Cancer Care Ontario

Lung SBRT Framework

Developed by the Lung SBRT Working Group, Lung Community of Practice, Cancer Care Ontario

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Contents

i. Treatment Planning/Dosimetry

Contours – Target:

- For planning, the primary data set is the 4D maximum, average or free-breathing helical (centre dependent)

Contours – OARs:

- Any OARs that are not contoured by the oncologist, would need to be completed by a therapist

Technique:

- Ideally, the isocentre is located in the centre of the PTV. However, its location is impacted by machine and/or patient limitations.
- VMAT, IMRT or 3DCRT (multiple static beams, including non-coplanar)
- Dose calculation must be set to heterogeneous with a grid spacing ≤0.3 cm
- Photon energies of 4-10 MV are recommended

Target coverage:

- Prescription isodose coverage: At least 95% of the PTV is covered by the prescription dose (PTV: D95% >= 100%)
    - 99% of the PTV must be covered by 90% of the prescription dose (PTV: D99%>=90%). Some centres dose to ITV (≥99% of ITV to receive prescription dose, ≥99% of PTV to receive 95% of the prescription dose).

Plan Evaluation:

- Maximum dose should be within the ITV (≤167%).
- Minimize 105% isodose outside the PTV
- Conformality indices to be evaluated for the ratio of prescription isodose volume to the PTV volume, the ratio of the 50% prescription isodose volume to the PTV volume, and the maximum dose (in % of dose prescribed) at 2 cm from the PTV (based on in-house criteria and RTOG 0915/0813).

Dose Constraints for OAR's

- Follow RTOG 0915/0813 and in-house guidelines see appendix

Implanted Cardiac Devices Issues & Constraints

- Document dose to pacemaker/defibrillator as per centre protocol

- Avoid energies >6MV
- Avoid VMAT, if the target is close to the device

Documentation

- As per centre policy

Patient Chart

- Complete as per centre policy, including target coverage and OAR doses
- Any prior treatments should be flagged and reviewed

ii. Contouring

Nomenclature

The generation of GTV/ITV/PTV is similar across Ontario cancer centres, but not 100% consistent.

All centres should be using 4DCT at time of simulation and generate GTVs from a combination of the average scan, maximal intensity projection and/or specific phases of the 4DCT. GTVs generated may include GTVaverage, GTVinspiration, GTVexpiration and/or GTVmip, as well as for any of the other 4DCT phases (ie GTV_{10}, GTV_{80}). Correlation of targets with available diagnostic imaging is recommended. ITV should be created by combining all GTVs into a single structure without additional expansion. The ITV should completely encompass all visible tumour on all phases of the 4DCT video. An additional margin for CTV is generally not recommended, though can sometimes be used at the discretion of the radiation oncologist. PTV is typically generated with a 5 mm uniform expansion from the ITV, though individual centres may choose to modify this expansion at their own discretion.

Contours

Prior to SBRT planning, the accurate contouring of numerous organs at risk (OARs) is essential. These should include: 1) Spinal cord/canal (+PRV); 2) Trachea/Proximal bronchial tree; 3) Both lungs; 4) Lungs – GTV/ITV; 5) Heart; 6) Esophagus; 7) Great Vessels (Aorta/Pulmonary Artery); 8) Chest wall/ribs; 9) Skin; and 10) Ipsilateral brachial plexus. Depending on tumour location, some OARs may be omitted or modified at the discretion of the radiation oncologist. For example, the brachial plexus may need not be contoured for a lower lobe lesion abutting the diaphragm. Conversely, ‘non-standard’ OARs may also be contoured when deemed clinically important, such as liver, stomach and small bowel.

Target Size

SBRT is recommended for smaller pulmonary lesions (typically ≤5 cm), though the maximum size of any SBRT target is left to the individual centre.

Radiation Prescription

For peripheral lesions, recommended dose/fractionation regimens include 54 Gy/3 Fr, 48-60 Gy/4 Fr, 50-60 Gy/5 Fr. For central lesions (central zone see RTOG 0813/0915 appendix for figure), either 50-55 Gy/5 or 60 Gy/8 Fr are recommended. Delivery may either be on consecutive or every second weekdays. Where available, established institutional protocols should be followed (RTOG 0813, RTOG0915 see appendix).

CT Simulation for SBRT Lung

Scan:

- Helical 1.5-3.0 mm free breathing
- 4DCT

Patient Preparation:

- IV contrast recommended if there is a central lesion

Patient Immobilization:

- Supine, and both arms up if possible
- Chestboard, wing board or Vaclok
- S-frame (mask) with arms down if the lesion is apical
- Chin extended comfortably
- Utilize knee wedge or leg immobilizer
- Compression device or breath-hold device (ex. Active Breathing Control) is site-specific

Special consideration:

- Minimize the motion of the tumour (site-specific)
- If tumour motion >1 cm, further motion management is required. To help further minimize motion, a compression device, breath-hold, or beam gating can be used.
- Ensure the patient is compressed enough to minimize as much motion as possible, but still able to tolerate.
- Documentation is required

Tattoos:

- Anterior set-up tattoo is inferior of SSN and midline
- Inferior alignment must be at least 15 cm inferior of anterior set-up tattoo
- Laterals (TTH) must be at mid- separation at the level of anterior set-up if possible. Otherwise, must be in line with inferior alignment tattoo.

Scanning Parameters:

- Helical and 4DCT scan limits:
  Superior limit is 5 cm above apex of lung
  Inferior limit is 5 cm below the most inferior aspect of lung

Scans for Planning:

- Review of 4D images for the assessment of artifacts and target motion
- Must send maximum (exhale) and minimum (inhale) phases to the planning system. The helical scan must be included.
- Create MIP (if appropriate) and average scans and send these to the planning system as well
- All other phases can be transferred. This is case dependent.

Documentation:

- In-patient chart must be used to document all pertinent information such as: scans sent, patient setup, immobilization, +/-compression and tattoo information.

iii. Treatment Delivery and Imaging

SBRT Lung Treatment Guideline

Technique:

VMAT, IMRT +/- non coplanar beams

Prescription:

Cancer Centre defined dose and fractionation *(considerations: RTOG, LUSTRE, Study)*

Pre-Treatment Check:

Optional trial/mock setup to check patient, machine/bed and treatment angle clearance. May require patient and/or Radiation Oncologist/designate present if acquiring and assessing a conebeam scan.

Treatment:

Prepare patient for treatment as per cancer centre defined policy on education and ID verification. Position and align patient as per CT documentation which may include immobilization devices, motion management and the use of a six degree of freedom couch. Perform DAILY online conebeam acquisition and review (*see SBRT Lung Imaging Workflow*). Ensure complete documentation of setup and image-guided treatment instructions/parameters.

Defining Automatch Parameters on Reference Image:

Ensure optimal display and visualization based on imaging software

Define the levels of vertebral bodies that are appropriate representatives of tumour/lesion and treatment isocentre. Assign matching software automatch around this spine boney anatomy.

Define relevant soft tissue match structures and regions of interest such as ITV and PTV. A soft tissue mask registration may also be used to aid in automatic registration as per Cancer Centre specific practices.

Performing DAILY Cone Beam Imaging:

Acquire DAILY cone beam using SBRT lung specific presets. Scan parameters such as mA, kV and degrees of scan rotation will be determined by Cancer Centre protocol and resources.

Perform initial automatch of spine boney anatomy with translation and rotation. Assess magnitude of translation as a check of patient setup. Assess rotation (pitch, roll, yaw) based on Cancer Centre defined allowed limits. If applicable, assess six degrees of freedom couch limits.

If tolerances are NOT met perform recheck of positioning and setup. Rescan following any adjustments (noting the limit of allowable rescans as per cancer centre protocol). It may be necessary to contact Radiation Oncologist, planner or physics designate to review.

If tolerances are met, perform conversion of match to remove rotation (if six degrees of freedom couch is not used).

Manually match the ITV to the tumour (or perform a soft tissue mask registration, if applicable). Assess magnitude of translational adjustment against cancer centre defined constraints. Evaluate coverage of target volume in relation to ITV, PTV, OARs (i.e. brachial plexus, canal, esophagus) and ROIs (i.e. spine, carina). Furthermore, evaluate normal anatomy changes (i.e. fluid, collapse, growth, shifting).

Radiation Oncologist or designate to be present on day 1 for online cone beam assessment of image match prior to delivery of treatment beam(s).

If tolerances are NOT met, perform recheck of positioning, setup and motion management (if applicable). Furthermore, contact the Radiation Oncologist/designate for review.

Apply final translational and/or rotational bed shifts. As determined by the Cancer Centre specific policies on cone beam CT scans, perform applicable verification, pre-couch rotation/intra, post treatment and/or study scans.

Deliver treatment beams and documentation as per cancer centre protocol. Determine if Radiation Oncologist/designate required to be present for DAILY imaging review.

iv. Equipment QA for SBRT Lung

Introduction:

This document specifies a minimum basic framework for Quality Control (QC) of equipment used in the delivery of SBRT lung treatment for centres in Ontario.

Generally, the recommendations are based on existing national or international guidelines with some clarifications and additions specific to the planning and treatment of SBRT lung. Readers are encouraged to review the ASTRO guidelines: Quality and safety considerations in stereotactic radiosurgery and stereotactic body radiation therapy: Executive summary (1), as well as all Canadian Partnership for Quality Radiotherapy (CPQR) guidelines that can be found on their website (2).

When implementing a new technique or utilizing systems in a different fashion such as when a centre begins an SBRT lung program, qualified medical physicists need to commission all equipment specifically for the scope and clinical goals required for their specific technique. For example, implementing and verifying the use of 1 mm CT slice thicknesses or commissioning small, off-axis beams in the treatment planning system. Qualified medical physicists need to characterize the systems that they employ, establish baselines for new tests or usage of equipment. Increasing the frequency of QA testing in the initial phases of implementation and adjusting the frequency of tests may be required to ensure quality of radiation therapy planning and delivery.

The scope of this work is limited to CT Simulation, photon linac-based delivery with kV CBCT imaging. These are the technologies currently in use in Ontario for Lung SBRT.

This document presents QC tests that are necessary for effective and accurate Lung SBRT, in addition to those described by the CPQR technical quality control guidelines.

Future changes in technology will require adaptations of these guidelines.

Section A: Simulation

Statement of Requirements for CT Simulation:

Basic quality assurance for CT Simulators have been documented by the American Association of Physicists in Medicine (AAPM) Task group 66 (3) and more recently, quality control specifications have been set out by CPQR's Technical Quality Control Guidelines for Canadian Radiation Treatment Centres: Computer Tomography Simulators revision July 16, 2016. (4). In addition to optical, mechanical, radiological, and image quality of CT scanning, the CPQR document addresses many of the quality

assurance aspects of performing 4D CT. Additional quality assurance for SBRT Lung should be directed to motion management (5), motion measurement (6), and immobilization systems. Suggested additional tests are outlined in Table 1.

Table 1: Additional suggested QA tests for 4DCT and motion management systems beyond those listed in CPQR reference 4.

Tests for 4D CT & motion management	Frequency	Minimum Spec	Comments
Mechanical/Visual Inspection of surrogates	Daily*	Intact	For bellow systems: leak-testing, cable integrity For optical systems: reflectors positioning against camera calibration
Breath hold systems not integrated with the CT scanner	Daily* Quarterly	Intact & Functional Reproducibility	leak-testing, cable integrity, flow rate, reproducibility (example Elekta Active Breathing Coordinator)
Immobilization equipment inspection (e.g., abdominal compression: mechanical or pneumatic)	Daily*	Intact & Functional	For mechanical systems: structural integrity and rigidity For pneumatic systems: leak-testing, pressure gauge accuracy, reproducibility

*Daily = days that 4DCT will be performed

Section B: Treatment Planning System

Treatment planning system considerations related to SBRT lung are mainly around commissioning of the planning system and the beam models. However, QC of the systems (particularly after software changes) must include sufficient tests to ensure the salient features still provide the necessary accuracy. Baseline tests should be established at commissioning to allow proper testing of the system.

SBRT lung typically involves very small and/or asymmetric fields, off-axis fields, and large inhomogeneity corrections. Beam models should be verified against small and off-axis fields. AAPM task group 101 report (7) has recommended using only modern 3d convolution/superposition or Monte Carlo algorithms which can calculate dose with acceptable accuracy. Even so, most convolution/superposition algorithms over predict dose by 3-5% within lung (8). On commissioning, the system should be characterized with baseline examples for SBRT lung.

In SBRT, skin dose must be carefully considered as many beams may enter through the posterior surface of the patient and the use of carbon fibre couch tops for imaging purposes has led to increased skin dose. It is usually necessary to include the effect of

patient couch or other support/immobilization devices as recommended by AAPM report 176 (9).

TG-101 "recommends the use of an isotropic grid size of 2 mm or finer. The use of grid sizes greater than 3 mm is discouraged for SBRT (7). QC tests should be run at the conditions used for calculation.

Secondary monitor unit check software may have difficulty with the above dosimetric conditions. Correction methods will be needed, or measured confirmation. Baseline calculations need to be established for the secondary software, to be used in routine QC, or at least following changes to the system.

QC efforts should also include tests to ensure correct calculation after system changes or updates.

Guidelines as per CPQR Canadian Partnership for Quality Radiotherapy: Technical Quality Control Guidelines for Canadian Radiation Treatment Centres: Treatment Planning Systems (10) should be followed with additional focus on the technique, segment sizes, and calculation parameters to be used for SBRT lung. If the treatment planning system offers Monte Carlo algorithms, AAPM Task Group 105 provides further guidelines (11).

Section C: Transfer Between TP System and Radiation Oncology Information System (if applicable)

Statement of Requirements for Transfer:

Quality control for the transfer of information between an independent TP system and the Radiation Oncology Information System (ROIS) should follow guidelines set out by the Canadian Partnership for Quality Radiotherapy: Technical Quality Control Guidelines for Data Management Systems (12). The AAPM task group 201 also provides recommendations for QA of external beam therapy data transfer (13, 14). Transfer of data between the ROIS and the linac controller should involve both vendors' checksum as well as therapists' manual verification of key parameters between the ROIs and the linac console.

Requirements for Lung SBRT should be no different than those for any IMRT/VMAT technique.

Table 2: Additional suggested QA tests for Data Transfer beyond those listed in the CPQR Technical Quality Control Guidelines for Data Management Systems (12)

Tests if Transfer is Required between TP and ROIS	Frequency	Minimum	Desirable	Comments

Data Transfer Integrity of IMRT/VMAT segments	Every Case	Inspection of minimum number of segments, MUs per segment.	Inspection of all segments	Patient-specific QA measurements or linac log-based checks are recommended
Data Transfer integrity of images, isocentre location, and ROIs	Every Case	Visual Inspection		Ensure total number of slices and location of ROI overlay. Correct image set – e.g. Average scan if used for final plan.
Data Transfer Integrity of Test Case of SBRT Lung (benchmark case)			Annually	End-to-end test of benchmark case

Section D: Verification Imaging

SBRT lung should not normally require a different imaging QC. As noted in AAPM TG-179:

"Because the geometric accuracy of CT-based imaging systems for image-guidance is inherently high, a well-designed QA program will satisfy simultaneously the requirements of conventional and SBRT radiotherapy". (15)

This report recommends following the CPQR Technical Quality Control Guidelines for Canadian Radiation Treatment Centres: Accelerator–integrated Cone-Beam Systems for Verification Imaging recommendations for QC (16), which are essentially the same as TG-179 (15). However, it is recommended to keep in mind the short fractionation of SBRT treatments with knowledge of the imaging systems in use for SBRT in determining the appropriate frequency for these short courses.

Section E: Linac

Statement of Requirements for Linac:

Linac QC has been extensively reported and detailed in CPQR Technical Quality Control Guidelines for Medical Linear Accelerators and Multileaf Collimators (17) and AAPM Task group 142 report (18). SBRT Lung may be delivered with 3D Conformal Radiation Therapy (3DCRT), Intensity Modulated Radiation Therapy (IMRT), or Volumetric Modulated Arc Therapy (VMAT) techniques. Numerous publications provide

further details if using IMRT or VMAT (19-22). If using Dynamic IMRT or VMAT delivery techniques, additional testing on dosimetric parameters such as dose, symmetry, flatness, and linearity with mechanical motions and varying dose rates are recommended.

QC tests and their tolerances have been recommended by CPQR (17). In Table 3, we provide a detailed example set of tests that may be used to test variation of dose rate, gantry speed, MLC leaf speed, and position during arc delivery.

If a six degree of freedom couch is used for Lung SBRT, additional QC is required beyond that performed for conventional couches. These are listed in Table 4 below.

Table 3: Example QA tests for IMRT and VMAT

Tests for Linacs Used for IMRT or VMAT	Frequency	Minimum Tolerance	Desirable
All Mechanical Rotations	Monthly	Radius < 1.0 mm	Radius < 0.5 mm
IMRT (step & shoot) Leaf position vs Radiation Dose rate linearity Dose constancy vs Gantry Angle Flatness vs Gantry Angle Symmetry vs Gantry Angle	 Monthly Monthly Monthly Monthly Monthly	 <1 mm ± 1.5% ± 1.5% ± 2.0% ± 2.0%	<0.5 mm
VMAT/Dynamic MLC IMRT Dose rate linearity Flatness vs Dose rate Symmetry vs Dose rate Dose constancy vs Gantry Angle DMLC MU linearity DMLC MU constancy VMAT leaf position constancy Verify gantry speed	 Monthly Monthly Monthly Monthly Monthly Monthly Monthly Monthly	 ± 1.5% ± 2.0% ± 2.0% ± 1.5% ± 2.0% ± 2.0% <3mm Within vendor spec	
Gating Systems Functionality Gated VMAT leaf position constancy and gantry speed verification	 Daily Monthly	 Functional <3mm and within vendor spec	

Table 4: QC for 6 Degree of Freedom Couch

Test	Frequency	Minimum Tolerance	Desirable	Comments
Safety and Interlock Checks: Movement prevented during Linac Ready, Beam on, or CBCT	Daily	Functional		
Table Position Monitoring System: Hardware Movement Detection Calibration Check	 Daily Daily Monthly	 Secure ± 2.0 mm	 ± 1.0 mm	
Table Translations	Monthly	± 0.4 mm	± 0.2 mm	Or vendor's specs
Table Rotations	Monthly	± 0.2°	± 0.1°	Or vendor's specs
End to end testing with imaging tests	Daily	≤ 1.5 mm any one translation ≤ 1.5 mm RMS for all translations		

Patient-Specific Measurements and End-to-end QA verification

CPQR Technical Quality Control Guidelines for Patient-Specific Dosimetric Measurements for Modulated Therapies describe the QC steps for all modulated therapies (23). These should be performed for all SBRT lung cases.

All centres are encouraged to perform an external audit of their SBRT Lung planning and delivery process whether or not they are participating in multi-centre trials. An example of an external audit for moving lung tumours is the Imaging and Radiation Oncology Core (IROC) lung phantom audit, details can be found at: http://rpc.mdanderson.org/RPC/home.htm (24).

APPENDIX

RTOG 0813

RTOG 0915

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