Canadian Partnership for Quality Radiotherapy

Technical Quality Control Guidelines for Accelerator-Integrated Cone-Beam Systems for Verification Imaging

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 *Accelerator-Integrated Cone-Beam Systems for Verification Imaging.* 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

In this report, a linac integrated cone-beam CT (CBCT) imaging system is defined as a kV source and a flat panel x ray detector that are attached orthogonally to a linear accelerator (kV-CBCT). Unlike conventional CT, kV-CBCT uses a cone shaped x ray beam and acquires an entire volume (14–26 cm in length) in a single gantry rotation lasting ~2 mins. To acquire the kV-CBCT projection data, flat-panel detectors are used in fluoroscopy mode, obtaining multiple projections per second; these projections are used to reconstruct the CBCT volumetric images. The imaging system is capable of providing radiographic, fluoroscopic, and CBCT imaging capabilities for image-guided radiation therapy, and possibly simulation. kV-CBCT produces a full CT data set that, although below diagnostic quality, is generally adequate for directly targeting bone and, in some sites, soft tissue. At this writing, two commercial systems are available in Canada: the

On-Board Imager™ (OBI) by Varian Medical Systems, Inc. (Palo Alto, CA), and the Elekta XVI system by Elekta Oncology Systems (Stockholm, Sweden).

A variant commercial offering from Siemens uses similar principles, but uses the linear accelerator as the imaging x ray source and an optimized portal imaging system for CBCT image acquisition and reconstruction.

All systems can produce two-dimensional (2D) images that can be registered with reference digitally-reconstructed radiographs generated by treatment planning systems and three-dimensional (3D) datasets that can be aligned with the planning CT. Both the 2D and 3D approaches allow verification and correction of patient positioning prior to delivery of the therapeutic dose.

Various attempts to recommend guidelines for accelerator-integrated cone-beam systems have been reported in the literature and have been considered in developing the current guidelines.[2–13]

Related Technical Quality Control Guidelines

In order to comprehensively assess accelerator-integrated cone-beam systems performance, additional guideline tests, as outlined in related CPQR Technical Quality Control (TQC) guidelines must also be completed and documented, as applicable. Related TQC guidelines, available at cpqr.ca, include:

- Safety Systems
- Medical Linear Accelerators and Multileaf Collimators
- Major Dosimetry Equipment

Test Tables

Table 1: Daily Quality Control Tests

Designator	Test	Performance
		Action
Daily		
DS1	Collision and safety interlocks	Functional
DS2	Laser/image/treatment isocentre coincidence; *or*	±2 mm
	Phantom localization and repositioning with couch shift	±2 mm
DS3	Warm-up: x ray tube and flat panel operation	Functional
DS4	Database integrity and software operation	Functional

Notes on Daily Tests

DS1 As per manufacturer recommendations. Variations exist between manufacturers.

DS2 Phantom localization and repositioning tests can be performed using dedicated phantoms that offer orientation features or simple ball bearings. An accuracy of ±2 mm has been published for this test.

DS3 These quality control tests are typically integrated within the procedure for DS2.

DS4 Software does not crash during test acquisition, and sufficient disk space is available for the day's operation. Digital Imaging and Communications in Medicine (DICOM) links to and from treatment planning system and picture archiving and communication system (PACS) systems should be functional.

These quality control tests are typically integrated within the procedure for DS2.

Table 2: Monthly Quality Control Tests

Designator	Test	Performance
		Action
Monthly		
MS1	Geometric calibration maps; *or*	Replace/refresh; ±0.25 mm
	kV/MV/laser alignment	±1 mm
MS2	End-to-end test, including couch shift accuracy	±1 mm
MS3	Image quality: spatial integrity	Reproducible
MS4	Image quality: uniformity, noise	Reproducible
MS5	Image quality: low contrast visibility	Reproducible
MS6	Image quality: high contrast resolution	$\leq$ 2 mm (or $\leq$ 5 lp/cm)
MS7	Image quality: CT number accuracy and stability	Reproducible
MS8	Records	Complete

Notes on Monthly Tests

MS1 The geometric calibration procedure should follow the manufacturer's instructions. Depending on user experience and data demonstrating stability of geometric

calibration, frequency of testing may be relaxed to biannually or upon service/upgrade, whichever occurs first.

MS2 End-to-end test of the image-guidance procedure using rigid phantoms. A reference CT scan of the phantom is required.

MS3–6 Image quality control tests results can be extracted from a single image acquisition of a standard CT image quality phantom. Manufacturers typically supply such phantoms as part of the purchase. Users are strongly recommended to follow exactly the instructions from the manufacturer's Customer Acceptance Documents.

Depending on user experience and data demonstrating stability of these quality control metrics, frequency of testing may be relaxed to biannually or upon service/upgrade, whichever occurs first.

MS7 Image quality control tests results can be extracted from a single image acquisition of a standard CT image quality phantom. Manufacturers typically supply such phantoms as part of the purchase. Users are strongly recommended to follow exactly the instructions from the manufacturer's Customer Acceptance Documents.

Depending on user experience and data demonstrating stability of these quality control metrics, frequency of testing may be relaxed to biannually or upon service/upgrade, whichever occurs first.

Perform only if the clinic uses such images for treatment planning and dose calculations performed with heterogeneity corrections. This should be tested only for those validated techniques used clinically.

MS8 Documentation relating to the daily quality control checks, preventive maintenance, service calls, and subsequent checks must be complete, legible, and the operator identified.

Table 3: Annual Quality Control Tests

Designator	Test	Performance
		Action
Annual		
AS1	Radiation dose	Reproducible
AS2	X ray generator performance	Reproducible
AS3	Orientation	Reproducible

AS4	System operation: disk space and IT infrastructure	Functional
AS5	Independent quality control review	Complete

Notes on Annual Tests

AS1 Point dose measurements using a Farmer ion chamber calibrated for orthovoltage energies. Suitable points would be representative of axial and skin doses. See Osei et al., 2009 for details.[14]

AS2 For kV-CBCT systems only. As for any x ray tube used clinically, tube kVp, half value layers (HVLs), mAs linearity, and accuracy of time and mA should be verified for those tube settings used by the CBCT system. Provincial regulations may supersede the baseline tolerances.

AS3 Using a phantom with asymmetrical features (e.g., anthropomorphic phantom or daily quality assurance phantom), compare a CBCT image with reference images in terms of orientation (i.e., anterior/posterior, superior/inferior, left/right directions). Also, verify that CT images obtained with the phantom in prone or supine positions, or scanned head first or feet first, are suitably transmitted to the CBCT system.

AS4 The clinic is encouraged to have a documented protocol for image archival. This protocol would specify how long files are kept in the clinical database, whether raw projections are stored or not, the pixel size of stored 3D datasets, and archival protocols and frequencies to offline disk systems or PACS.

AS5 To ensure redundancy and adequate monitoring, a second qualified medical physicist must independently verify the implementation, analysis, and interpretation of the quality control tests at least annually.

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