**COMP Report: CPQR technical quality control guidelines for conventional radiotherapy simulators**

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Abstract

The Canadian Organization of Medical Physicists (COMP), in close partnership with the Canadian Partnership for Quality Radiotherapy (CPQR) has developed a series of Technical Quality Control (TQC) guidelines for radiation treatment equipment. These guidelines outline the performance objectives that equipment should meet in order to ensure an acceptable level of radiation treatment quality. The TQC guidelines have been rigorously reviewed and field tested in a variety of Canadian radiation treatment facilities. The development process enables rapid review and update to keep the guidelines current with changes in technology (the most updated version of this guideline can be found on the CPQR website). This particular TQC details recommended quality control testing of conventional radiotherapy simulators.

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**KEY WORDS**

conventional simulator, PCQR, quality control

1 | 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 Conventional Radiotherapy Simulators. Please refer to the overarching document Technical Quality Control Guidelines for Canadian Radiation Treatment Centres 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. The development of the individual TQC guidelines is spearheaded by expert reviewers and involves broad stakeholder input from the medical physics and radiation oncology community.

All information contained in this document is intended to be used at the discretion of each individual center to help guide quality and safety program improvement. There are no legal standards supporting this document; specific federal or provincial regulations and license conditions take precedence over the content of this document.
2 | SYSTEM DESCRIPTION

Simulators are essentially general radiography/fluoroscopy units with mechanical and optical capabilities extended to reproduce the geometric conditions of megavoltage radiation treatment machines. The mechanical and optical systems for simulators, therefore, shall duplicate those for linear accelerators and Cobalt teletherapy units, as appropriate. The radiation production systems, however, are very different for simulators and accelerators, the former being low dose and low energy imaging systems, the latter being high dose and high energy treatment systems.

Radiotherapy simulators have two roles in the preparation of patients for radiotherapy. The first is localization in which the high contrast and resolution achievable with kilovoltage x rays are used to guide the oncologist in the determination of the anatomical volumes to receive therapeutic radiation doses and those to be avoided. The information obtained during localization can be used as the input to two-dimensional dose computation. The second role is that of true simulation. Beams, which may have been designed during a three-dimensional treatment planning process, are set on the patient and the oncologist confirms that the geometric aspects of the treatment intent are being met.

Basic simulator design varies little across manufacturers. Detailed descriptions of the conventional radiotherapy simulators have been reported in the literature. A rotatable gantry c-arm is mounted on a stand. The source end of the c-arm supports an x ray head consisting of a shielded x ray tube, field delineation, and collimation systems; the opposing end supports an image receptor and film cassette holder. The x ray head is translatable to enable different focus-to-axis distances (FAD). A treatment couch capable of translation, elevation, and full rotation on a turntable is used to position the patient. A control console is located in a shielded area adjacent to the simulator room. Some of the mechanical and optical systems may also be operated using controls inside the simulator room, for example, a hand pendant.

Traditionally, the image receptor used most often has been an image intensifier. A permanent record of the x ray image has been acquired either through digitally capturing the image as presented on the TV monitor connected to the camera viewing the output phosphor of the image intensifier, or through the use of film. More recently, large area flat panel detectors have become widely available and these are finding increasing use in radiotherapy simulation.

A major difference between conventional radiography and therapy simulation is the large distance (typically 120–170 cm) between the x ray focal spot and the image receptor. Since the simulator has geometric flexibility (to rotate around the patient), the image receptor is further away from the patient. Furthermore, simulation often requires beam-patient geometries not normally used in conventional radiography/fluoroscopy, such as lateral or oblique views through large body thicknesses. These requirements result in higher skin exposures than would be encountered in diagnostic radiography. The requirement for geometric flexibility also limits the amount of shielding that can be attached to the x ray image intensifier and precludes restrictions on x ray beam size.

3 | RELATED TECHNICAL QUALITY CONTROL GUIDELINES

In order to comprehensively assess conventional radiotherapy simulators 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
- Major Dosimetry Equipment

4 | TEST TABLES

Table 1 Daily quality control tests.

| Designator | Test                                      | Performance |
|------------|-------------------------------------------|-------------|
| DS1        | Collision avoidance                        | Functional  |
| DS2        | Lasers/crosswires                          | 1 mm 2 mm   |
| DS3        | Optical distance indicator                  | 1 mm 2 mm   |
| DS4        | Crosswires/reticle/block tray              | 1 mm 2 mm   |
| DS5        | Light/radiation coincidence                | 1 mm 2 mm   |
| DS6        | Optical and x ray field size indicators    | 1 mm 2 mm   |

Notes for daily tests

DS1 The configuration of this test will depend on the design of the facility and equipment. Safety is the concern and tests should be designed accordingly. As a minimum, manufacturer’s recommendations and applicable regulations shall be followed.

DS2 Alignment of crosswires and appropriate lasers for collimator angle 0°, gantry angles 0°, 90°, and 270° at the isocenter.

DS3 Gantry angle 0° and at isocenter.

DS4 Coincidence of crosswires and/or reticle and/or block tray axes for collimator angle 0°, gantry angle 0° at isocenter.

DS5 Coincidence of the x ray and optical images of the field defining wires for a 10 × 10 cm² field with a gantry angle 0°, collimator angle 0°, and source-to-surface distance (SSD) 100 cm. The tolerance and action levels apply to each field border. With an appropriate tool the test should be performed using the real time imaging device.

DS6 Both the optical and x ray images of the field defining wires for each field border should agree with the electronically indicated field size within the specified tolerance and action levels and for the geometry in DS5 above. With a verified reticle these tests can be performed with the aid of the real-time imaging device.
Notes for monthly tests

MS1 Mechanical and digital gantry angle readouts shall be verified using a spirit level, or other appropriate levelling device, for at least 0°, 90°, 180°, and 270°.

MS2 After determination of the 0° collimator position, which is then used as a reference, mechanical and digital collimator angle readouts shall be verified using millimeter paper for at least 0°, 90°, and 270°.

MS3 This test refers to the field wires orthogonality and to their perpendicularity to the crosswires. This test should be performed on both the optical and radiation image.

MS4 Automatic setting of the focus-axis-distance shall be checked, if relevant, using mechanical devices.

MS5 The possibility to move the amplifier to limits (determined at commissioning) in three cardinal axes should be verified.

MS6 The couch isocentricity shall be checked over a range of couch angles from 90° to 270°. The tolerance and action levels refer to the maximum displacement of crosshair projection from the initial position in the isocenter plane.

MS7 With a couch angle 0°, couch motions shall be parallel the cardinal axes of the simulator geometry over an appropriate clinical range.

MS8 The couch rotation angle shall be verified over an appropriate clinical range. Deviation between the true 0° and the mechanical and numerical scale should be determined.

(Continued)

Table 2 Monthly quality control tests.

| Designator | Test | Tolerance | Action |
|------------|------|-----------|--------|
| Monthly    |      |           |        |
| MS1        | Gantry angle readouts | 1°    |        |
| MS2        | Collimator angle readouts | 1°    |        |
| MS3        | Wires perpendicularity and orthogonality | 1°    |        |
| MS4        | Verification of FAD setting | 1 mm 2 mm |        |
| MS5        | Image amplifier movement | Functional |        |
| MS6        | Couch isocenter | 1 mm 2 mm |        |
| MS7        | Couch parallelism | 1 mm 2 mm |        |
| MS8        | Couch angle | 1° |        |
| MS9        | Couch position readouts | 1 mm 2 mm |        |
| MS10       | Couch displacement | 1 mm 2 mm |        |
| MS11       | Laser/crosswire isocentricity | 1 mm 2 mm |        |
| MS12       | Optical distance indicator | 1 mm 2 mm |        |
| MS13       | Crosswire centring | 1 mm 2 mm |        |
| MS14       | Light/radiation coincidence | 1 mm 2 mm |        |
| MS15       | Field size indicators | 1 mm 2 mm |        |
| MS16       | Records | Complete |        |

Table 3 Semiannual quality control tests.

| Designator | Test | Tolerance | Action |
|------------|------|-----------|--------|
| Semiannually |      |           |        |
| SS1        | Lead apron | Functional |        |
| SS2        | Focal spot | Reproducible |        |
| SS3        | Contrast | Reproducible |        |
| SS4        | Resolution | Reproducible |        |
| SS5        | Fluoroscopic timer | 5% 10% |        |
Notes for annual tests

SS1 Any available lead aprons, gloves, and other protective wear should be visually and radiologically inspected for cracks and appropriate action taken should cracks be found.

SS2–4 A variety of equipment is available for performing these tests. The tolerance and action levels will need to be developed locally depending on the equipment available and the performance variability in the observers. Routine monitoring of these parameters should be based on performance at installation.

SS5 The limit on fluoroscopy time is verified.

Table 4 Annual quality control tests.

| Designator | Test | Performance |
|------------|------|-------------|
|            |      | Tolerance   | Action |
| Annually   |      |             |        |
| AS1        | Isocenter definition and coincidence | 1 mm | 2 mm |
| AS2        | Crosswire centring | 1 mm | 2 mm |
| AS3        | Couch deflection | 3 mm | 5 mm |
| AS4        | Alignment of focal spots | 0.5 mm | 1 mm |
| AS5        | kVp | 5% | 10% |
| AS6        | Reference dosimetry | 5% | 10% |
| AS7        | Beam quality (half-value layer) | 5% | 10% |
| AS8        | Automatic exposure control | 5% | 10% |
| AS9        | Independent quality control review | Complete |

Notes for semiannually tests

(Continued)

AS7 Half-value layer (HVL) is to be compared at three kVp values with the baseline values established at acceptance.

AS8 Where more than one detector can be used for automatic exposure control, consistency between the exposures delivered should be established.

AS9 To ensure redundancy and adequate monitoring, a second qualified medical physicist shall independently verify the implementation, analysis, and interpretation of the quality control tests at least annually.

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Conflict of interest

The author has no conflict of interest to disclose.

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