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National radiotherapy dosimetry audit in the UK – A vision and roadmap

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ABSTRACT

Radiotherapy dosimetry audit is an important element in the overall quality assurance of radiotherapy delivery and has become established as best practice prior to implementation of new equipment, techniques or clinical trials.

The Institute of Physics and Engineering in Medicine (IPEM) Interdepartmental Dosimetry Audit group (IDA) facilitates regional audits across the UK through a network of 8 regional chairs. This is a well-established and successful network utilising local staff resources and dosimetry equipment from each region to conduct audits for new radiotherapy equipment, techniques and annual reference audits. All dosimeters used are traceable to the National Physical Laboratory's (NPL) primary standard.

NPL and the National Radiotherapy Trials Quality Assurance Group (RTTQA) perform audits for new techniques and clinical trials in the UK. The IPEM IDA, NPL and RTTQA have a joint vision of a national audit network so that comprehensive audits can be offered to all UK centres and bring together all UK dosimetry audit data within a centralised database to facilitate coordinated national audits. This will also allow centres to access and review their data for anonymous benchmarking against other UK centres to support quality improvement.

Increasing the frequency and complexity of national audits to reflect current clinical practice is often inhibited by the cost of purchasing appropriate equipment. IPEM have now funded two phantoms that will enable national audits of gynae brachytherapy and head and neck external beam treatments through 2024–25.

The aim of this Position Paper is to provide an update on the activities of the IPEM IDA and present the future vision and roadmap for the three UK dosimetry audit groups.

Introduction

Radiotherapy dosimetry audit is an important element in the overall quality assurance of radiotherapy delivery, providing dose verification using independent measurement equipment and test objects, as well as validation of local processes. The measurements are performed using the auditor's independent equipment and methods to assess dosimetric accuracy either in-person or remotely. This independence provides robustness in the audit's ability to identify issues in local practices.

External dosimetry audit is well-established as best practice [1,2] in radiotherapy in the UK in a number of situations: prior to a machine first entering clinical use; credentialing for clinical trials; when implementing new technologies and/or techniques; and, routinely, to maintain and improve standards. Since 1987, repeated regional and national UK audits have shown improvement in clinical dosimetry consistency, which in turn supports improved treatment precision and accuracy. For example demonstrating a reduction in the variation of absolute dose calibration between centres [3-5], which should thereby lead to improved proximity of the auditors' measurements compared to the expected doses. For the specific case of megavoltage photon beam reference dose audits between 1987 and 2015, the standard deviation across the centres audited was observed to reduce from 1.5 % to 0.7 % [4], with the last 20 measurements in that period showing 0.4 % [5]. The mean dose difference between the measured and stated doses has

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consistently been 0.3 % since 1987[5].

The requirement for audit is specified in the NHS England External Beam Radiotherapy Service Specifications (2019) [6] where it states, 'Ensure the quality and safety of radiotherapy services delivered to a consistently high standard in England *through comparative audit and quality assurance to reduce variation in clinical practice*'. Participating in external dosimetry audit networks has also been recommended in Towards Safer Radiotherapy (2008) [2].

UK radiotherapy dosimetry audit groups

There are currently three groups in the UK providing radiotherapy dosimetry audits: the National Physical Laboratory (NPL), the National Radiotherapy Trials Quality Assurance Group (RTTQA) and the Institute of Physics and Engineering in Medicine (IPEM) Interdepartmental Dosimetry Audit Group (IDA).

NPL develops and maintains the primary standards for radiation dosimetry in the UK [5]. It also provides dosimetry audit for novel techniques being implemented into the clinic and works to develop dosimetric capability for upcoming technologies which may become the treatments of the future, such as FLASH.

When the new techniques are used in clinical trials RTTQA work with NPL to carry out dosimetry audits for the trials and require centres to have an external, independent audit at least every 3 years, or more frequently after a major change.

IPEM IDA is the longest-established UK radiotherapy dosimetry audit programme and conducts a flexible range of audits related to aspects of clinical radiotherapy practice, providing audit at a higher frequency than the above organisations and also developing new auditing methodologies.

The groups disseminate their audit methodologies, findings and lessons learned through publications to foster continuing confidence and quality improvement in dosimetry practice. Publications have covered. audit experience [4,5,7], development of specialist end-to-end audits [8,9] and advanced technique audit [10,11,12].

The purpose of this article is to provide an update on the activities of the IPEM IDA and present the future vision and roadmap for the three UK dosimetry audit groups.

IPEM interdepartmental dosimetry audit group

IPEM supported the creation of the IDA in 1993 as a long-standing working party of the Radiotherapy Special Interest Group (RTSIG) following the findings of the first UK national photon audit of 62 centres, which took place between 1987 and 1991 [13]. The audit identified 2 centres that had a linear accelerator calibration error >5 % and 9 centres that had treatment planning system errors (including errors in source data and incorrect lung density correction).

The IDA is a regional audit network comprising 8 cooperative regions (Fig. 1) with 5–12 radiotherapy centres per region, covering all 61 UK NHS centres. Private centres have joined some regions voluntarily. The regional chairs are volunteers and coordinate on-site external audits (for new equipment or techniques) in the region, annual peer-to-peer audits and report back at the annual IDA meeting. All radiotherapy ionisation chambers used in audit are traceable to the NPL primary standard for each treatment modality.

Dosimetry audits for complex techniques

The IDA worked with the NPL to run a national intensity modulated

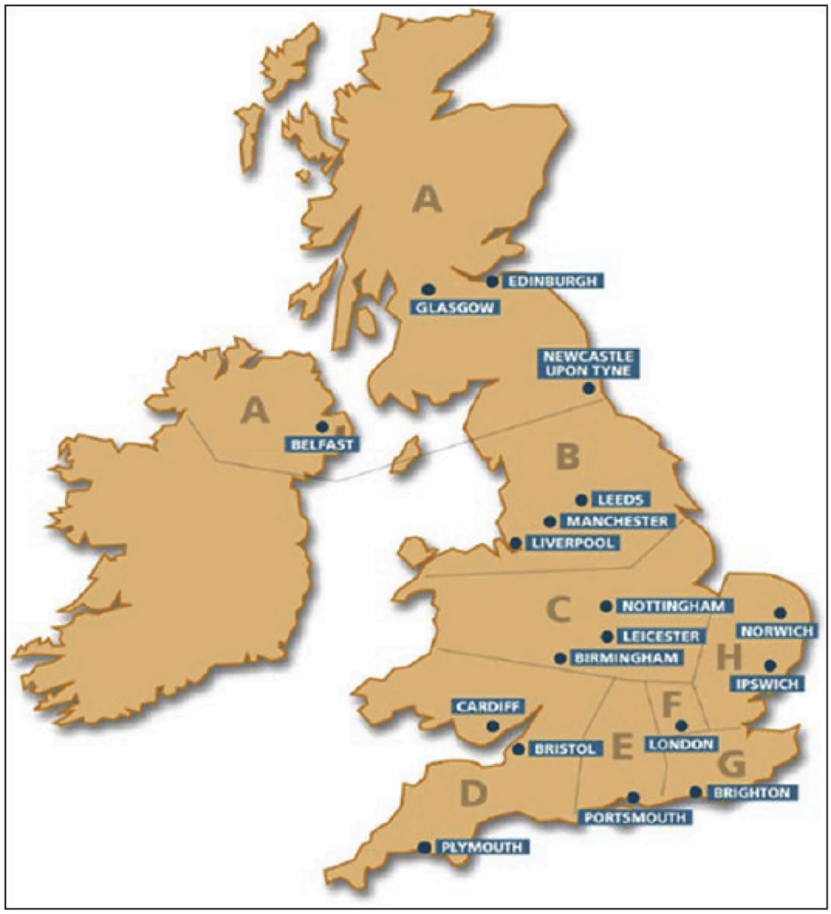

Fig. 1. Map of regional audit groups in the UK (Reproduced from [3] with permission).

radiotherapy (IMRT) postal audit in UK centres between 2008 and 2009, due to the increased use of the technique. Results demonstrated high levels of dosimetric accuracy (within 5 %) [41].

NPL and RTTQA provide national audits ensuring confidence in the rolling out of new techniques and credentialing for clinical trials. Planning techniques are becoming increasingly complex additionally with a move towards hypofractionated treatments. This requires higher geometric accuracy: a reduced number of fractions results in a greater impact of any positional uncertainties on treatment delivery compared to standard fractionations. In addition, the advent of SABR (stereotactic ablative body radiotherapy) has introduced new planning techniques using very high doses and steep dose gradients, requiring high geometric and dosimetric accuracy, necessitating appropriately designed phantoms for verification. The audits undertaken by NPL/RTTQA have included the national high dose rate (HDR) brachytherapy audit 2012–2013 [15], the volumetric arc therapy (VMAT) audit in 2014 [9], the stereotactic radiosurgery (SRS) audit 2017–2019 [11], the lung SABR audit [12] and spine SABR audit which are both ongoing. RTTQA holds a record of all audits conducted.

Almost all UK centres have now taken part in the VMAT and SABR audits [9,11,-12] through clinical trials or national technique implementation. Once these initial audits have been completed, there has been no funding for ongoing follow-up audits to ensure that accuracy is maintained, and standards continue to be met. This is required as clinical techniques, treatment equipment, software versions and their implementation continue to evolve over time. Regional IDA audits have been developed for some complex techniques such as 4DCT and HDR brachytherapy [8,9], with the latter rolled out nationally via IPEM one-off funding awarded to a dosimetry audit working party. A lack of on-going funding has meant it has not been possible to adopt some other regionally developed audits nationwide.

Methods for the routine interdepartmental dosimetry auditing of MV photon, kV photon and electron treatments have been developed regionally based on local resources and equipment, leading to variations in audit methodology, reporting and data collection.

While the development of different approaches is not problematic in itself, it has prevented direct comparison of results. National audit templates are being developed to improve the consistency and intercomparability of regional auditing in the future, with the audit methodology and spreadsheet formulae independently checked by IPEM IDA, RTTQA, and NPL.

Vision for a comprehensive UK dosimetry audit network

The IPEM IDA, NPL and RTTQA have a joint vision to offer comprehensive audit to all UK centres, by creating a complete audit cycle (Fig. 2) and bringing together all UK dosimetry audit data within a single centralised database. This will allow centres to access their data for benchmarking anonymously against other UK centres enabling quality improvement in routine practice as well as providing evidence of ongoing audit for clinical trial participation or for service review (United Kingdom accreditation service (UKAS), Care Quality Commission (CQC) etc.).

Data comparison across centres requires standardisation of auditing methodology. The IPEM IDA is currently implementing national templates for photon, electron and kilovoltage external audits for reference dosimetry and clinical simulations

Standardisation is one part of the process; the greatest challenge is developing and enabling national audits to reflect current, and rapidly evolving, advanced clinical practice. As long as staff resource is already available via the UK audit groups or regional centres, one of the highest costs associated with auditing is for purchasing appropriate equipment that can be utilised for multiple audits. In the case of audits for specialised techniques, such as brachytherapy, or other specialist complex external beam techniques, bespoke phantoms must be designed.

Therefore, completing the audit cycle requires, standardisation, delivery of national audits for complex techniques, database integration and data sharing (Fig. 3). Current progress of theses aims is given in the sections below.

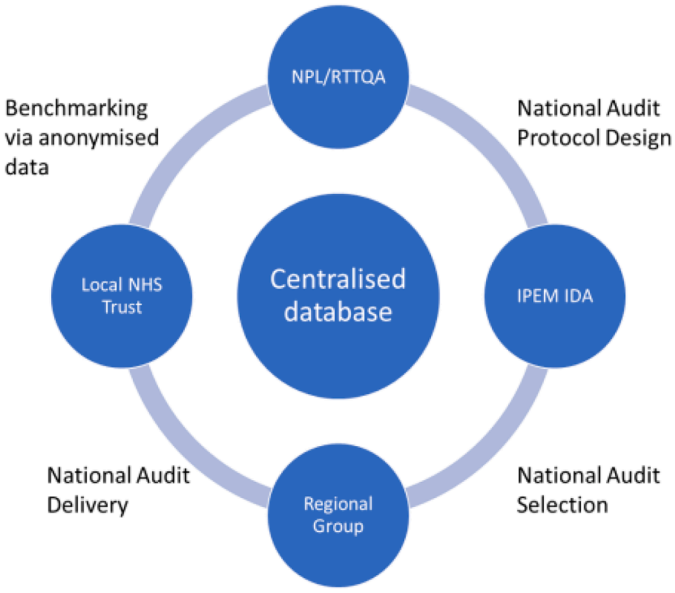

Fig. 2. Completing the audit cycle.

Current status

Funding has been provided by IPEM for the development of a gynae brachytherapy phantom and purchase of the CIRS© SHANE [16] head and neck external beam radiotherapy phantom, to conduct end-to-end audits. Details are provided below. The IPEM IDA is currently working with NPL and RTTQA on the development and implementation of these audits and the collection of results.

The ongoing support of the IPEM IDA chairs and wider community, all of whom are volunteers, is vital for this work to continue. However, achieving a long-term program of national audits will require a sustainable funding model and a strategy for how national audits will be delivered by the regional groups across the UK. The capital funding from IPEM for two strategic phantoms has provided the investment to work towards this goal and the delivery of ongoing UK-wide audits is under discussion.

NPL are developing a Dosimetry Audit for Advanced RadioTherapy (DAART) digital database that will act as the centralised database to collate all UK dosimetry audit data for the first time. Further details are provided below.

National HDR brachytherapy audit

IPEM has a unique, custom-made phantom for end-to-end dosimetry audit of HDR brachytherapy within its phantom library; the Brachytherapy Applicator Dosimetry (BRAD) phantom. Since its first use for a UK-wide HDR cervix brachytherapy audit in 2014 [10], clinical treatment techniques have developed, with increasing use of CT-MR registration for planning and interstitial needles for asymmetric dose distribution treatments. BRAD is currently being modified to make it fit for purpose for current advanced brachytherapy treatment verification. This will enable assessment of planning approach, target coverage and organ at risk doses using interstitial ring applicators based on MR or CT planning, using audit measurements with advanced film dosimetry and microdiamond or pinpoint ionisation chamber point dose measurements.

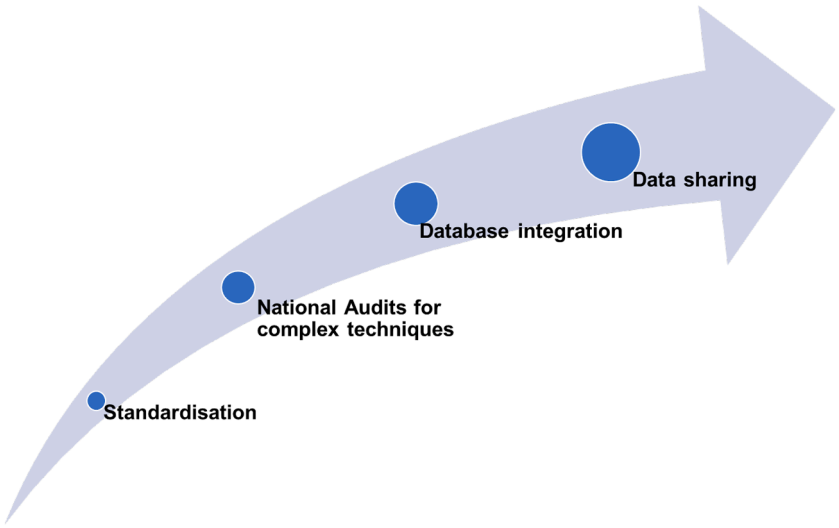

Fig. 3. IDA roadmap.

National head and neck VMAT audit

The most recent UK head and neck national audits were conducted in 2009 [14] and 2014 [9] for IMRT and VMAT, respectively.

There have been extensive changes in both equipment, software and imaging for treatment planning and adaptation on a national scale over the last decade and there is a need for an up-to-date end-to-end audit. The previous audits utilised homogenous phantoms which do not account for the impact of complex internal patient anatomies.

A research group has recently designed the CIRS© SHANE head and neck phantom [16] for the International Atomic Energy Agency (IAEA) that can be used for end-to-end VMAT and IMRT auditing. The SHANE phantom contains complex internal anatomy realistic of a typical patient and the ability to measure 2D dose maps with radiochromic film or point doses with ion chambers. Detailed auditing protocols were also developed alongside the phantom and have been used in a recently published IAEA pilot audit [17]. This phantom provides a ready-made solution for end-to-end head and neck auditing in the UK, with the results being directly comparable to international data. This CIRS head and neck phantom will also be suitable for development of future national audits, such as for adaptive techniques whose use is rapidly expanding in the UK clinical practice.

Centralised audit database – DAART

The DAART database is a web-based digital platform designed to collect and curate audit data into a centralised database hosted by NPL. In the first instance, this will be used to streamline the NPL and RTTQA audit workflow by semi-automating report generation, allowing participating centres to upload their results and download the audit report once it is completed. Development work is ongoing to build live dashboards to enable auditors and centres to visualise data in meaningful ways. For example, it is anticipated that a centre will be able to anonymously visualise and review their results compared to national results or compare against other centres with similar equipment. In the near future, IDA audits conducted via the national reference audit

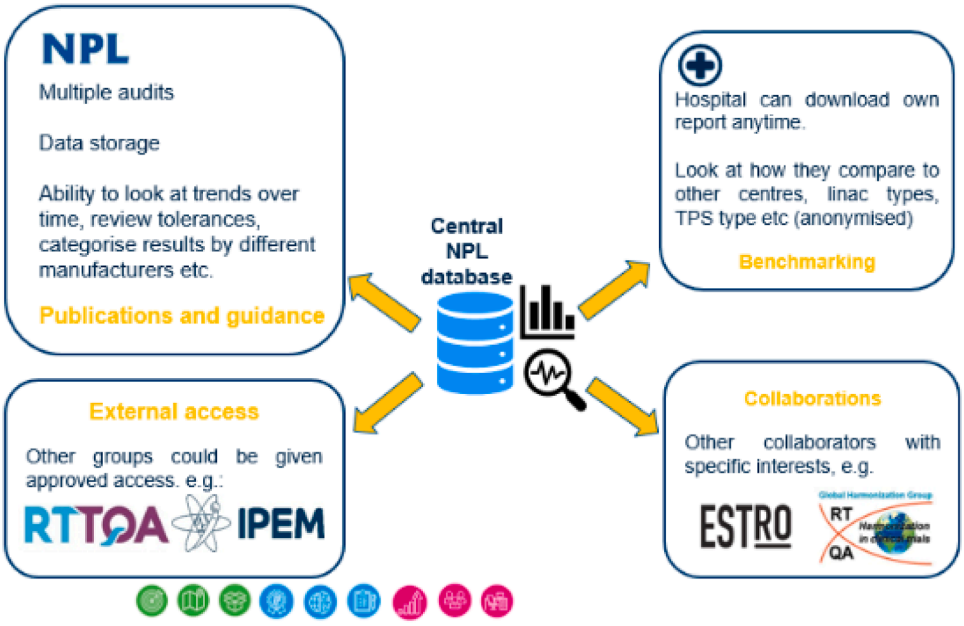

Fig. 4. DAART data sharing and future impact.

templates will be compatible with DAART, such that all audit data for a centre will be stored in one location. Longer term, data sharing and collaboration will be possible with other audit groups for example, the Global harmonization Group (GHG) which consists of international audit groups including RTTQA, the European Organisation for Research and Treatment of Cancer (EORTC), Trans-Tasman Radiation Oncology Group (TROG), Japan Clinical Oncology Group (JCOG) and Imaging Radiation and Oncology Core (IROC) (Fig. 4).

Conclusion

Radiotherapy technology and clinical techniques are continually advancing, with the capability to deliver smaller and more complex treatment volumes at greater dosimetric and geometric precision with improved image guidance. External dosimetry audit protocols need to keep pace, to continue to provide regular and relevant independent quality assurance for verification of safe and accurate implementation, and ongoing use, of advanced clinical techniques.

A UK dosimetry audit framework will enable comprehensive external dosimetry audit methods and protocols for novel techniques, clinical trials and follow-up audits to ensure ongoing geometric and dosimetric accuracy, support the improvement of standards and provide evidence for trial QA.

Greater collaboration, standardisation and data sharing will enable the UK to continue to evolve into a world-class model for national dosimetry auditing in radiotherapy.

Ethical approval

Not required.

Funding

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Declaration of competing interest

None declared.

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