Canadian Partnership for Quality Radiotherapy

Technical Quality Control Guidelines for Gamma Knife Radiosurgery

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

June 30, 2016

GKR.2016.06.01

www.cpqr.ca

CPQR
Canadian Partnership for Quality Radiotherapy
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Partenariat canadien pour la qualité en radiothérapie

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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 *Gamma Knife Radiosurgery.* 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

The Gamma Knife (GK) Perfexion™ (Elekta AB, Stockholm, Sweden) is used to treat intracranial lesions using stereotactic radiosurgery (SRS) procedures. Radiation is delivered by means of 192 ^{60}Co sources arranged in rings with a common focus point.[2,3] By distributing the incident radiation over nearly the entire brain, a very large dose can be delivered to a well localized target with minimal harm to healthy brain tissue. These single fraction treatments are a less invasive alternative to cranial surgery.

The 1 mm × 20 mm ^{60}Co sources are encapsulated in bushings and are arranged in eight sectors. The sectors move independently to position a subset of 24 sources over one of three different hole sizes in a tungsten collimator or to an "off" (blocked) position between holes. This allows the delivery of "marbles" of radiation (4 mm, 8 mm, or 16 mm shots), which can be combined to conform to the shape of the tumour. Since the different field sizes are created by means of precisely machined collimators, and the radiation is delivered using ^{60}Co, much of the variability in dose delivery associated with other external beam devices is eliminated.

Dose rates at the centre of an 8 cm radius polystyrene sphere are on the order of 3.5 Gy/min for a newly loaded unit. The sources are enclosed within an iron "ball"; additional shielding for scattered radiation is provided by sliding shutters. No primary radiation exits the unit.

Before imaging, a frame is fixed to the head of the patient. This serves two purposes: to define a coordinate system common to the imaging, planning, and treatment system, and to ensure that the patient cannot move during treatment. The patient positioning system (PPS; treatment couch) is rigidly affixed to the treatment unit, and the head frame is in turn locked into place on the PPS. Drive motors within the couch automatically position the patient to the prescribed isocentres during treatment. Head frame immobilization and high mechanical reproducibility allow for the accuracy required to deliver large doses to targets near relevant structures within the brain.

Related Technical Quality Control Guidelines

In order to comprehensively assess GK 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

Test Tables

Table 1: Daily/Weekly Quality Control Tests

Designator	Test	Performance	
		Tolerance	**Action**
Daily			
D1	GK unit interlocks (frame adapter, side panels)	Functional	
D2	Timer accuracy, linearity	1%, 0.5%	2%, 1%
D3	Treatment console alarm test	Functional	
D4	Emergency procedure placards	Present	
Weekly			
W1	Focus precision test	Functional	

Notes on Daily Tests

D1 The GK inhibits beam on if the patient is not locked in place, at the correct gamma angle with the side protection panels engaged.

D2 The GK timer agrees with an independent measurement (e.g., stopwatch). Linearity can be tested by cycling through shots of different durations over multiple days.

D3 The GK built-in alarm test causes the console alarm to sound.

D4 The emergency procedure placards are posted.

W1 The GK built-in focus precision test indicates “PASS.”

Table 2: Monthly/Quarterly Quality Control Tests

Designator	Test	Performance	
		Tolerance	**Action**
Monthly			
M1	Clearance test tool check	Functional	
M2	UPS battery check	Functional	
M3	Patient positioning system retraction	Functional	
M4	Patient positioning system accuracy	n/a	0.5 mm

Quarterly			
Q1	Sector alignment	n/a	0.5/1.0 mm[I]

[I] 0.5 mm for 4 and 8 mm collimators, 1.0 mm for 16 mm collimator

Notes on Monthly/Quarterly Tests

M1 The GK clearance test tool check passes. Also check after possible damage to the tool. At the discretion of the physicist, test frequency may be reduced to semi-annually.

M2 The Elekta uninterruptible power supply (UPS) check passes.

M3 Disengaging the x/z couch clutch allows the couch to be manually moved in the x/z direction.

M4 The position of the patient positioning system must be verified against physical reference positions over an appropriate clinical range in the directions of the three axes (x,y,z).

Q1 The sectors move to correct alignment with the 4, 8, or 16 mm collimators.

Table 3: Annual Quality Control Tests

Designator	**Test**	**Performance**	
		Tolerance	**Action**
Annual			
A1	Coincidence of radiation and mechanical isocentre	0.1 mm relative to baseline	0.5 mm absolute
A2	Timer linearity	0.5%	1%
A3	Timer transit error	Baseline	
A4	Profile accuracy	n/a	1 mm
A5	Backup timer on GK sector computer	Functional	
A6	Absolute calibration	1%	2%
A7	External service dose verification	n/a	5%[II]
A8	End-to-end test	1–5%/0.5 mm	1–5%/1.0 mm
A9	Radiation leak test	Baseline	
A10	Radiation survey	Background	

A11	Independent quality control review	Complete

[II] After each major maintenance and then every other year; tolerance as per testing institution (e.g., Imaging and Radiation Oncology Core [IROC]).

Notes on Annual Tests

A1 The positions of the radiation and mechanical isocentres agree with each other.

A2 The GK timer is linear. Test over a larger range than daily testing.

A3 The transit error is consistent with that measured during commissioning.

A4 The measured profiles agree with those in the treatment planning system. Stated tolerance applies to the 50% isodose line for each collimator size.

A5 The backup timer on the GK sector computer agrees with the console computer.

A6 The absolute dose rate in the treatment planning system matches the measured dose rate. Measurements must be made with a calibrated chamber using an accepted protocol (e.g., TG-21[(4)]).

A7 The absolute dose is independently verified by an external service (e.g., IROC Houston OSLD/TLD [optically-stimulated/thermoluminescent dosimeter] Monitoring Program).

A8 An end-to-end phantom test is performed including frame placement, imaging, treatment planning, treatment, and verification that the intended treatment was delivered with the stated dose and positioning accuracy. The dosimetric accuracy depends on the dosimeter being used. For example, 1% accuracy would apply when using an ion chamber, whereas 5% would be appropriate for film.

A9–10 The configuration of these tests will depend on the design of the facility and equipment. As a minimum, Canadian Nuclear Safety Commission (CNSC) license conditions and applicable regulations must be followed.

A11 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.

Acknowledgements

We would like to thank the many people who participated in the production of this guideline. These include: Kyle Malkoske and Laurent Tantôt (associate editors); the Quality Assurance and Radiation Safety Advisory Committee; the COMP Board of Directors, Erika Brown and the CPQR Steering Committee, and all individuals that submitted comments during the community review of this guideline.

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