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PRACTICE GUIDELINE FOR 3D EXTERNAL BEAM RADIATION PLANNING AND CONFORMAL THERAPY

PREAMBLE

These guidelines are an educational tool designed to assist practitioners in providing appropriate radiologic care for patients. They are not inflexible rules or requirements of practice and are not intended, nor should they be used, to establish a legal standard of care. For these reasons and those set forth below, the American College of Radiology cautions against the use of these guidelines in litigation in which the clinical decisions of a practitioner are called into question.

The ultimate judgment regarding the propriety of any specific procedure or course of action must be made by the physician or medical physicist in light of all the circumstances presented. Thus, an approach that differs from the guidelines, standing alone, does not necessarily imply that the approach was below the standard of care. To the contrary, a conscientious practitioner may responsibly adopt a course of action different from that set forth in the guidelines when, in the reasonable judgment of the practitioner, such course of action is indicated by the condition of the patient, limitations on available resources, or advances in knowledge or technology subsequent to publication of the guidelines. However, a practitioner who employs an approach substantially different from these guidelines is advised to document in the patient record information sufficient to explain the approach taken.

The practice of medicine involves not only the science, but also the art of dealing with the prevention, diagnosis, alleviation, and treatment of disease. The variety and complexity of human conditions make it impossible to

always reach the most appropriate diagnosis or to predict with certainty a particular response to treatment. Therefore, it should be recognized that adherence to these guidelines will not assure an accurate diagnosis or a successful outcome. All that should be expected is that the practitioner will follow a reasonable course of action based on current knowledge, available resources, and the needs of the patient to deliver effective and safe medical care. The sole purpose of these guidelines is to assist practitioners in achieving this objective.

I. INTRODUCTION

This guideline was revised collaboratively by the American College of Radiology (ACR) and the American Society of Therapeutic Radiology and Oncology (ASTRO).

The potential of delivering higher radiation doses to tumor or target volumes with little or no increase in normal tissue complications provides the motivation for developing three-dimensional (3D) conformal treatment planning. This procedure requires careful delineation of the tissues at risk and the target volumes in order to reduce the volume of tissue that is included in the prescription isodose and thus reduce the amount of normal tissue receiving high irradiation doses. The prescription dose conforms as closely as possible to the target volume; the precision and accuracy required for the 3D treatment planning process exceeds accepted tolerances generally found in 2D treatment planning. The 3D process requires a team effort between the radiation

oncologist, the medical physicist, the dosimetrist, and the radiation therapist.

This guideline describes a quality assurance (QA) program for 3D treatment planning, which includes 1) systematic testing of the hardware and software used in the 3D treatment-planning process, 2) careful review of each patient's treatment plan, and 3) review of the physical implementation of the treatment plan. This guideline supplements the [ACR Practice Guideline for Radiation Oncology](#) and the [ACR Technical Standard for the Performance of Radiation Oncology Physics for External Beam Therapy](#).

II. DEFINITION

3D external beam radiation planning involves three-dimensional computer-generated reconstruction of tumor or target volume and surrounding critical normal tissue structures from computed tomography (CT), positron emission tomography (PET) or magnetic resonance imaging (MRI) data in preparation for therapy. The simulation uses 3D beam's-eye view (BEV) volume-dose displays of multiple or moving beams. Documentation with 3D volume reconstruction, dose distribution, and/or dose volume histograms (DVH) is required.

III. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

See the [ACR Practice Guideline for Radiation Oncology](#) where qualifications, credentialing, professional relationships, and development are outlined.

A. Radiation Oncologist

The responsibilities of the radiation oncologist shall be clearly defined and should include the following:

1. Plan and/or approve the immobilization/repositioning system in consultation with other members of the team.
2. Define the goals and requirements of the treatment plan.
3. Delineate tumor and specify and approve target volumes, preferably using International Commission on Radiation and Measurements (ICRU) 50 methodology.
4. Contour critical normal structures not clearly discernible on treatment planning images.
5. Review and approve all critical structures contoured.
6. Prescribe the appropriate target dose and limitations on critical normal structures.
7. Perform the final evaluation and approve the 3D treatment plan for implementation. The plan must be signed and dated by the physician.

8. Review all implementation and verification images (simulation and/or portal images), and initial and date.
9. Participate in peer review of contours and 3D treatment plans in conjunction with other members of the team.

B. Qualified Medical Physicist

The responsibilities of the qualified medical physicist shall be clearly defined and should include the following:

1. Perform acceptance testing, commissioning, and implementation of the 3D radiation treatment-planning (RTP) system.
2. Understand the limitations and appropriate use of the 3D RTP system, including the precision of generated 3D patient and beam geometry and the applicability of dose calculation algorithms to different clinical situations.
3. Establish and manage a QA program for the 3D RTP system.
4. Serve as a "technical resource" for the 3D team.
5. Consult with the radiation oncologist and other team members in implementing the immobilization/repositioning system for the patient.
6. Participate in review of contours and anatomical structures for the 3D treatment plan.
7. Review each patient's 3D treatment plan for technical accuracy and precision.
8. Provide physical measurements, as appropriate, for verification of the 3D treatment plan.
9. Verify that the results of an independent check on monitor units are within established department guidelines.

C. Treatment Planner

The responsibilities of the treatment planner shall be clearly defined and should include the following:

1. Contour clearly discernible critical normal structures.
2. Ensure proper orientation of volumetric patient image data on the 3D RTP system.
3. Design and generate the 3D treatment plan in consultation with the radiation oncologist and physicist as required.
4. Generate all technical documentation required to implement the 3D treatment plan.

D. Radiation Therapist

The responsibilities of the radiation therapist shall be clearly defined and should include the following:

1. Understand the appropriate use of the patient immobilization/repositioning device(s).
2. In consultation with the radiation oncologist and medical physicist, obtain the imaging data appropriate to the 3D RTP system.
3. Implement the 3D treatment plan on the therapy machine under the supervision of the radiation oncologist and medical physicist or medical dosimetrist.
4. Acquire periodic verification images for review by the radiation oncologist.
5. Perform periodic evaluation of the stability and ongoing reproducibility of immobilization/repositioning systems and report inconsistencies immediately to the radiation oncologist and/or medical physicist.

IV. QA FOR THE 3D TREATMENT PLANNING (RTP) SYSTEM

Image-based 3D RTP systems are very complex. Data input from medical imaging devices are used in conjunction with a mathematical description of the external radiation beams to produce an anatomically detailed patient model illustrating the dose distribution with a high degree of accuracy and precision. Documentation must exist indicating that the medical physicist has authorized the system for clinical use and has established a QA program to monitor the 3D system's performance as it relates to the 3D planning process. Consequently, the QA program involves elements that may be considered to be both dosimetric and nondosimetric in nature. Furthermore, it is recognized that various testing methods may be used, with equal validity, to assure that a system feature or component is performing correctly. Also, the commercial manufacturer may recommend specific QA tests to be performed on its planning system. Because of the system complexity, the medical physicist may elect to release the system in stages, and the required validation and verification testing will reflect only the features of the system that are in current clinical use at that facility. A comprehensive 3D RTP QA program is essential to test the planning system in the manner in which it will be used clinically.

As the lines between 3D RTP systems and the radiation therapy treatment machines continue to blur with the progression of high-tech delivery methods (multileaf collimators, beam intensity modulation, computer control, etc), the performance and maintenance of such a QA program will be as important as the routine QA performed on therapy machines now.

The important elements of the QA program for the image-based 3D RTP system are identified below, but the method and testing frequency are not specified.

Information with more scientific detail may be found in the AAPM TG-53 report.

A. System Log

Maintain an ongoing system log that indicates system component failures, error messages, corrective actions, and system hardware or software changes.

B. System Data Input Devices

Check input devices for image-based planning systems for functionality and accuracy. Devices include: digitizer tablet, medical imaging data (CT, MR, PET, ultrasound, etc) input interface, video digitizers, simulator control systems, and mechanical devices for obtaining patient contours. Assure correct anatomical registration from all the appropriate input devices.

C. System Output Devices

Assure the functionality and accuracy of all printers, plotters, and graphical display units that produce BEVs of anatomical structures from digitally reconstructed radiographs (DRRs) or beam aperture designs (such as custom blocks and multileaf collimator blades). Assure correct information transfer and appropriate dimensional scaling of block cutters and compensator makers. Assure the correct transfer of information to the Record and Verify system.

D. System Software

Assure the continued integrity of the RTP system information files used for modeling the external radiation beams. Confirm agreement of the beam modeling to currently accepted clinical data derived from physical measurements. Similarly, assure the integrity of the system to render the anatomical modeling correctly, including CT number consistency for conversion to relative electron density (heterogeneity correction). Confirm the accuracy of the calculated monitor units. Confirm the accuracy of the system-generated dose volume histograms or other "tools" for plan evaluation.

V. 3D TREATMENT PLAN IMPLEMENTATION

Conforming the dose distribution to the target tissues with a high degree of precision and accuracy requires a greater complexity not only in the planning aspects but also in the implementation process. The implementation process may be defined as an accurate registration of the patient geometry with the dose delivery geometry of the treatment unit. The relationship between those two geometries is specified by the imaged-based 3D treatment plan that delineates the patient anatomy relative to the external beam parameters of the treatment unit.

Implementation requires attention to detail and the combined skills of all members of the treatment team. The following are required:

A. Correct Patient Positioning

The patient geometry must be inherently reproducible and be in correct registration relative to the treatment unit. In unusually complicated setups, personnel designated by the radiation oncologist should be present for the first treatment.

B. Correct Beam Delivery Parameters

The beam delivery geometry of the image-based 3D treatment plan must be correctly transferred to the treatment unit. This means using the “approved” treatment plan specifications: beam energies, collimator jaw settings, treatment aids (compensators, wedges, custom blocks, and bolus), gantry angles, patient treatment table settings, treatment distance, and isocenter location.

Beam shape may be defined by custom blocking or by circular or multileaf collimation. If custom blocking is used, correct shape, distance, and orientation must be transferred to the blockcutter for construction of the required block. If circular or multileaf collimation is used to define beam shape, leaf positions must be correctly transferred to the treatment unit.

Information related to dynamic motions of jaws, circular or multileaf collimators, or other components must be correctly transferred to the treatment unit. Lastly, the approved monitor unit setting and, when appropriate, the correct beam intensity must be used.

VI. IMAGE-BASED 3-D TREATMENT VERIFICATION AND DELIVERY

Treatment verification is directly linked to implementation; it may be considered as the confirmation phase of the 3D treatment process. It assures compliance with the aforementioned sections for the individual patient. Verification data are information that confirms the correctness of the administered dose using accurate transfer of both the technical setup and dose delivery data. The verification process is ongoing. The entire process administered by the radiation therapist must be evaluated continually both for technical accuracy and for the clinical efficacy intended by the radiation oncologist. The treatment team should remain available to revise any aspects of the initial plan as the clinical situation warrants.

Verification of the patient treatment plan includes documentation of all of the elements associated with implementation as well as images of treatment ports and, on occasion, physical dose measurements. Each facility

may derive its own means to document and assure communication of the exact details required to achieve daily, ongoing correlation between the image-based 3D plan and dose delivery. The information content of the important treatment verification elements is described below.

Beam verification should be consistent with the [ACR Technical Standard for the Performance of Radiation Oncology Physics for External Beam Therapy](#).

A. Verification and Documentation

Correct verification of the 3D external beam plan in the actual setting requires proper understanding, interpretation, transfer, and documentation of all of the aspects of the patient’s clinical setup, positioning, and immobilization, as well as treatment unit parameters such as jaw setting, treatment aids, gantry angle, collimator angle, patient support table angle and position, treatment distance, and monitor unit setting. Record and Verify systems couple computer monitoring and control to the delivery aspects of the treatment unit. These systems have the ability to enhance the precision and accuracy of treatment delivery; they serve to verify proper settings on the treatment unit and capture all details of the actual treatment unit parameters in a computer record for each patient.

B. Image-Based Verification Data

The radiation oncologist must establish congruency between the portal images acquired with the treatment unit and approved simulator images or DRRs to assure that the subsequent treatment delivered is properly administered to the designated clinical volumes. Each facility will internally establish its own procedures for initial and ongoing portal imaging throughout the treatment process. Since not all radiation fields can be imaged, the use of BEV images should be considered to verify the correct placement of the treatment plan isocenter relative to the patient anatomy.

C. Dose Delivery Verification by Physical Measurement

At the clinical discretion of the radiation oncologist, the actual radiation doses being received during treatment delivery should be verified by the medical physicist, using appropriate instrumentation and scientific rigor. The results of the measurements should be communicated to the responsible radiation oncologists and incorporated into the patient chart.

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