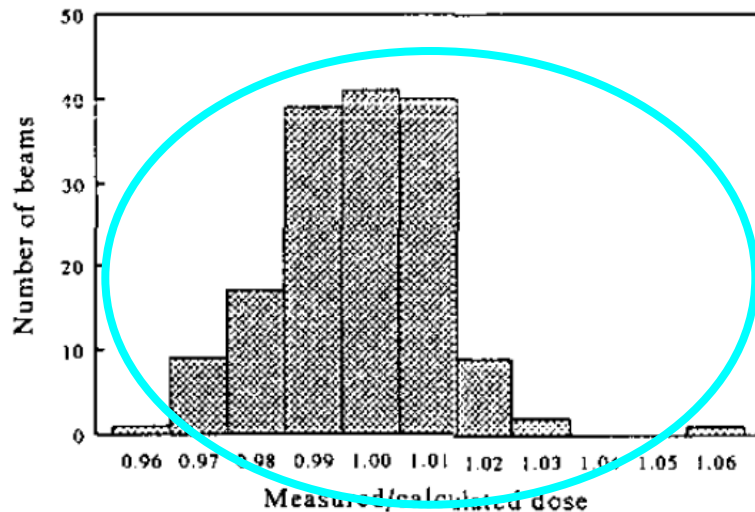


Figure 4. Results for the reference-point measurement showing the distribution of the ratio of the measured dose to the calculated dose. The average value of the ratio for the three field sizes has been used.

- Auditor meas/ local calc
- Mean = 1.003 sd=1.5%
 - 5% difference seen for 9/62 centres
 - 25% difference seen for 1/62 centre
 - More about this later!

Analysis for 9 centres showing diff >5%

- Small errors in data (DDR, wedge factors) used in dose calculations → corrected
- DDR for one FS/wedge angle found corrupted in TPS → corrected
- Software faults identified in TPS → TPS QC
- No lung correction and excessive lung density values (0.5) used → review of values
- High output value on treatment unit (policy not to correct one day instance) → review of practice
- Output drift for wedge output related to monitor system → led to new QC systems introduced

Most significant finding

- Picked up the 'Devon-Exeter' Co-60 calibration error
- 25% dose error seen
- These results were not reported in the published paper
 - Electrometer over-ranged; measured for 0.8 min; recorded that reading as Gy/min → subsequently used an underestimate of output by $1.0/0.8 = 1.25$
- Arguably, this finding is single most 'justification' for continuation of the UK audits

<http://www-pub.iaea.org/books/IAEABooks/5818/Lessons-Learned-from-Accidental-Exposures-in-Radiotherapy> ; Event no 10 on page 13 (pdf page 23)

Regional Interdepartmental audit

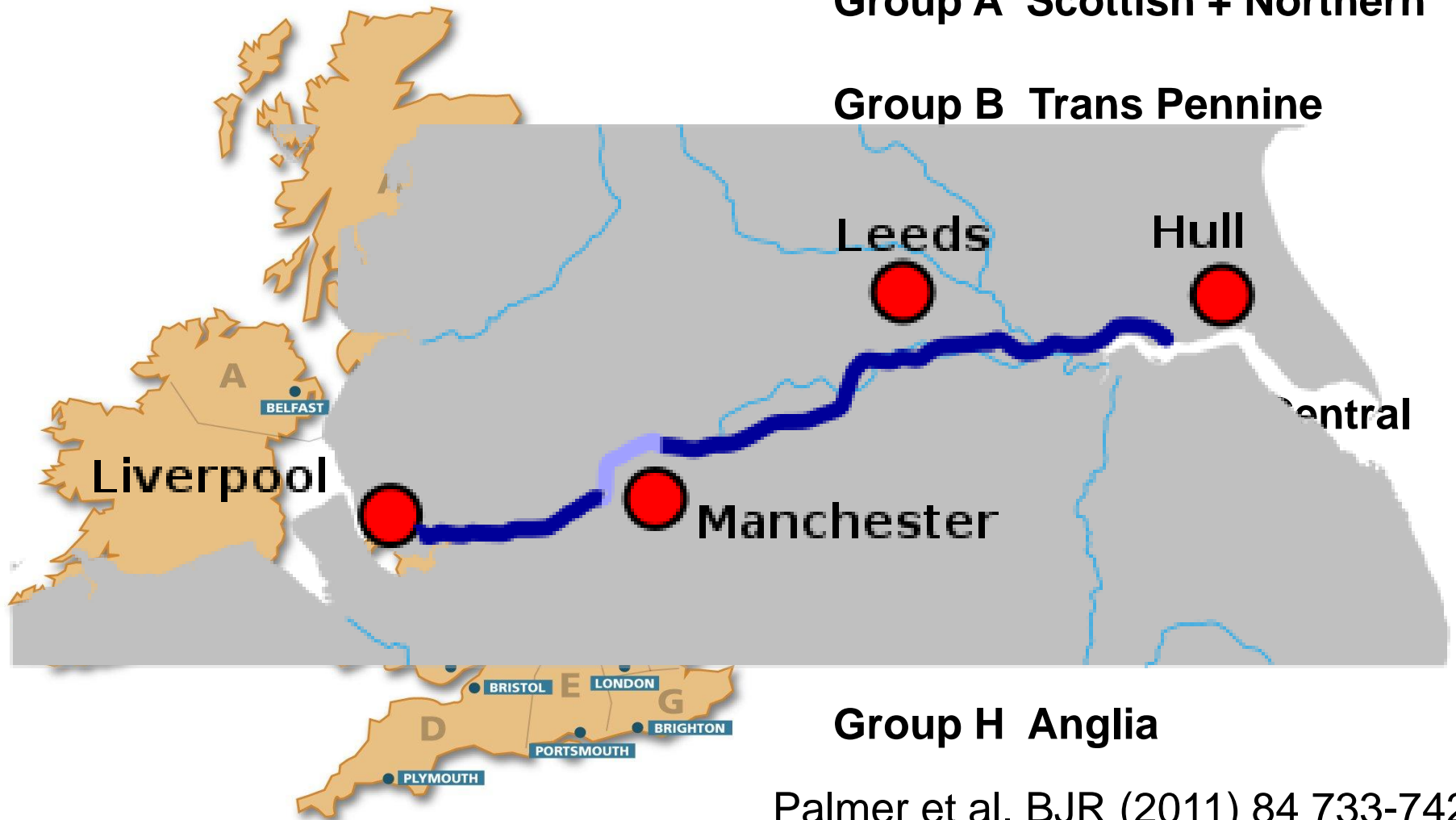
- This 'discovery' gave strong support for more audit!
- 1993 a method for regional interdepartmental audit strategy was developed
- Actually a trial undertaken, against a comprehensive plan, between two centres
- Broadened the scope out to include examination of documentation and QC procedures
- This began circa 1993/94

Bonnett et al BJR 1994 **67** 275-82

UK Audit Groups – regional management

Group A Scottish + Northern

Group B Trans Pennine



Group H Anglia

Palmer et al. BJR (2011) 84 733-742

1996 Electron audit

- One person (PhD student) visited all 52 centres using electrons
 - Funded project!
- Measured energy and output for three energies
 - Beams were from 3 MeV to 22 MeV
 - Using auditor's electrometer and chamber
- 156 beams were included in the inter-comparison
- Ratio of auditor to local quoted output/ dose
 - Mean 0.994 st dev = 1.8% (max +4.6%, min -5.1%)

Nisbet and Thwaites PMB 1997 **42** 2393–2409

1996 Photon re-audit

- Also performed single MV photon output measurement whilst performing the main audit
 - Follow up to the 1988-91 MV audit
- 52 MV measured (16 Co and 36 Linac)
 - All intercomparisons within 3%
 - Mean audit:local = 1.003 sd=1%
- For photon MV beams the s.dev/ spread had **DECREASED** in this repeat of the 88-91 audit

Nisbet and Thwaites PMB 1997 **42** 2393–2409

Regional programme – continued success?

- Worked well in some regions (100% compliance)
- However in some regions progression was sporadic with some audits not taking place
- Once audits completed the reports often were a long time coming (months!)
- Issue was essentially lack of funding/ coordinators were volunteers
- In 2006 Steve Bolton became Chair of the IPEM National Intercomparison Audit Group
 - Promoted the idea of a ‘re-boot’

2008 MV photon (minimum) audit

- The concept of a minimum audit was introduced
 - To be undertaken along with whatever else the regional groups might decide to do on that audit round
- Intercomparison was expanded to include a measure of a clinically relevant situation using local and auditor's equipment
 - Wedged fields
- Spreadsheet designed to gather immediate feedback
 - To combat frustration that often took long time to get results/ reports back

Learning points

- Lower participation than desired/ hoped for
- Output measurements and QI measurements showed (usual) good agreement
- Wedged field comparison showed more variation
 - mean ratio = -0.49% with sd= 1.3%
 - 4 departments >2% with 2 of those >3%
 - The 2 departments demonstrating the largest difference attributed the cause to be the calculation algorithm in use, and perhaps the data, in the planning system.
- Pre-configured/ automated Spreadsheets tool was a huge success

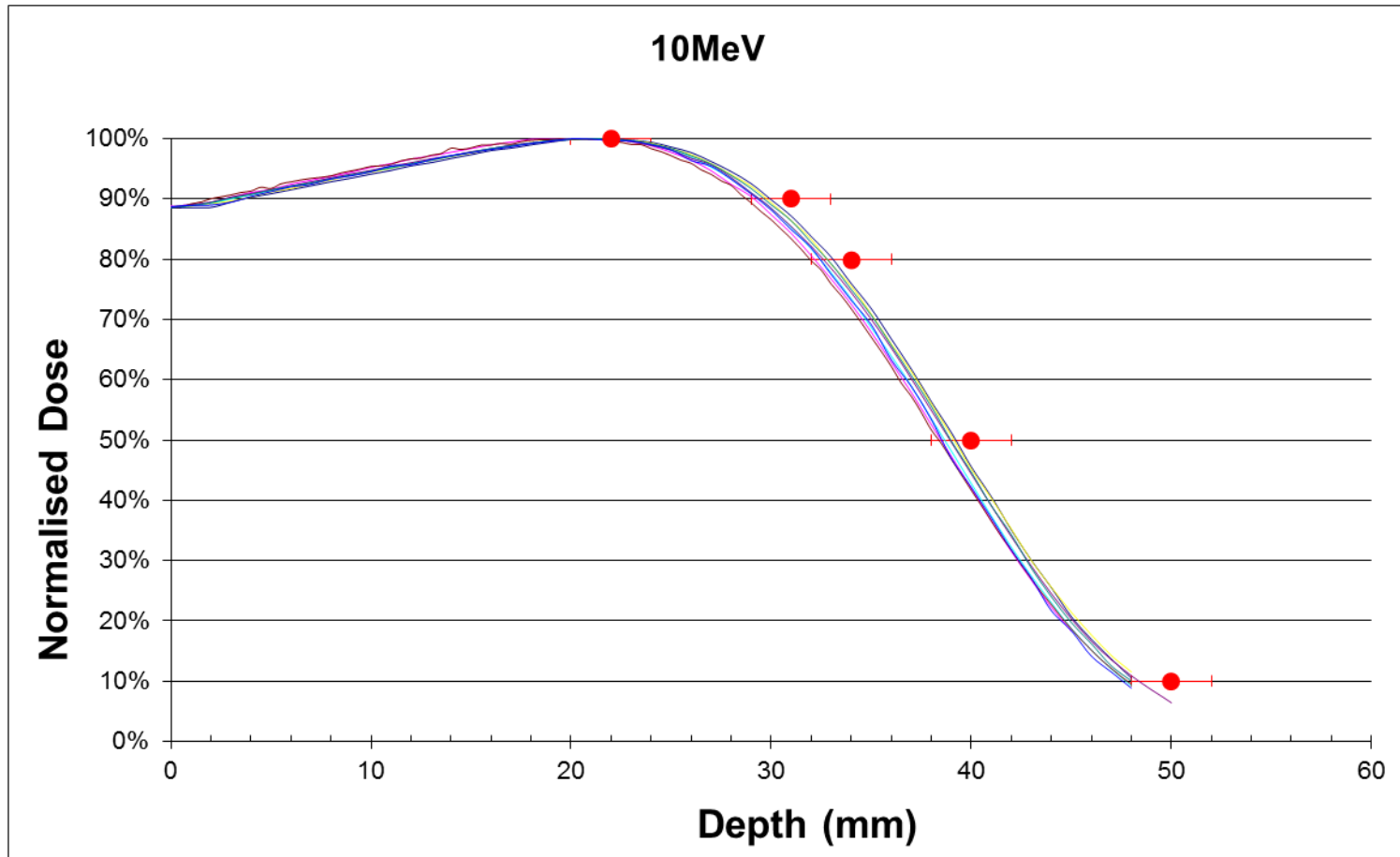
2009/10 Electron audit

- Audit was performed against the IPEM 2003 Code of Practice
 - 1996 audit had been against the previous code
- Spreadsheet tool again produced to give immediate results/ feedback
- Three energies/ beams audited
 - lowest and highest energy and one around 9 MeV
 - Measured R_{50} , output at Z_{ref}
- Dose for a cut-out, with bolus and standoff (again a clinical application rather than simple measure)

Planned Cutout Field by Department

- Again, range of results was much broader than for simple outputs/ energy measures
- Generally measured dose was less than calculated and in many cases is $>4\%$.
 - A number of reasons for this discrepancy were explored including approximations made in the calculation process.
- 3 departments were found to have a difference of $>10\%$ between the calculated μ for 2Gy at 2.5 cm depth and the measured dose.

Department 1 (>10% discrepancy)



- All linacs matched 50% electron ionisation depth to within 1mm
- One set of reference values used clinically, turns out all Linacs were at edge of agreed tolerances for the local 'golden beam data'

Departments 2&3 (>10% discrepancy)

- Dept 2: Two contributory factors
 - clinical issued depth dose data was average of two different machines
 - bolus material “SuperFlab” not water equivalent
- Making allowances for these reduced dose error to 4.8%

- Dept 3: bolus sheet used was incorrect thickness – not as stated
 - Dept introduced further QC to control for it

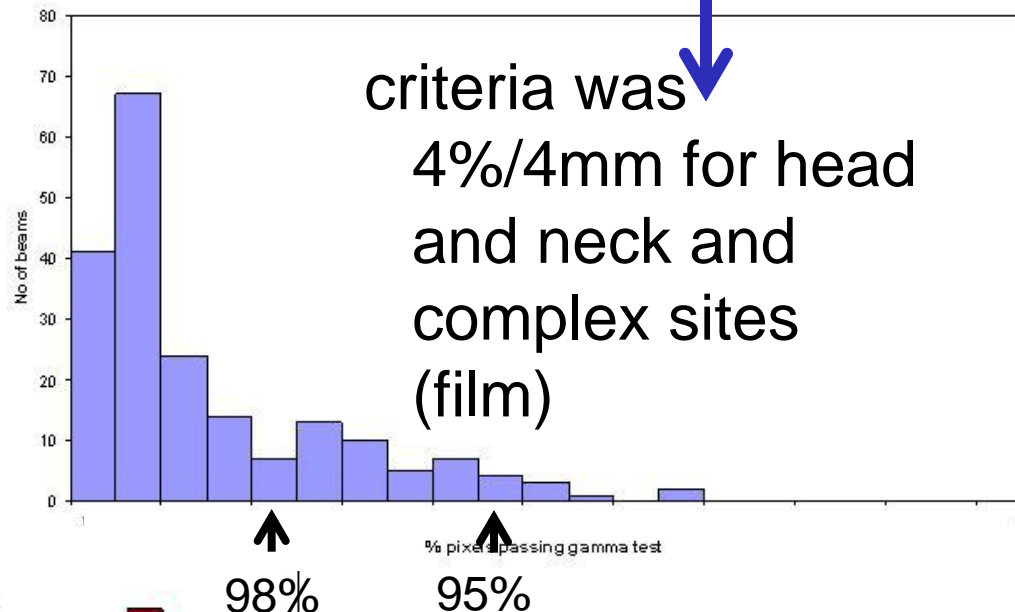
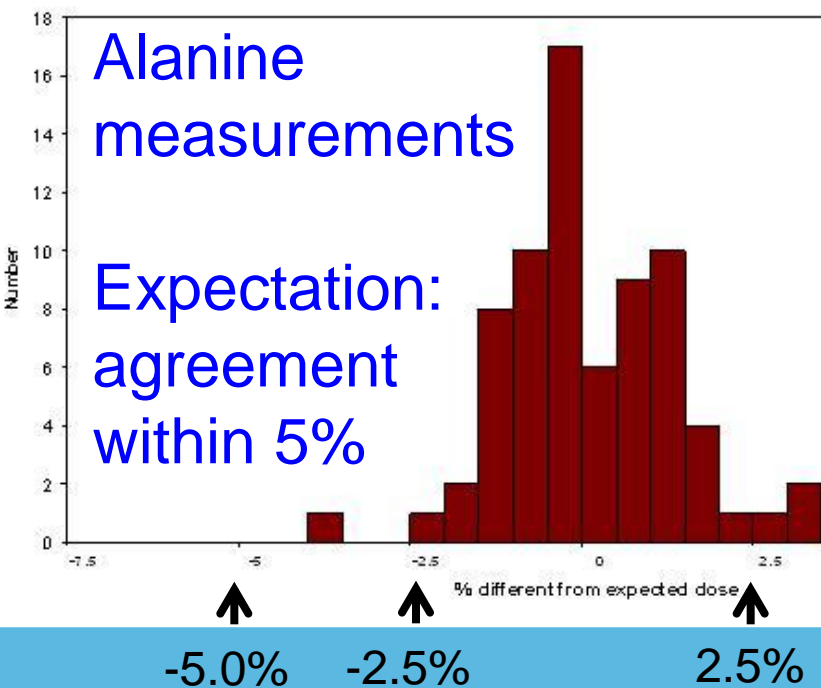
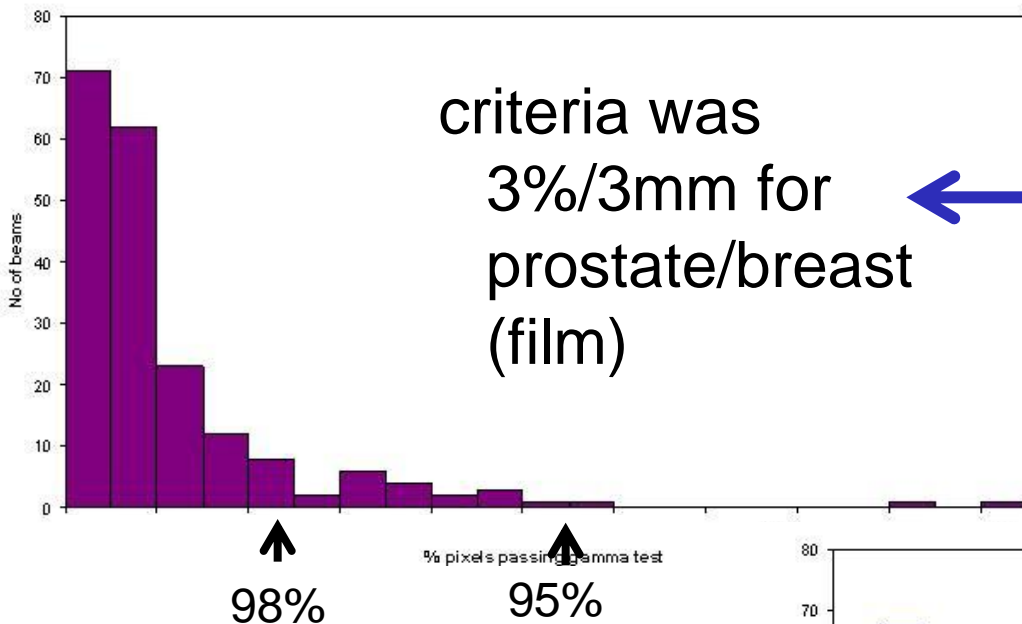
2010 IMRT audit

- Designed to be Independent of linac, TPS and treatment delivery method
- Suitable for a plan from any clinical site
 - Plan IMRT plan on TPS / recalculate existing plan
 - Calculate dose grid for each beam at gantry 0°
 - Irradiate supplied EDR film at 95 cm FSD
5 cm deep in a phantom
 - Measure dose with ion chamber and alanine
 - Return films and alanine with DICOM dose grids for independent analysis

Film

measurements

Expectation: 95% pixels should pass gamma criteria within 20% isodose



2012 kV audit

- Audit was concerned with verifying the calibration of the SXR machines at all energies used clinically.
- Measured half value layers and compared to those in use
- Measured output of each beam using independent calibration factors

2012 kV audit

- Significant realisation of communities 'audit confidence':
 - A few cases of the local team 'challenging' the auditors statements
 - Both centres performed investigation and auditors identified own improvements
 - Minor example, my centre where a 2.1% discrepancy in output for 80kV (within audit 3% tolerance!)
 - Traced to be a 1mm measurement discrepancy in the stand-off measurement
 - Auditor used a steel rule, we had measured in the workshop on engineering bench!

2012/13 Rotational IMRT audit

- Good example of a contemporary independent audit that has aided in a more efficient roll-out of a new technique across our UK community
- Used to sense check own implementation
 - Gave confidence to those recently 'struggling with IMRT'
- Issues identified:
 - Lack of couch modelling in some TPS
 - Minimum gap too small
 - High modulation/ high MUs
 - Lack of info re what some TPS/Linac combinations are capable of
 - Non-cts variable dose rate
 - Lasers and barometers variation existed



2012/13 Rotational IMRT audit

- More than 93% of analysed planes achieved more than 95% pass rate for gamma parameters of 3%/3mm
 - For many systems 3%/2mm were considered better criteria
- The majority of centres achieved accurate implementation of TPS modelling and delivery for VMAT and helical tomotherapy
- Evaluation of the standards which others starting a VMAT programme should be able to achieve

Hussain et al. Radioth Oncol 2013 108(1) 78-75



Brachytherapy audits

- Two audits in recent years
- 2010 and 2013/4
- The first was linked to the introduction of the new National Calibration Code of practice
- Second was related to participation in a trial and around the use of IGBT

- Review: Palmer et al. BJR 2014
 - Available 'ahead of print'
 - <http://dx.doi.org/10.1259/bjr.20140105>

Extension to 'IPEM audits': NPL audits

- In UK also have an option to 'buy-in' an audit from the National Physics Lab (Primary Standards Lab)
 - Initially was funded by government and therefore free
- The NPL was invited to join in the IPEM audit group in 1994 to give advice and conduct an audit of each region on an annual basis.
- Visited over 50 centres and undertaken nearly 100 audits to date
- Also offers Alanine dosimetry service
 - not available elsewhere

Reducing spread; increasing consistency?

MV
Photons

NPL/Host (1994-2011) 1.003 std dev 0.7%
Nisbet/Host (1996) 1.003 std dev 1.0%
Thwaites/Host (1987-1991) 1.003 std dev 1.5%

MeV
Electrons

NPL/Host (ongoing) 1.003 std dev 0.4%
Nisbet/Host (1996) 0.994 std dev 1.8%

RTTQA activity

- From as early as 1985 dosimetry audits were associated with Radiotherapy Trials
- In 2003 it was formalised as RTTQA group (some funding from NCRI)
 - regular QC associated with the participation of any radiotherapy trial
 - Now standard practice and experience of many trials
- Not strictly Inter-departmental audit
 - Though all QC originating from peers and ‘benchmarked’ at various other centres & definitely independent audit!
 - Can even get funding into department for trials QC staffing!

A relevant aside: 2008 reflection

Radiother Oncol. 2008 Feb;86(2):195-9. Epub 2007 Aug 28.

Quality assurance of dosimetry and the impact on sample size in randomized clinical trials.

Petersen MN¹, Aird E, Olsen DR.

Author information

Abstract

BACKGROUND AND PURPOSE: The aim of this study was to investigate the impact of appropriate dosimetry quality assurance (QA) on patient number required in radiotherapy randomized control trials (RCT).

MATERIALS AND METHODS: The steepness of clinical dose-response curves, $\gamma(\text{clin.})$, was calculated by a convoluting a biological dose-response distribution and the distribution of technical and dosimetrical factors. Population size calculation was performed taking into account $\gamma(\text{clin.})$ and expected difference in outcome between two arms of an RCT, for different levels of variation in dose to the patient population.

RESULTS: Uncertainties in dose reduces $\gamma(\text{clin.})$ to the largest extent when the initial γ -value is high and less so for low γ -value. Reduced uncertainty in dose led to a significant reduction in the number of patients required in an RCT if the expected difference between the experimental and conventional arm is small. The reduction in patient numbers is less when the differences between the conventional and experimental arm is larger.

CONCLUSION: The number of patients required in an RCT 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.

PMID: 17727987 [PubMed - indexed for MEDLINE]

The number of patients required in a Randomised Controlled Trial may be reduced by appropriate dosimetry QA as ... risk of under-powering minimised..... Cost effective

Summary

- In the UK we have 25 years experience of doing interdepartmental audit
- It is embedded in a safety culture that utilises dosimetry audit, quality audit, trial QC processes and error reporting
 - Multi-dimensional, multi-disciplinary approach
- Centres often request 'buddy visits' when introducing new techniques as final checks
 - Indication of how ingrained the culture is
- Current plans exist to extend scope further – imaging/ SABR/ SBRT etc

Palmer et al. BJR (2011) 84 733-742

Summary

- There is a drive (led by Catharine Clark) to create more joined up thinking over audit in the UK
 - <http://www.uk-dan.co.uk/>
- Given the overlap of trial participation requirement (EORTC bi-annual submission, UK trial work,) and general resource pressures, we are looking to see where can cross-link 'trial accreditation' with 'safety audits' via acknowledgement of third parties
 - UK Dosimetry Audit Network (uk-dan)
 - IPEM / RTTQA / NPL
- Also working with other International stakeholders to broaden collaboration further

Inbox - Outlook Web App, li: x UK Dosimetry Audit Network x NPL Radiation Dosimetry : Scienc: x

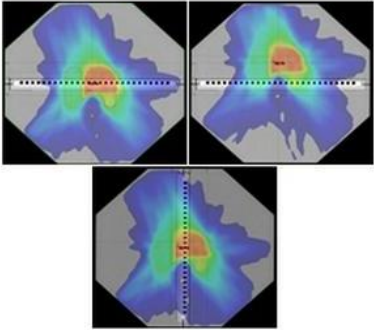
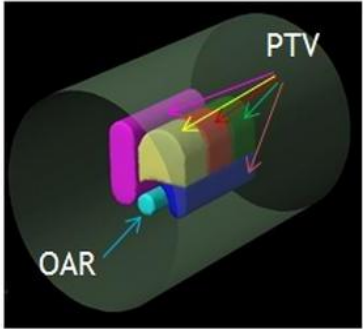
→ www.uk-dan.co.uk/uk-dan/

UK Dosimetry Audit Network

UK-DAN Contributing Groups UK Audit Groups International Audit Groups Audits Meetings Contact

The aim of this website is to provide a resource for information on audit activity in the UK and links to international bodies and to create a forum to present and discuss current and future audits, with a focus on the strategies for co-ordination which exist and can be developed between active audit groups.

Contact [Catharine Clark](#) for more information



Summary

- Currently we have a set of peer review standards that each department must prove to ‘assessors’ they meet in an annual quality review
 - Participation in interdepartmental audit is one of those standards
- These are likely to be developed into standards that ‘commissioners’ / health care purchasers will demand evidence for
 - Financial incentives: if you can’t prove you are safe and accurate service you will not be engaged to provide radiotherapy

Conclusion

- Interdepartmental audit (1988-91) was responsible for catching a systematic mis-calibration error
- Since audit programme introduced no further such errors have been experienced in UK
 - Regular systematic audits check calibration, TPS implementations, new technique implementation
- Complex treatment techniques have been introduced and tested through National and regional audits, trial QC, voluntary 'buddy visit' audits
 - Example: VMAT/ Rotational IMRT audit

Thwaites and Verellen: Radioth Oncol (2010) 94 125-128

Conclusion

- Interdepartmental audit is embedded into the UK radiotherapy philosophy
- Departments participate willingly and use it positively
 - Collegiate approach to support each other
 - Lack of funding can, however, prove challenging
- Data indicates that independent measurements of machine calibration has become more consistent over the last 20 years
 - Reduction in st dev of audit/local output ratios

Written about trials but true for any Inter-departmental audit → collegiate spirit

“The implementation of QA in radiotherapy has become vitally important in recent years. Often, as has been demonstrated here, a clinical trial has led the way to the general benefit of all patients receiving radiotherapy. By pursuing QA in the first year of the clinical trial, the standard of treatment was set and any later uncertainties when analysing the results were avoided. Wariness at each centre visited was replaced by active co-operation and satisfaction with the high standards that could be achieved and maintained. In addition, these visits gave an opportunity for mutual exchange of ideas.”

Aird et al R+O 36(1995)235-245

SAM

Independent audit of some description is sufficient to achieve best practice and consistent treatments within a Safe Radiotherapy Service?

- a. Yes – if your dosimetry is good, everything is safe
- b. Yes – it's the ultimate example that we have applied due diligence over everything
- c. No – good processes are the other thing required
- d. No – a multi- dimensional, multi-professional approach is required
- e. No – but it's the main concern of the Physicists

**‘Towards safer Radiotherapy.’ RCR Publications,
RCR, London ISBN: 978-1-905034-25-3**

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SAM

The rotational IMRT independent audit was considered a success because:

- a. The NHS was confident it was a sensible new technique
- b. A rapid sense check was available to those embracing new technology for the first time
- c. It was funded and therefore proof the establishment finally 'got it'
- d. The Legislators 'police agency' was happy for those passing to provide the service
- e. The results were better than the previous IMRT audit

Clark et al. 'A national Dosimetry audit of VMAT and Tomotherapy.' R&O 106(sup2) S195

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SAM

Regarding Dosimetric accuracy, the NPL observation of repeated mean values and reducing standard deviation, tells us:

- a. All centres were always good at dosimetry
- b. The larger sample size improved the statistics
- c. Audit has played a role in reducing variability between departments in the UK
- d. The 1990 MV calibration code of practice was more accurate than the previous one
- e. The NPL Physicists are better at measuring than departmental Physicists

Thomas. 'A review of NPL audit' IPEM Biennial RT mtg 2010

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SAM

Thinking about patient safety, arguably the most significant outcome from the UK independent audit practice, is:

- a. A major (long term) incident was discovered in 1988
- b. Audit has played a role in reducing dosimetric variability between departments in the UK
- c. The collegiate approach has bred a generation of Radiotherapy professionals who embrace openness and sharing of information – good and bad
- d. We identified it is the single most important driver for safety
- e. Physicists now have enough work to do to justify salary

www.hpa.org.uk – newsletters/ reports

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Thanks

- You for your attention
- Jean Moran and the organisers for the chance to speak at this meeting
- All my colleagues in Hull for their patience with me!
- My UK colleagues who have worked at developing the fantastic radiotherapy culture we are very proud of.



Dedicated to Steve Prescott MBE
On 9 Nov 2013 he lost his 7 year
battle against a rare Stomach
cancer during which he raised
£0.5M for charity