Physics and Imaging in Radiation Oncology 5 (2018) 85–87

Contents lists available at ScienceDirect

Physics and Imaging in Radiation Oncology

journal homepage: www.elsevier.com/locate/phro

Editorial

The role of dosimetry audit in achieving high quality radiotherapy

1. Introduction

Dosimetry audit is a key component in quality management programmes in radiotherapy, playing an important role in the safe implementation of new treatment modalities and techniques [1–4]. National and large scale audits provide data which can help to create, sustain and increase standards as well as have the potential to identify issues which may cause harm to patients, thus improving both quality and safety [1,4–13]. They can also help to reduce variability in dose delivered to the patient both nationally, internationally and within multi-institutional trials [3,13–16]. At an institutional level, an external dosimetry audit provides an independent check of the local approaches and thus supports the implementation of novel and complex techniques [6,7,13,15,17–20]. Where multiple centres have been included in the audit, the process of comparison with other centres facilitates awareness and understanding of issues which may exist and which may not be identified by a single centre alone [5,6,21]. Furthermore this sharing of experience allows benchmarking of centres with similar equipment and thus increases the knowledge of what is achievable with a particular combination of equipment [22,23].

There are multiple challenges in designing and running effective dosimetry audits, including an ever expanding horizon, with new techniques and new equipment combined with increasingly high expectations from both patients and professionals in outcomes and safety [24]. This leads us to question whether the same things still need auditing or whether assumptions can be made on previously validated techniques [25]. However, the design must still consider what needs to be tested, where the highest risks lie, how the auditing equipment will work, e.g. if the detector will work with the chosen phantoms, as well as whether the process is appropriate.

There are different types of audit from postal to an on-site visit and from basic measurements in reference conditions through to a full end-to-end audit where an anthropomorphic phantom takes the place of the patient and follows the full pathway from imaging, through planning and to complex dose distribution delivery [1]. The development of techniques for dosimetry audit can include the development of new materials [26], development of anthropomorphic phantoms [27,28] as well as characterisation of detectors prior to audit use [29,30].

The special issue available online at https://www.sciencedirect.com/journal/physics-and-imaging-in-radiation-oncology/special-issue/10S8T6FN296, presents an extensive range of dosimetry auditing activity and highlights the different approaches, including whether an external measurement is needed or whether data measured by the local centre can be assessed externally for a dosimetry audit [31–34]. The papers in the issue represent efforts on regional, national and international levels, each of which has been designed to focus on a specific problem or technique where variation in implementation or practice is known or issues with beam modelling capabilities may exist, thus creating a comprehensive set of publications in a single location.

2. Beam output

Measurement of beam output is the most fundamental measurement which confirms whether the machine has been correctly calibrated [8]. Existing errors will create a systemic error for every patient treated on the machine and therefore have the potential to create systematic differences in treatment outcomes. Worldwide dosimetry audits are organised in different ways, often for geographical, economic or political reasons [35] but fundamentally are checking the same thing. Over recent decades the variability between centres has generally reduced [9,36], however globally there are still findings outside tolerance (e.g. of ± 5%) [35] that can be attributed to a wide range of causes, including equipment failures, errors in setup, and incorrect implementation of the calibration protocol [37–39]. Several of these could create a systematic error for every patient treatment on a given machine. However data from centres that strictly follow a code of practice (such as the Belgian-Dutch NCS-18 CoP [40]) can give very high standards of compliance [10].

3. Advanced techniques

One of the strengths of external dosimetry audit is the ability to independently verify, and thus give confidence in, a new technique which has been recently commissioned in a centre. Ideally this should take place between the end of commissioning and the beginning of clinical practice. Recent advances in radiotherapy have posed many challenges for radiotherapy centres to use techniques which use extreme conditions which no longer fit comfortably into the routine protocols and codes of practice. An example of this is the expanding use of small fields which are too small to adhere to the standard codes of practice. This has been recently addressed by the publication of the IAEA code of practice [41] but the accurate modelling of small fields and how the correct detector is used to collect the commissioning data is still challenging. Several groups [11,12,21] conducted national and multi-national audits respectively, of calculated small field output factors by comparing with standardised data published by the IROC-Houston QA center at MD Anderson [22,23,42] and found that not all centres were modelling these fields well. The audits found that the deviations increased with decreasing field size and the treatment planning system commonly overestimated in comparison with the reference data. Several of the centres adjusted their

https://doi.org/10.1016/j.phro.2018.03.009

calculation data following these audits, thus improving their beam models for small fields.

Another technique which is rapidly expanding, due to the increased interest in hypo-fractionated regimens, is that of stereotactic ablative body radiotherapy (SBRT). This is a higher risk technique as greater doses are given in fewer fractions and therefore there is less room for error correction. The most common site for SBRT is in the lung and several trials have been run to assess the effect on treatment outcome of this approach. Tsang et al. [14] found that although the clinical trial plans pre-treatment verifications were within the tolerance of +/3%, there were certain scenarios of basic beam tests using single beams which failed, indicating that care must be taken in commissioning as although results may be good for some beam combinations, this may not be the case for all scenarios, depending on the algorithm used [13,15–17,43].

There are also more specialised techniques being implemented which may only be used by a few centres. The safety issue here is that there is little data about what can and should be achieved with these systems. An example is rectal contact brachytherapy where no specific code of practice exists and hence a kV code is often used. A national audit for rectal contact brachytherapy was carried out in the UK [44] to assist users to optimize their own practice, thus providing reassurance that the implementation had been performed within the standards stated in previously published audit work and recommendations for kV and electronic brachytherapy units. However, it was recommended that optimised and standardised quality assurance testing could be achieved by reducing some methodological differences observed between the centres.

4. Future directions

As radiotherapy techniques become more complex and less intuitive, there is a potentially greater risk for errors to be missed. This is particularly true in places which may not have an established culture of peer-to-peer review. Thus there is a need for wider access to audit in a cost effective and efficient manner. Several groups have investigated methods for remote auditing including the use of local EPID data which can be analysed centrally [45]. Further approaches have suggested the use of locally measured QA data, however there is still a debate as to the sensitivity and specificity of the local detection of errors in comparison with independent measurements [31,32]. Alternative approaches could include collection of log-files for continued assessment of quality [25], which could be of particular value in clinical trials. Alternative methods for efficiency of audit include the use of complexity metrics to pre-determine which plans should be investigated, however no metric appears to yet exist which gives a robust response across all planning and/or delivery systems [46].

5. The role for ESTRO in dosimetry audit

Dosimetry audit has been identified in the ESTRO physics strategy as being a topic of high importance which can support quality improvement through standardisation of radiotherapy practice across Europe. Two workshops have been held during 2017 to address this subject to identify how existing groups, including IAEA and clinical trials QA groups, can work together to develop methods to address specific issues as well as to encourage new national groups to start running regional dosimetry audits. The combined body of data from dosimetry audits published in this special issue and elsewhere, represents an opportunity to share protocols and best practice, with examples of how to start a regional audit system, thus augmenting the potential for increased quality of radiotherapy. Furthermore the dosimetry audit data can be combined to create datasets for meta-analysis which can identify issues for investigation into beam modelling and measurement methodologies that need further research, which would not be seen in smaller studies.

6. Conflict of interest

There is no conflict of interest.

References

[1] Clark CH, Aird EG, Bolton S, Miles EA, Nisbet A, Snaith JA, et al. Radiotherapy dosimetry audit: three decades of improving standards and accuracy in UK clinical practice and trials. Br J Radiol 2015;88:1055.

[2] Thwaites D. Accuracy required and achievable in radiotherapy dosimetry: have modern technology and techniques changed our views? J Phys Conf Ser 2013;444:012006.

[3] Followill DS, Evans DR, Cherry C, Molineu A, Fisher G, Hanson WF, et al. Design, development, and implementation of the Radiological Physics Center's pelvis and thorax anthropomorphic quality assurance phantoms. Med Phys 2007;34:2070.

[4] Izewska J, Andreo P. The IAEA/WHO TLD postal programme for radiotherapy hospitals. Radiother Oncol 2000;54:65–72.

[5] Jornet N, Carrasco P, Beltrán M, Calvo JF, Escudé L, Hernández V, et al. Multicenter validation of IMRT pre-treatment verification: comparison of in-house and external audit. Radiother Oncol 2014;112:381–8.

[6] Jurado-Bruggeman D, Hernandez V, Saez J, Navarro D, Pino F, Martinez T, et al. Multicenter audit of VMAT planning and pre-treatment verification. Radiother Oncol 2017;124:302–10.

[7] Lehmann J, Alves A, Dunn L, Shaw M, Kenny J, Keehan S, et al. Dosimetric end-to-end tests in a national audit of 3D conformal radiotherapy. Phys Imag Radiat Oncol 2018. http://dx.doi.org/10.1016/j.phro.2018.03.006.

[8] Bolt MA, Clark CH, Chen T, Nisbet A. A multi-centre analysis of radiotherapy beam output measurement. Phys Imag Radiat Oncol 2017;4:39–43.

[9] Thomas RAS, Bolt MA, Bass G, Nutbrown R, Chen T, Nisbet A, et al. Radiotherapy reference dose audit in the United Kingdom by the National Physical Laboratory: 20 years of consistency and improvements. Phys Imag Radiat Oncol 2017;3:21–7.

[10] de Prez L, Heukelom S, Jansen B, Jansen W, van de Kamer J, van Klink W, et al. An on-site dosimetry audit for high-energy electron beams. Phys Imag Radiat Oncol 2018;5:44–51.

[11] Chelminski K, Bulski W. A multi-centre analytical study of small field output factor calculations in radiotherapy. Phys Imag Radiat Oncol 2018. http://dx.doi.org/10.1016/j.phro.2018.03.007.

[12] Clemente S, Masi L, Fiandra C, Cagni E, Villaggi E, Esposito M, et al. A multi-center output factors intercomparison to uncover systematic inaccuracies in small field dosimetry. Phys Imag Radiat Oncol 2018 (in press).

[13] Distefano G, Lee J, Jafari S, Gouldstone C, Baker C, Mayles H, et al. A national dosimetry audit for stereotactic ablative radiotherapy in lung. Radiother Oncol 2017;122:406–10.

[14] Tsang Y, Carver A, Groom N, Harris C, Faivre-finn C, Eaton D. A multi-centre dosimetry audit on advanced radiotherapy in lung as part of the isotoxic IMRT study. Phys Imag Radiat Oncol 2017;4:17–21.

[15] Lambrecht M, Melidis C, Sonke J, Adebahr S, Boellaard R, Verheij M, et al. Lungtech, a phase II EORTC trial of SBRT for centrally located lung tumours – a clinical physics perspective. Radiat Oncol 2016;20:7.

[16] Kry S, Alvarez P, Molineu A, Amador C, Galvin J, Followill DS. Algorithms used in heterogeneous dose calculations show systematic differences as measured with the Radiological Physics Center's anthropomorphic thorax phantom used for RTOG credentialing. Int J Radiat Oncol Biol Phys 2013;85:95–100.

[17] Clark CH, Hurkmans CW, Kry SF. The role of dosimetry audit in lung SBRT multi-centre clinical trials. Phys Med 2017;44:171–6.

[18] Molineu A, Hernandez N, Nguyen T, Ibbott G, Followill D. Credentialing results from IMRT irradiations of an anthropomorphic head and neck phantom. Med Phys 2013;40:022101.

[19] Schiefer H, Fogliata A, Nicolini G, Cozzi L, Seelentag WW, Born E, et al. The Swiss IMRT dosimetry intercomparison using a thorax phantom. Med Phys 2010;37:4424.

[20] Adolfsson E, Gustafsson H, Lund E, Alm Carlsson G, Olsson S, Carlsson Tedgren S. A system for remote dosimetry audit of 3D-CRT, IMRT and VMAT based on lithium formate dosimetry. Radiother Oncol 2014;113:279–82.

[21] Lechner W, Wesolowska P, Azangwe G, Arib M, Alvese V, Suming L, et al. A multinational audit of small field output factors calculated by treatment planning systems used in radiotherapy. Phys Imag Radiat Oncol 2018. http://dx.doi.org/10.1016/j.phro.2018.02.005.

[22] Followill D, Kry S, Qin L, Lowenstein J, Molineu A, Alvarez P, et al. The Radiological Physics Center's standard dataset for small field size output factors. J Appl Clin Med Phys 2012;13:3962.

[23] Followill D. Erratum: "The Radiological Physics Center's standard dataset for small field size output factors". J Appl Clin Med Phys 2014;15:4757.

[24] Kron T, Haworth A, Williams I. Dosimetry for audit and clinical trials: challenges and requirements. J Phys Conf Ser 2013;444:012014.

[25] Pasler M, Hernandez V, Jornet N, Clark CH. Novel methodologies for dosimetry audits: adapting to advanced radiotherapy techniques. Phys Imag Radiat Oncol 2018. http://dx.doi.org/10.1016/j.phro.2018.03.002.

[26] Lourenço A, Shipley D, Wellock N, Thomas R, Bouchard H, Kacperek A, et al. Evaluation of the water-equivalence of plastic materials in low- and high-energy clinical proton beams. Phys Med Biol 2017;62:3883–901.

[27] Steinmann A, Stafford R, Sawakuchi G, Wen Z, Court L, Fuller C, et al. Developing and characterizing MR/CT-visible materials used in QA phantoms for MRgRT systems. Med Phys 2018;45:773–82.

[28] Dimitriadis A, Palmer A, Thomas R, Nisbet A, Clark CH. Adaptation and validation

of a commercial head phantom for cranial radiosurgery dosimetry end-to-end audit. Br J Radiol 2017;90:1094.
[29] Palmer A, Dimitriadis A, Nisbet A, Clark CH. Evaluation of Gafchromic EBT-XD film, with comparison to EBT3 film, and application in high dose radiotherapy verification. Phys Med Biol 2015;60:8741–52.
[30] Hussein M, Tsang Y, Thomas RAS, Gouldstone C, Maughan D, Snaith JAD, et al. A methodology for dosimetry audit of rotational radiotherapy using a commercial detector array. Radiother Oncol 2013;108:78–85.
[31] Seravalli E, Houweling AC, Van Battum L, Raaben TA, Kuik M, De Pooter A, et al. Auditing local methods for quality assurance in radiotherapy using the same set of predefined treatment plans. Phys Imag Radiat Oncol 2018;5:19–25.
[32] Kry SF, Molineu A, Kerns JR, Faught AM, Huang JY, Pulliam KB, et al. Institutional patient-specific IMRT QA does not predict unacceptable plan delivery. Int J Radiat Oncol Biol Phys 2014;90:1195–201.
[33] Melidis C, Bosch WR, Izewska J, Fidarova E, Zubizarreta E, Ulin K, et al. Global harmonization of quality assurance naming conventions in radiation therapy clinical trials. Int J Radiat Oncol Biol Phys 2014;90:1242–9.
[34] Weber D, Vallet V, Molineu A, Melidis C, Teglas V, Naudy S, et al. IMRT credentialing for prospective trials using institutional virtual phantoms: results of a joint European Organization for the Research and Treatment of Cancer and Radiological Physics Center project. Radiat Oncol 2014;9:123.
[35] Izewska J, Lechner W, Wesolowska P. Global availability of dosimetry audits in radiotherapy: the IAEA dosimetry audit networks database. Phys Imag Radiat Oncol 2018;5:1–4.
[36] Izewska J, Georg D, Bera P, Thwaites D, Arib M, Saravi M, et al. A methodology for TLD postal dosimetry audit of high-energy radiotherapy photon beams in non-reference conditions. Radiother Oncol 2007;84:67–74.
[37] Lillicrap SC, Owen BJRW, Williams PC. Institute of Physical Sciences in Medicine (IPSM) 1990 code of practice for high-energy photon therapy dosimetry based on the NPL absorbed dose calibration service. Phys Med Biol 1990;35:1355–60.
[38] Andreo P, Burns DT, Hohlfeld K, Huq MS, Kanai T, Laitano F et al. Absorbed dose determination in external beam radiotherapy: an international code of practice for dosimetry based on standards of absorbed dose to water: IAEA Proc Ser Stand Codes Pract Med Radiat Dosim IAEA – TRS 398 (ISBN 92-0-102200-X) 2000.
[39] Almond PR, Biggs PJ, Coursey BM, Hanson WF, Huq MS, Nath R et al. Protocol for clinical reference dosimetry of high-energy photon and electron beams. AAPM TG51 1999:1847–70.
[40] Aalbers AHL, Hoornaert M-T, Minken A, Palmans H, Pieksma MWH, Prez LA de, et al. NCS report 18 – Code of Practice for the absorbed 403 Dose determination in high energy photon and electron beams, 2008.
[41] IAEA. Dosimetry of small static fields used in external beam radiotherapy: an international code of practice for reference and relative dose determination. TRS 483 2017.
[42] Kerns J, Followill D, Lowenstein J, Molineu A, Alvarez P, Taylor P, et al. Technical report: reference photon dosimetry data for Varian accelerators based on IROC-Houston site visit data. Med Phys 2016;43:2374–86.
[43] Fogliata A, Cozzi L. Dose calculation algorithm accuracy for small fields in non-homogeneous media: the lung SBRT case. Phys Med 2017;44:157–62.
[44] Humbert-Vidan L, Sander T, Eaton DJ, Clark CH. National audit of a system for rectal contact brachytherapy. Phys Imag Radiat Oncol 2017;1:1–5.
[45] Miri N, Lehmann J, Legge K, Zwan BJ, Vial P, Greer PB. Remote dosimetric auditing for intensity modulated radiotherapy: a pilot study. Phys Imag Radiat Oncol 2017;4:26–31.
[46] Hernandez V, Saez J, Pasler M, Jurado-Bruggeman D, Jornet N. Comparison of complexity metrics for multi-institutional evaluations of treatment plans in radiotherapy. Phys Imag Radiat Oncol 2018;5:37–43.

Catharine H. Clark
Medical Physics Department, Royal Surrey County Hospital, Guildford Surrey, UK
Metrology for Medical Physics, National Physical Laboratory, Teddington, Middx, UK
E-mail address: catharine.clark@nhs.net

Núria Jornet
Servei de Radiofísica i Radioprotecció, Hospital Sant Pau, Barcelona, Spain

Ludvig P. Muren
Department of Medical Physics, Aarhus University/Aarhus University Hospital, Aarhus, Denmark