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ACR PRACTICE PARAMETER FOR THE PERFORMANCE OF BRAIN STEREOTACTIC RADIOSURGERY

PREAMBLE

This document is an educational tool designed to assist practitioners in providing appropriate radiation oncology care for patients. Practice Parameters and Technical Standards are not inflexible rules or requirements of practice and are not intended, nor should they be used, to establish a legal standard of care¹. For these reasons and those set forth below, the American College of Radiology and our collaborating medical specialty societies caution against the use of these documents 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 practitioner in light of all the circumstances presented. Thus, an approach that differs from the guidance in this document, 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 this document when, in the reasonable judgment of the practitioner, such course of action is indicated by the condition of the patient, limitations of available resources, or advances in knowledge or technology subsequent to publication of this document. However, a practitioner who employs an approach substantially different from the guidance in this document 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 the guidance in this document 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 this document is to assist practitioners in achieving this objective.

¹ *Iowa Medical Society and Iowa Society of Anesthesiologists v. Iowa Board of Nursing*, ___ N.W.2d ___ (Iowa 2013) Iowa Supreme Court refuses to find that the *ACR Technical Standard for Management of the Use of Radiation in Fluoroscopic Procedures* (Revised 2008) sets a national standard for who may perform fluoroscopic procedures in light of the standard's stated purpose that ACR standards are educational tools and not intended to establish a legal standard of care. See also, *Stanley v. McCarver*, 63 P.3d 1076 (Ariz. App. 2003) where in a concurring opinion the Court stated that "published standards or guidelines of specialty medical organizations are useful in determining the duty owed or the standard of care applicable in a given situation" even though ACR standards themselves do not establish the standard of care.

I. INTRODUCTION

Stereotactic radiosurgery (SRS) historically referred to targeting intracranial lesions. As various technologies have advanced, SRS has come to refer also to targeting extracranial lesions. For the purpose of this document, SRS is strictly defined as radiation therapy delivered via stereotactic guidance with approximately 1-mm targeting accuracy to intracranial targets in 1 to 5 fractions. For information regarding extracranial target treatments, refer to the [ACR–ASTRO Practice Parameter for the Performance of Stereotactic Body Radiation Therapy](#) [1,2].

SRS has been applied to a number of benign and malignant intracranial conditions [3-12]. The delivery of a high dose of ionizing radiation that conforms to the shape of the target mandates an overall accuracy of approximately 1 mm [13]. Gamma ray photons, x-ray photons, protons, and heavy particles have been used for SRS. SRS can be delivered using a medical linear accelerator, a gamma ray treatment device, or a particle beam accelerator. Despite the variety of stereotactic radiosurgical techniques, many commonalities exist [14-17].

The shape of the beam aperture used with linear accelerator–based systems is usually defined by secondary collimation positioned near the patient to reduce the beam penumbra. A large number of such beams sequentially irradiate the target, typically using a dynamic delivery. Gamma ray treatment devices also position the collimation near the patient’s skin surface to control the penumbra. In this case, numerous fixed gamma ray beams simultaneously irradiate a single point (called the isocenter) within the patient. In the early implementation of either the x-ray or gamma ray treatment approach, all beams were directed to converge to this single point in space so that a dose distribution devoid of surface concavities was produced. More recently, multiple points in space (isocenters) are irradiated to shape the dose distribution to allow for critical structures that surround or invaginate the target.

Robotic, nonisocentric, frameless, stereotactic radiosurgery is a type of SRS treatment consisting of dozens of nonisocentric beams with distinctive quality assurance procedures and continuous target tracking that results in comparable dose conformity to gamma ray treatment devices and reduction in interfraction systematic error when more than 1 fraction is used.

Intensity-modulated radiation therapy (IMRT) is also used for SRS. In this case a single isocenter can be used with off-axis beams created by a multileaf collimator (MLC) so that the equivalent effect obtained with multiple isocenters is achieved. The MLC is often placed as a tertiary device nearer the patient and with narrow leaves to improve penumbra. A related approach that is used for robotic dose delivery does not have a mechanical isocenter as a reference in space for the treatment beams. Like IMRT, this technology also uses a large number of beams that crisscross through the target(s) from different directions that are not necessarily oriented toward any single point in space. As is the case for a number of the other SRS approaches, the robotic delivery approach usually irradiates a subregion of the target with any 1 beam in order to paint the dose for complex, irregularly shaped targets. Stereotactic localization of the lesion uses an appropriate imaging modality to identify a reference point for positioning the individual treatment beams. Traditionally, a rigid frame that included a fiducial system for precisely locating coordinate positions within the frame was attached to the patient’s head. More recently, “frameless” approaches have been introduced. These approaches incorporate image-guided radiation therapy (IGRT) techniques. While being irradiated, the patient may be immobilized when appropriate, and patient and target positioning are verified to ensure accurate treatment delivery.

Imaging, planning, and treatment typically are performed in close temporal proximity. Treatment delivery should be accurate to within approximately 1 mm. This leaves little room for error in the overall process. Strict protocols for quality assurance (QA) must be followed, and multiple checking, preferably repeated by different individuals, is required at critical junctures. SRS requires the participation of a multidisciplinary team, as outlined below.

The practice parameters outlined in this document describe a minimal set of criteria for an SRS quality assurance program. The reader is also referred to other publications regarding quality control for stereotactic radiosurgery and its related procedures [18-34]. In some cases, a stereotactic radiosurgery procedure may incorporate IGRT. The recommendations are described in both the [ACR–ASTRO Practice Parameter for Image-Guided Radiation](#)

[Therapy \(IGRT\)](#) [35,36] and the [ACR–AAPM Technical Standard for Medical Physics Performance Monitoring of Image-Guided Radiation Therapy \(IGRT\)](#) [37].

II. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

See the [ACR–ASTRO Practice Parameter for Radiation Oncology](#), where qualifications, credentialing, professional relationships, and development are outlined [38].

The following are minimal recommendations for staffing levels and staff responsibilities while participating in an SRS procedure. Specific duties may be reassigned where appropriate.

A. Radiation Oncologist

1. Certification in Radiology in Radiation Oncology or Therapeutic Radiology by the American Board of Radiology, the American Osteopathic Board of Radiology, the Royal College of Physicians and Surgeons of Canada, or the Collège des Médecins du Québec, or certification in Radiology by the American Board of Radiology of a physician who confines his/her professional practice to radiation oncology.
and/or
2. Satisfactory completion of a residency program in radiation oncology approved by the Accreditation Council for Graduate Medical Education (ACGME), the Royal College of Physicians and Surgeons of Canada (RCPSC), the Collège des Médecins du Québec, or the American Osteopathic Association (AOA).

If the radiation oncology residency training did not include SRS training and direct clinical experience, then specific training or mentoring in SRS should be obtained prior to performing any radiosurgical procedures. In addition, there may be vendor-specific delivery systems that require additional training.

For stereotactic radiosurgery treatment devices that use sealed isotope sources, the radiation oncologist is the “authorized user” as defined by Nuclear Regulatory Commission (NRC) regulations. The responsibilities of the radiation oncologist must be clearly defined, and irrespective of the treatment device, his or her duties should include the following:

1. Participating in initial treatment decision making and obtaining informed consent
2. Overseeing radiation therapy management of the patient
3. In concert with the neurosurgeon, neuroradiologist, or other physicians, specifying the target volume and relevant critical normal tissues
4. Participating in the iterative process of plan development and approving the final treatment plan and dose prescription
5. Ensuring that patient positioning on the treatment unit is appropriate
6. Attending and directing the radiosurgical treatment delivery according to NRC regulations where appropriate
7. Following the patient and participating in the monitoring of disease control and complications

B. Neurosurgeon

Satisfactory completion of an ACGME-approved neurosurgical residency program.

If the neurosurgical residency training did not include SRS training and direct clinical experience, then specific training or mentoring in SRS should be obtained prior to performing any radiosurgical procedures. In addition, there should be vendor-specific delivery systems that require additional training.

An appropriately trained neurosurgeon is an integral member of the multidisciplinary SRS team and his or her services may include:

1. Participating in initial treatment decision making and obtaining informed consent
2. Placement of stereotactic head frame, where necessary
3. Locating and specifying the target volume and relevant critical normal tissues in concert with the radiation oncologist and neuroradiologist or other physicians
4. Participating in the iterative process of plan development and approving the final treatment plan and dose
5. Ensuring that patient positioning on the treatment unit is appropriate
6. Attending and directing treatment delivery according to NRC regulations where appropriate
7. Following the patient and participating in the monitoring of disease control and management of treatment complications

C. Continuing Medical Education

The radiation oncologist's continuing medical education should be in accordance with the [ACR Practice Parameter for Continuing Medical Education \(CME\)](#) [39].

The physician should also meet the CME requirements as is the standard at the physician's institution.

D. Qualified Medical Physicist

A Qualified Medical Physicist is an individual who is competent to practice independently one or more of the subfields in medical physics. The American College of Radiology considers that certification, continuing education, and experience in the appropriate subfield(s) to demonstrate that an individual is competent to practice one or more of the subfields in medical physics, and to be a Qualified Medical Physicist. The ACR strongly recommends that the individual be certified in the appropriate subfield(s) by the American Board of Radiology (ABR), the Canadian College of Physics in Medicine, or by the American Board of Medical Physics (ABMP).

A Qualified Medical Physicist should meet the [ACR Practice Parameter for Continuing Medical Education \(CME\)](#). (ACR Resolution 17, 1996 – revised in 2012, Resolution 42) [39]

The appropriate subfield of medical physics for this practice parameter is Therapeutic Medical Physics. (Previous medical physics certification categories including Radiological Physics and Therapeutic Radiological Physics are also acceptable.)

If the above training did not include SRS, then specific training or mentoring in SRS should be obtained prior to performing any radiosurgical procedures. There may be vendor-specific delivery systems that require additional training. For stereotactic radiosurgery treatment devices that use sealed isotope sources, the Qualified Medical Physicist is the "Authorized Medical Physicist" as defined by Nuclear Regulatory Commission (NRC) regulations.

The Qualified Medical Physicist is responsible for many technical aspects of radiosurgery and must be available for consultation throughout the entire procedure: imaging, treatment planning, and dose delivery. Those responsibilities must be clearly defined and should include the following:

1. Acceptance testing and commissioning of the radiosurgery system to assure its initial geometric and dosimetric precision and accuracy [13,40]. This includes:
 - a. Localization devices used for accurate determination of target coordinates
 - b. The treatment-planning system [41]
 - c. The radiosurgery external beam delivery unit
 - d. The precision of the imaging device, such as the MRI scanner, used for target and normal tissue identification
2. Implementing and managing a QA program for the radiosurgery system to monitor and assure its proper functioning [42-44]
 - a. The radiosurgery external beam delivery unit
 - b. The treatment-planning system

- c. The precision of the imaging device, such as the MRI scanner, used for target and normal tissue identification
3. Initiating and maintaining a comprehensive QA checklist that acts as a detailed guide to the entire treatment process
4. Directly planning, supervising, or overseeing the treatment-planning process, including verification of dosimetric calculations using monitor unit double-check software
5. Consulting with the radiation oncologist and/or medical dosimetrist to determine the optimal patient plan
6. Using the plan approved by the radiation oncologist and an appropriate patient-specific measurement technique, performing checks of the appropriate beam-delivery parameters
7. Supervising the technical aspects of the beam-delivery process on the treatment unit to assure accurate fulfillment of the prescription of the radiation oncologist

E. Radiation Therapist (when applicable)

A radiation therapist must fulfill state licensing requirements and should have American Registry of Radiologic Technologists (ARRT) certification in radiation therapy.

The responsibilities of the radiation therapist must be clearly defined and may include the following:

1. Preparing the treatment room for the stereotactic radiosurgery procedure
2. Assisting the treatment team with patient positioning/immobilization
3. Operating the treatment unit after the clinical and technical aspects of beam delivery are approved

If the dosimetry training did not include SRS training and direct clinical experience, then specific training or mentoring in SRS should be obtained prior to performing any radiosurgical procedures. In addition, there may be vendor-specific delivery systems that require additional training.

F. Medical Dosimetrist (when applicable)

The responsibilities of the medical dosimetrist or other designated treatment planner must be clearly defined and may include the following:

1. Contour clearly discernible critical normal structures
2. Ensure proper orientation of volumetric patient image data on the radiation therapy treatment planning (RTP) system (from computed tomography and other fused-image data sets)
3. Design and generate the treatment plan under the direction of the radiation oncologist and a Qualified Medical Physicist as required
4. Generate all technical documentation required to implement the treatment plan
5. Be available for the first treatment and assist with verification for subsequent treatments as necessary

If the radiation therapy training did not include SRS training and direct clinical experience, then specific training or mentoring in SRS should be obtained prior to performing any radiosurgical procedures. In addition, there may be vendor-specific delivery systems that require additional training.

III. QUALITY ASSURANCE OF THE TREATMENT UNIT

The mechanical precision and electronic complexity of the treatment-delivery unit require the implementation of and adherence to an ongoing QA program. This program assures that the SRS treatment unit is in compliance with recommendations of the treatment unit manufacturer, with the specified clinical tolerances recommended by the ACR, AAPM, and ASTRO and with applicable regulatory requirements. It is recognized that various test procedures, with equal validity, may be used to ascertain that the treatment-delivery unit is functioning properly and safely. However, it is the responsibility of the Qualified Medical Physicist to determine that the testing

procedure used is equivalent to the recommendations listed above. The test results should be documented, signed by the person doing the testing, and archived.

Important elements of the treatment-delivery unit QA program are:

1. Radiation-beam alignment testing to assure the beam can be correctly aimed at the targeted tissues (see section IV for a complete list of the references describing this test) [40]
2. Calculation of radiation dose per unit time (or per monitor unit) based on physical measurements for the treatment field size at the location of the target

IV. QUALITY CONTROL OF STEREOTACTIC ACCESSORIES

In some cases stereotactic radiosurgery may be an image-guided radiation therapy (IGRT) procedure. As such, all of the recommendations previously stated in the [ACR–ASTRO Practice Parameter for Image-Guided Radiation Therapy \(IGRT\)](#) and the [ACR–AAPM Technical Standard for Medical Physics Performance Monitoring of Image-Guided Radiation Therapy \(IGRT\)](#) [36,37] apply to this treatment modality. Additionally, the AAPM Task Group 142 report [45] was written to extend the information in the previous AAPM Task Group 40 report [46] to specifically include guidelines for SRS. This document calls for daily verification of the correspondence of the treatment and imaging reference coordinate systems. Tolerance limits for this test are also stated in the AAPM Task Group 142 report [45]. For the use of frameless localization systems, a precise description of the required test is given in the practice parameter and technical standard referred to above. For frame-based linear accelerator–based systems, the classic Winston-Lutz test is recommended on a regular basis when applicable [23].

V. QUALITY CONTROL OF IMAGES

Stereotactic radiosurgery is image-based treatment. All salient anatomical features of the SRS patient, both normal and abnormal, are defined with computed tomography (CT), magnetic resonance imaging (MRI), angiography, and/or other applicable imaging modalities. Both high 3-D spatial accuracy and tissue-contrast definition are very important imaging features if one is to utilize SRS to its fullest positional accuracy. When the imager is located in the radiology department and not under direct control of the radiation oncology department, considerable cooperation is required for good quality control specific to the needs of SRS.

The medical images used in SRS are critical to the entire process. They are used for localizing target boundaries as well as generating target coordinates at which the treatment beams are to be aimed (see section IV). They are used for creating an anatomical patient model (virtual patient) for treatment planning, and they contain the morphology required for the treatment plan evaluation and dose calculation. The accuracy and precision required by SRS are to be assured. This assurance issue is addressed in section VI below. However, general consideration should be given to the following issues.

Imaging, whether by CT, MRI, or other applicable modalities, should assure creation of a spatially accurate anatomical patient model for use in the treatment planning process. The chosen image sets should also allow optimal definition of target(s) and normal tissue(s). The chosen imaging modality must be thoroughly investigated before use in the SRS treatment-planning process. Some imaging considerations are the following: partial volume averaging, pixel size, slice thickness, distance between slices, image reformatting for the treatment-planning system, spatial distortion and image warping, motion artifacts, magnetic susceptibility artifacts, and others.

VI. QUALITY ASSURANCE FOR STEREOTACTIC RADIOSURGERY TREATMENT-PLANNING SYSTEMS

Stereotactic radiosurgery treatment-planning systems are very complex. Data 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 precision. The level of complexity is also related to the treatment planning techniques used for SRS. When IMRT techniques are employed, inverse treatment planning methodologies are necessary. However, these same inverse planning approaches are used for

some of the multi-isocenter and nonisocentric treatment approaches. Inverse treatment planning provides computer-selected weights for a very large number of independent treatment beams. As such, it significantly complicates the treatment planning process and requires QA steps that are different than the information provided in some earlier reports on treatment planning QA (AAPM TG-53 report) [41]. Because of the system's complexity, the Qualified Medical Physicist may elect to release the system in stages, and the required validation and verification testing will only reflect the features of the system that are in current clinical use at the facility. Documentation must exist indicating that the Qualified Medical Physicist has authorized the system for clinical use and has established a QA program to monitor the system's performance as it relates to the treatment planning process.

The QA program for SRS involves elements that may be considered to be both dosimetric and nondosimetric. In addition to the IGRT recommendations given in section IV, it is further recommended that the [ACR Practice Parameter for Intensity Modulated Radiation Therapy \(IMRT\)](#) [47,48] be followed when IMRT is used as well as when other techniques that use inverse planning are employed. 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. However, it is the responsibility of the Qualified Medical Physicist to determine that the alternative testing methods are equivalent to the testing procedures presented in the [ACR-ASTRO Practice Parameter for Image-Guided Radiation Therapy \(IGRT\)](#), the [ACR-AAPM Technical Standard for Medical Physics Performance Monitoring of Image-Guided Radiation Therapy \(IGRT\)](#), and the [ACR Practice Parameter for Intensity Modulated Radiation Therapy \(IMRT\)](#) [36,37,48]. Although the AAPM document on QA for treatment planning systems (AAPM TG-53 report) [41]. It is also noted that the commercial manufacturer may recommend specific QA tests to be performed on its planning systems. Although a manufacturer's testing procedure can be very helpful, it is the Qualified Medical Physicist's responsibility to attest that the total QA is complete in that it addresses all modes of possible failure. The references given above should be consulted to make this determination.

A. System Log

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

B. System Data Input Devices

Check the input devices of image-based planning systems for functionality and accuracy. Devices include digitizer tablets, input interfaces for medical imaging data (CT, MRI, angiography, etc), and video digitizers. Assure correct anatomical registration: left, right, anterior, posterior, cephalad, and caudad 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, using digitally reconstructed radiographs or the like, a beam's-eye-view rendering of anatomical structures near the treatment beam isocenter. Assure correct information transfer and appropriate dimensional scaling.

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.

VII. VALIDATION OF THE TECHNIQUE AS IMPLEMENTED

Once the individual components of the SRS planning and treatment technique are commissioned, it is recommended that the QA program include an “operational test” of the SRS system before clinical treatment begins or whenever a plan modification is implemented for a fractionated treatment schedule. This testing should mimic the patient treatment and should use all of the same equipment used for treating the patient. The testing is given the name “patient-specific end-to-end testing” and is described in the [ACR Practice Parameter for Intensity Modulated Radiation Therapy \(IMRT\)](#) [47,48]. An added benefit to this approach is that it provides training for each team member who will participate in the procedure.

VIII. FOLLOW-UP

There should be follow-up of all patients treated and maintenance of appropriate records. The data should be collected in a manner that complies with statutory and regulatory guidelines to protect confidentiality.

IX. DOCUMENTATION

Procedure documentation should be in accordance with the [ACR–ASTRO Practice Parameter for Communication: Radiation Oncology](#) [49].

X. SUMMARY

The quality of a stereotactic radiosurgery program is defined by the strength of the multidisciplinary team involved in the management of the patient, as well as the attention to detail for this highly complex and demanding procedure. Radiosurgery is an involved procedure requiring participants from many disciplines. High spatial accuracy is expected, and there may be time constraints. Numerous systems to achieve optimal accuracy have been developed, and specific training in their use is required. All of the above demands a highly organized and efficient SRS team. Checklists are required to ensure that all aspects of the procedure are completed properly by each team member. The procedure must be appropriately staffed.

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* As of May 2010, all radiation oncology collaborative practice parameters are approved by the ACR Council Steering Committee and the ACR Board of Chancellors and will not go through the ACR Council (ACR Resolution 8, 2010). The effective date is displayed below:

Development Chronology for This Practice Parameter

1997 (Resolution 15)

Revised 2001 (Resolution 22)

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Revised 2011 (CSC/BOC) – Effective August 1, 2011

Amended 2014 (Resolution 39)

Revised 2016 (Resolution 41)