COMP REPORTS AND DOCUMENTS

COMP report: CPQR technical quality control guidelines for Gamma Knife radiosurgery

Anita Berndt¹ | Monique van Prooijen² | Mathieu Guillot³

¹Department of Medical Physics, CancerCare Manitoba, Winnipeg, MB, Canada
²Department of Medical Physics, Princess Margaret Cancer Centre, University Health Network, Toronto, ON, Canada
³Département de Radio-Oncologie, Centre hospitalier universitaire de Sherbrooke, Sherbrooke, QC, Canada

Author to whom correspondence should be addressed. Anita Berndt
Email: aberndt@cancercare.mb.ca

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 for Gamma Knife radiosurgery.

PACS
87.56.Fc

KEY WORDS
Gamma Knife, quality assurance, radiosurgery

1 | INTRODUCTION

The CPQR is an alliance among 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 publication, CPQR TQC Guidelines for Gamma Knife Radiosurgery, contains detailed performance objectives and safety criteria for Gamma Knife Radiosurgery. The development of the individual Technical Quality Control (TQC) guidelines is spearheaded by expert reviewers and involves broad stakeholder input from the medical physics and radiation oncology community.¹ 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 Canadian Partnership for Quality Radiotherapy (CPQR) website). This article details recommended quality control testing for Gamma Knife radiosurgery. Please refer to the overarching document TQC Guidelines for Canadian Radiation Treatment Centres² 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.

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

------------------------------------------------------------------------------------------------------------------------------- ---------------------------------------
This is an open access article under the terms of the Creative Commons Attribution License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited.
© 2018 The Authors. Journal of Applied Clinical Medical Physics published by Wiley Periodicals, Inc. on behalf of American Association of Physicists in Medicine.

J Appl Clin Med Phys 2018: 19:5:365–367 wileyonlinelibrary.com/journal/jacmp | 365
and license conditions take precedence over the content of this document.

2 | 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. 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 $\times$ 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 tumor. 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 center 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 isocenters 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.

3 | RELATED TECHNICAL QUALITY CONTROL GUIDELINES

In order to comprehensively assess GK performance, 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:

- Safety Systems
- Major Dosimetry Equipment

4 | TEST TABLES

Tables 1–3 list the daily/weekly, monthly/quarterly and annual recommended quality control tests.

**Table 1** Daily/weekly quality control tests.

| Designator | Test Description | 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 for Daily/Weekly 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 Description | 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 | |

$^{a}0.5$ mm for 4 and 8 mm collimators, 1.0 mm for 16 mm collimator.

**Notes for 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 semiannually.

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.
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).

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 isocenter | 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%*         |        |
| 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                     |             |        |

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

### Notes for Annual Tests

- **A1** The positions of the radiation and mechanical isocenters 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-215)
- **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

### Acknowledgments

The authors thank the many people who participated in the production of this guideline. These include Michelle Nielsen and Normand Freniere (associate editors for COMP); COMP’s Quality Assurance and Radiation Safety Advisory Committee; the COMP Board of Directors; Erika Brown, Michael Milosevic, and the CPQR Steering Committee, and all individuals that submitted comments during the community review of this guideline. The production of this manuscript has been made possible through a financial contribution from Health Canada, through the Canadian Partnership Against Cancer.

### Conflict of Interest

The authors have no other relevant conflicts of interest to disclose.

### References

1. Nielsen MK, Malkoske KE, Brown E, et al. Production, review, and impact of technical quality control guidelines in a national context. *J Appl Clin Med Phys.* 2016;17:2–15.
2. Canadian partnership for quality radiotherapy. Technical quality control guidelines for safety systems at radiation treatment centres. 2016. Jul 12 [cited 2017 Jun 20]. Available from: http://www.cpqr.ca/programs/technical-quality-control
3. Gamma Knife (GK) Perfexion™, Elekta AB. 2015. [cited 2016 Jul 19]. Available from: http://www.elekta.com/
4. Leksell Gamma Knife Perfexion™ Instruction for Use, Elekta AB. 2007. Available from: https://www.elekta.com/
5. Task Group 21, Radiation Therapy Committee, AAPM. A protocol for the determination of absorbed dose from high-energy photon and electron beams. *Med Phys.* 1983;10:741–771.