Canadian Partnership for Quality Radiotherapy

Technical Quality Control Guidelines for Patient-Specific Dosimetric Measurements for Intensity Modulated Radiation Therapies

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A guidance document on behalf of:

Canadian Association of Radiation Oncology

Canadian Organization of Medical Physicists

Canadian Association of Medical Radiation Technologists

Canadian Partnership Against Cancer

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Introduction

The Canadian Partnership for Quality Radiotherapy (CPQR) is an alliance amongst the three key national professional organizations involved in the delivery of radiation treatment in Canada: the Canadian Association of Radiation Oncology (CARO), the Canadian Organization of Medical Physicists (COMP), and the Canadian Association of Medical Radiation Technologists (CAMRT). Financial and strategic backing is provided by the federal government through the Canadian Partnership Against Cancer (CPAC), a national resource for advancing cancer prevention and treatment. The mandate of the CPQR is to support the universal availability of high quality and safe radiotherapy for all Canadians through system performance improvement and the development of consensus-based guidelines and indicators to aid in radiation treatment program development and evaluation.

This document contains detailed performance objectives and safety criteria for *Patient-Specific Dosimetric Measurements for Intensity Modulated Radiation Therapy*. Please refer to the overarching document *Technical Quality Control Guidelines for Canadian Radiation Treatment Centres*[1] for a programmatic overview of technical quality control, and a description of how the performance objectives and criteria listed in this document should be interpreted.

System Description

Intensity modulated radiation therapy (IMRT) is a type of treatment delivery technique that involves modulation of the treatment beams' fluence to create a clinically acceptable dose distribution, with appropriate target coverage, while limiting the dose to organs at risk.[2,3] IMRT treatment can be delivered in several manners, but all methods include fluence modulation within a single treatment beam, including step-and-shoot delivery (static gantry, leaf motion while beam is off), dynamic or sliding window delivery (static gantry, leaf motion continues while beam is on), or volumetric modulated arc therapy (VMAT) (gantry and leaf motion during beam delivery). Several documents include guidelines for the safe implementation of IMRT technology into a radiotherapy clinic.[4] The most recent practice guidelines from the American College of Radiology (ACR) and American Society for Radiation Oncology (ASTRO) form the basis of this document with respect to the process of IMRT patient-specific measurements.[5,6] The

accurate delivery of IMRT is dependent upon many components of the radiation treatment process. This includes the commissioning and quality assurance of equipment for which specific quality control guidelines are available, including the treatment planning system (TPS), the medical linear accelerator and multileaf collimator (MLC), and major dosimetry equipment (see related Technical Quality Control [TQC] Guideline documents at cpqr.ca).[7–9] IMRT may produce plans that are sensitive to limitations in the accuracy of TPS and secondary monitor unit (MU) software calculations (e.g., high dose gradients and small field sizes). The degree to which these limitations are exposed may depend highly on the local treatment planning technique. This creates the need for validation of the treatment plans using patient-specific dosimetric measurements. These tests compare the dose delivered for a specific clinical treatment plan to the dose computed by the TPS. In addition to dosimetric fidelity of the plan, by measuring the dose, verification of beam deliverability and indirect verification of proper beam transfer to the record-and-verify system are also completed.

The dose measurement can be acquired using various dosimetry equipment. It is the role of the qualified medical physicist to select an appropriate dosimeter for the purpose of patient-specific IMRT quality control. Dosimeters that enable high-resolution planar or volumetric sampling are recommended in order to assess the accuracy of the delivery in high gradient regions better (as compared to the planned dose). This could include diode or ion chamber arrays, electronic portal imaging devices (EPID), or film.[10] The chosen dosimeter should allow for the comparison of the planned dose to the measured dose (to be performed in absolute dose [Gy]), in addition to a comparison with the relative dose, through calibration or cross-calibration processes. Multiple dosimeters can be incorporated into the clinical procedure if a single tool is not available that meets all criteria. As noted recently by other organizations (i.e., ACR/ASTRO), the actual patient treatment beams should be used for delivery.[5,6] This requirement necessitates a dosimeter that is appropriate for the fractional dose being delivered, as MU scaling must be avoided. This ensures that the patient-specific IMRT quality control tests include verification of the treatment plan parameters, and that any aspect of dynamic delivery (e.g., leaf speed and dose rate) is not affected by the MU scaling. Quality control of the dosimeter(s) should be completed according to established quality control guidelines (such as the CPQR *Technical Quality Control Guideline for Major Dosimetry Equipment* available at cpqr.ca).[7–9]

Results for the comparison between planned and delivered doses are typically reported in terms of a percentage pass rate. This pass rate indicates the percentage of measurement points that meet user-specified criteria for agreement with the planned dose distribution. The results will be dependent upon the dosimetric tool, the analysis software, and the method of comparison.[10,11]

Patient-specific IMRT quality control measurements should be employed as part of the commissioning process for new treatment techniques and when software or hardware related to any of the supportive infrastructure (Table 1) is new or updated. These measurements can also be completed on a per-patient basis as part of individual patient's plan verification.

This quality control guideline is applicable to scenarios where, in the opinion of the local qualified medical physicist, patient-specific dosimetric measurements are required. In some specific situations, software-based verification (e.g., secondary MU calculation software or independent dose calculation) may replace measurement-based techniques (contingent on experience and a thorough understanding of the planning and verification software limitations). In these scenarios, the justification must be well documented by the local institution.

As detailed in the previous paragraphs, many factors can impact the agreement between planned and delivered dose. Therefore, a well-defined institutional protocol for patient-specific dosimetric measurements for IMRT is required. The protocol for the patient-specific IMRT quality control test should address and provide instructions for the following components (at a minimum):

1. Dose calculation from TPS for comparison with measured dose

   The protocol should define the method and conditions for the calculation of the 2D (planar) or 3D dose calculation in the TPS and export instructions. The required details are dependent upon the TPS and the chosen dosimeter, but may include parameters related to the resolution of the dose grid, any required dose overrides, geometric settings for planar dose calculations, etc.

2. Acquisition of the measured dose

   2.1. The method of dose calibration or cross-calibration should be developed and documented for the IMRT quality control dosimetry equipment (as appropriate). This includes documentation of any calibration fields that are required when patient specific IMRT quality control measurements are acquired.

   2.2. Include instructions for dosimeter and/or phantom set-up.

   2.3. The method of delivery of treatment beams must be specified (e.g., composite delivery, single-beam acquisition, elimination of gantry, collimator, or couch kicks). Details for delivery depend upon the type of dosimeter and technique being used for IMRT delivery and appropriate choices are the responsibility of the qualified medical physicist. MU must not be scaled for delivery, and dose rate should not be altered. For VMAT techniques the delivered beam, including gantry speed, dose rate and leaf speed should reflect the intended beam for delivery, therefore no edits should be completed during quality control that could alter that.

   2.4. Definition of software settings for the dosimeter(s) must be specified (as appropriate). Primarily applicable for 2D or 3D arrays or film dosimetry.

3. Analysis of comparison between planned and measured dose

The protocol must define any specific software settings that are required for analysis. This may include thresholds for analysis, criteria for analysis (e.g., percent dose difference and distance to agreement), and method of analysis (e.g., composite analysis or gamma analysis).[12,13]

Determination of tolerances is part of the development of the patient-specific IMRT quality control procedure and is the role of the qualified medical physicist. The qualified medical physicist can rely upon the literature for guidance in the establishment of acceptable tolerances, which is an active area of research. Institutional tolerances are required as pass rates may depend upon the dosimeter used as well as analysis methods. Additionally, treatment site-specific or technique-specific tolerances may need to be considered. Statistical process control approaches can be considered to define thresholds and as part of the documentation in support of a lower measurement frequency (i.e., less than per patient).[14–18]

The protocol should include timelines and responsibilities for review, including a procedure to follow for measurements that are out of tolerance.

4. Documentation of results

   A method for documentation of the results of planned versus measured dose comparison must be formalized. In addition, the documentation may also include associated steps including documentation of plan approval or acceptance.

Related Technical Quality Control Guidelines

In order to comprehensively assess patient-specific dosimetric measurements for IMRT, additional guideline tests, as outlined in related CPQR TQC guidelines must also be completed and documented, as applicable. Related TQC guidelines, available at cpqr.ca, include:

- Medical Linear Accelerators and Multileaf Collimators
- Treatment Planning Systems
- Major Dosimetry Equipment

Test Tables

Table 1: IMRT quality control tests

Designator	Test	Performance	
		Tolerance	**Action**
IMRT1	Patient-specific IMRT quality control test	Complete	
IMRT2	IMRT quality control test case	Complete	
IMRT3	IMRT quality control constancy test	Complete	
IMRT4	Patient-specific IMRT quality control procedure review of protocol	Complete	
IMRT5	Independent audit or review	Complete	

Notes on Table 1

IMRT1 The patient-specific IMRT quality control test compares measured to planned dose for a clinical treatment plan. Testing should be completed as part of routine physics plan review following the procedure established locally using the appropriate dosimeter and analysis techniques as detailed in the Acceptance Testing and Commissioning section of the *Technical Quality Control Guidelines for Canadian Radiation Treatment Centres.*[(1)] The frequency is per patient (prior to treatment start); however, the frequency may be reduced at the discretion of a qualified medical physicist, as justified by a rigorous statistical analysis of existing data and documentation. Additional tests may be suitable to assess aspects of the plan (e.g., beam deliverability and accurate transfer to the record and verify system that are indirectly included in the IMRT1 test) in the absence of dosimetric measurements. If a centre with multiple linear accelerators is compliant with all of the documents listed in Table 1, then the patient-specific IMRT quality control test does not have to be performed on the linear accelerator that the patient will be treated, and it can be delivered on a compatible linear accelerator instead.

Frequency: The frequency is per patient (prior to treatment start)

IMRT2 IMRT quality control test case is a test comparing measured to planned dose for an IMRT plan. This test is unique from IMRT1 in that this plan is one that is used for testing outside of the plan review process (non-patient specific). These test cases may be created specifically for commissioning purposes, or could be derived from previous clinical plans as appropriate. However, these test cases should be similar to clinically acceptable plans. Testing should be completed following the procedure established

locally using the appropriate dosimeter and analysis techniques. These tests are recommended as part of the commissioning process for any of the planning or delivery infrastructure or the development of new clinical delivery techniques or planning processes. This test may or may not be an end-to-end test. Repeat imaging of the phantom or dosimeter may not be required at each instance. The qualified medical physicist will identify the extent to which the IMRT2 test needs to be end-to-end according to the context in which the test is being performed.

Occasion: Commissioning of supportive infrastructure detailed in Table 1, or new planning or delivery technique.

Frequency: As required

IMRT3 An IMRT quality control test case (IMRT2) is chosen for repeat delivery (recommended at least quarterly), measurement, analysis, and results are compared to baseline measurements. This should be completed for each linear accelerator which is used to treat IMRT. The IMRT quality control test case chosen for repeat delivery should be chosen to reflect the maximum variation in leaf position, leaf speed, and variation in gantry speed and dose rate that will be used clinically.

Frequency: Quarterly

IMRT4 Commissioning of an IMRT patient-specific quality control program includes the creation of a staff protocol that encompasses (at a minimum) the components detailed in the Acceptance Testing and Commissioning section of the *Technical Quality Control Guidelines for Canadian Radiation Treatment Centres* document.[(1)] To ensure the protocol is up-to-date, it should be reviewed, yearly at minimum, but also at the time of any commissioning activities for supportive infrastructure identified in Table 1.

Frequency: Annually

IMRT5 Comparison of measured to planned dose for IMRT by an external party, with an independent dosimeter and calibration procedure. This could be completed through peer review or as part of trial accreditation. If resources do not permit a fully independent audit at the recommended frequency, the centre may choose to fulfill this recommendation by completing a full end-to-end test using a phantom or dosimeter that is not employed for their daily or monthly patient-specific quality control tests.

Frequency: Every 2 years

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References

1. Canadian Partnership for Quality Radiotherapy. Technical quality control guidelines for Canadian radiation treatment centres. 2016 May 1. Available from: http://www.cpqr.ca/programs/technical-quality-control

2. Alber M, Broggi S, De Wagter C, Eichwurzel I, Engström P, Fiorino C, Georg D, Hartmann G, Knöös T, Leal A, et al. Guidelines for the verification of IMRT, European guidelines for quality assurance in radiotherapy booklet no. 9. Brussels, Belgium: ESTRO; 2008. ISBN 90-804532-9.

3. Ezzell GA, Galvin JM, Low D, Palta JR, Rosen I, Sharpe MB, Xia P, Xiao Y, Xing L, Yu CX. Guidance document on delivery, treatment planning, and clinical implementation of IMRT: report of the IMRT subcommittee of the AAPM Radiation Therapy Committee. Med. Phys. 2003;30(8):2089–115. Available from: http://dx.doi.org/10.1118/1.1591194

4. Galvin JM, Ezzell G, Eisbrauch A, Yu C, Butler B, Xiao Y, Rosen I, Rosenman J, Sharpe M, Xing L, et al. Implementing IMRT in clinical practice: a joint document of the American Society for Therapeutic Radiology and Oncology and the American Association of Physicists in Medicine. Int. J. Radiat. Oncol. Biol. Phys. 2004;58(5):1616–34. Available from: http://dx.doi.org/10.1016/j.ijrobp.2003.12.008

5. Hartford AC, Galvin JM, Beyer DC, Eichler TJ, Ibbott GS, Kavanagh B, Schultz CJ, Rosenthal SA. American College of Radiology (ACR) and American Society for Radiation Oncology (ASTRO) practice guideline for intensity-modulated radiation therapy (IMRT). Am. J. Clin. Oncol. 2012;35(6):612–7. Available from: http://dx.doi.org/10.1097/COC.0b013e31826e0515

6. Moran JM, Dempsey M, Eisbruch A, Fraass BA, Galvin JM, Ibbott GS, Marks LB. Safety considerations for IMRT: executive summary. Pract. Radiat. Oncol. 2011;1(3):190–5. Available from: http://dx.doi.org/10.1016/j.prro.2011.04.008

7. Canadian Partnership for Quality Radiotherapy. Technical quality control guidelines for Canadian radiation treatment centres – major dosimetry equipment. 2015 Feb 28 [cited 2016 Jul 19]. Available from: http://www.cpqr.ca/programs/technical-quality-control

8. Canadian Partnership for Quality Radiotherapy. Technical quality control guidelines for Canadian radiation treatment centres – medical linear accelerators and multileaf collimators. 2016 Jul 20 [cited 2016 Jul 20]. Available from: http://www.cpqr.ca/programs/technical-quality-control

9. Canadian Partnership for Quality Radiotherapy. Technical quality control guidelines for Canadian radiation treatment centres – treatment planning systems. 2015 Jun 29 [cited 2016 Jul 19]. Available from: http://www.cpqr.ca/programs/technical-quality-control

10. Low DA, Moran JM, Dempsey JF, Dong L, Oldham M. Dosimetry tools and techniques for IMRT. Med. Phys. 2011;38:1313–38. Available from: http://dx.doi.org/10.1118/1.3514120

11. Ezzell GA, Burmeister JW, Dogan N, LoSasso TJ, Mechalakos JG, Mihailidis D, Molineu A, Palta JR, Ramsey CR, Salter BJ, et al. IMRT commissioning: multiple institution planning and dosimetry comparisons, a report from AAPM Task Group 119. Med. Phys. 2009;36(11):5359–73. Available from: http://dx.doi.org/10.1118/1.3238104

12. Harms Sr WB, Low DA, Wong JW, Purdy JA. A software tool for the quantitative evaluation of 3D dose calculation algorithms. Med. Phys. 1998;25:1830–36. Available from: http://dx.doi.org/10.1118/1.598363

13. Low DA, Dempsey JF. Evaluation of the gamma dose distribution comparison method. Med. Phys. 2003;30(9):2455–64. Available from: http://dx.doi.org/10.1118/1.1598711

14. Palaniswaamy G, Brame RS, Yaddanapudi S, Rangaraj D, and Mutic S. A statistical approach to IMRT patient-specific QA. Med. Phys. 2012;39(12):7560–70. Available from: http://dx.doi.org/10.1118/1.4768161

15. Breen SL, Moseley DJ, Zhang B, Sharpe MB. Statistical process control for IMRT dosimetric verification. Med. Phys. 2008;35(10):4417–25. Available from: http://dx.doi.org/10.1118/1.2975144

16. Ford EC, Terezakis S, Souranis A, Harris K, Gay H, Mutic S. Quality control quantification (QCQ): a tool to measure the value of quality control checks in radiation oncology. Int. J. Radiat. Oncol. Biol. Phys. 2012;84(3):263–9. Available from: http://dx.doi.org/10.1016/j.ijrobp.2012.04.036

17. Gérard K, Grandhaye JP, Marchesi V, Kafrouni H, Husson F, Aletti P. A comprehensive analysis of the IMRT dose delivery process using statistical process control (SPC). Med. Phys. 2009;36(4):1275–85. Available from: http://dx.doi.org/10.1118/1.3089793

18. Pawlicki T, Yoo S, Court LE, McMillan SK, Rice RK, Russell JD, Pacyniak JM, Woo MK, Basran PS, Shoales J, Boyer AL. Moving from IMRT QA measurements toward independent computer calculations using control charts, Radiother. Oncol. 2008;89(3):330–7. Available from: http://dx.doi.org/10.1016/j.radonc.2008.07.002