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Revised 2014 (CSC/BOC)*

ACR–ASTRO PRACTICE PARAMETER FOR IMAGE-GUIDED RADIATION THERAPY (IGRT)

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 care. 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.

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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.
INTRODUCTION

This practice parameter was revised collaboratively by the American College of Radiology (ACR) and the American Society for Radiation Oncology (ASTRO).

Image-guided radiation therapy (IGRT) is radiation therapy that employs imaging to maximize accuracy and precision throughout its entire process. This process includes target and normal tissue delineation, radiation delivery, and adaptation of therapy to anatomic and biological changes over time in individual patients. This practice parameter focuses on image-guidance at the time of radiation delivery to ensure its adherence to the planned treatment, referred to as in-room IGRT (hereafter referred to simply as IGRT).

Radiation therapy has long been image-guided, but rapidly evolving imaging technologies have led to substantially greater accuracy and precision of radiation delivery. The need for this improved accuracy and precision has been amplified by ongoing advances in radiation planning and delivery that permit much more conformal dose distributions with sharper dose gradients. Thus IGRT is particularly applicable to highly conformal treatment modalities such as 3-D conformal radiation therapy (3-D CRT), intensity-modulated radiation therapy (IMRT) or proton/hadron therapy [1,2]. In the very specialized case of stereotactic body radiation therapy (SBRT) or stereotactic ablative radiotherapy (SABR) [3], IGRT is considered a necessary and integral component of the entire procedure. Nevertheless, accurate radiation therapy is important even for simple treatments. A broad range of IGRT modalities is now available, and adoption of some form of IGRT is now widespread [4].

Historically, megavoltage “port films” were used as an early form of IGRT, but lacked 3-D visualization of soft tissue targets and often was not applied to every fraction. Such images can indicate the location of a beam isocenter and field outlines reasonably well relative to bony-landmarks. However the tumor being treated is often a mobile soft tissue mass within the body, and patient repositioning based on bony landmarks alone is subject to error. Addressing these uncertainties by to ensure target coverage inevitably irradiates a large volume of normal tissue unnecessarily in the process. With improving soft tissue localization and increasing frequency of imaging and correction, uncertainty is mitigated allowing correspondingly reduced margins and safer administration of curative radiation doses.

In its current state of evolution, IGRT is the use of imaging at the time of treatment delivery to ensure that the location of the target relative to the treatment beams based on a pre-determined plan is reproduced. In most cases, this spatial relationship is determined from a 3-D image, commonly X-ray computed tomography (CT), acquired at the initial simulation.

At the time of treatment delivery, an IGRT modality is employed to determine the location of the target (and often the surrounding normal organs) at some frequency, most often at the beginning, to as often as nearly continuously throughout delivery. The target location may be determined by a range of methods from soft tissue volumetric imaging (eg, kV or MV CT, ultrasound, magnetic resonance imaging) to localization of surrogates such as implanted fiducial markers or external surface markers or features (eg, by planar imaging or fluoroscopy, electromagnetic localization or optical surface imaging). The match or discrepancy between the simulated location and the “live” IGRT measurement at the time of treatment may be determined manually, or in some cases using automated image analysis software. If a discrepancy is found, a correction is applied. Corrections may include repositioning the patient, either through rigid corrections (shift and/or rotation) or readjustment of anatomic relationship (eg, neck and shoulder manipulations for head/neck treatments), or movement or reshaping of the radiation beam to match the target position, or holding the beam until the target falls in the correct location (eg, respiratory gating). In this manner, the treatment will be delivered precisely and accurately according to the treatment plan approved by the radiation oncologist.

This practice parameter addresses qualifications and responsibilities of personnel, clinical IGRT implementation, documentation, quality control and improvement, safety and patient education.
II. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

See the ACR–ASTRO Practice Parameter for Radiation Oncology [5] where qualifications, credentialing, professional relationships and development are outlined. If this certification did not include IGRT, then specific training in IGRT should be obtained before performing any stereotactic procedures.

A. Radiation Oncologist

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

1. The radiation oncologist will manage the overall disease-specific treatment regimen, including: careful evaluation of disease stage; assessment of comorbidities and previous treatments; thorough exploration of various treatment options; ample and understandable discussion with patients regarding the impact of treatment, including benefits and potential harm; knowledgeable conduct of IGRT as outlined below; and prudent follow-up after treatment.

2. The radiation oncologist will recommend and approve: a proper patient positioning method with attention to disease-specific targeting concerns; patient-specific capabilities (eg, arm position in arthritic patients, degree of recumbences in patients with severe chronic obstructive pulmonary disease); patient comfort; stability of setup; and accommodation of devices accounting for organ motion (eg, gating equipment) required for targeting through the IGRT approach.

3. The radiation oncologist will recommend and approve a procedure to account for the intra-treatment motion/variation, and the potential residuals from on-board image registration, localization and correction procedures (eg, breathing movement) for targets that are significantly affected by such motion (eg, lung and liver tumors), as they relate to and integrate with the IGRT approach chosen. This activity may include execution of a variety of methods, including: respiratory gating; tumor tracking; organ motion dampening; or patient-directed methods (eg, active breath holding).

4. It is the radiation oncologist’s responsibility to supervise the patient’s IGRT simulation using appropriate imaging methods (eg, 4-D CT for the case of thorax lesions). The radiation oncologist needs to be aware of the spatial accuracy and precision of the simulation modality and the IGRT delivery. Steps must be taken to ensure that all aspects of simulation, including positioning, immobilization, and accounting for inherent organ motions, are properly carried out using IGRT in a consistent fashion.

5. After the planning images have been acquired, they will be transferred to the treatment planning computer, and the radiation oncologist will contour the outline of the targets of interest. Normal organ structures may be contoured by the physicist or dosimetrist and reviewed by the radiation oncologist. Specific structures that may be used to facilitate IGRT may also be contoured. Various imaging platforms known to be useful for the specific disease treated should be fused into the planning dataset for targeting. Subsequently the radiation oncologist will coordinate the design for the proper planning target volume (PTV) beyond the tumor targets. In addition to these tumor targets, the radiation oncologist will confirm that relevant normal tissues adjacent to and near the targets are contoured, such that dose volume limits are considered. Locating and specifying the target volumes and relevant critical normal tissues will be carried out after consideration of all relevant imaging studies.

6. The radiation oncologist will convey case-specific expectations for prescribing the radiation dose to the target volume and set limits on dose to adjacent normal tissue. It may be required that certain normal tissues be tracked with the IGRT process just as with the tumor target(s). Participating in the iterative process of plan development, the radiation oncologist will approve the final treatment plan in collaboration with a medical physicist and dosimetrist.

7. After obtaining informed consent for the treatment, the radiation oncologist will oversee the actual treatment process. The conduct of all members of the treatment team will be under the supervision of the radiation oncologist. The radiation oncologist will be responsible for deciding what are the acceptable or unacceptable day-to-day variations in the treatment setup or provide the acceptable limit on movements.

8. The radiation oncologist will participate in the quality assurance (QA) processes, such as approval of IGRT assessments, in order to insure that the intended treatment is being delivered in the prescribed fashion.
B. Qualified Medical Physicist

For the qualifications of the Qualified Medical Physicist, see the ACR–AAPM Technical Standard for Medical Physics Performance Monitoring of Image-Guided Radiation Therapy (IGRT) [6].

C. Medical Dosimetrist

The responsibilities of the medical dosimetrist, or otherwise designated treatment planner, should be clearly defined and should include the following:

1. Contouring clearly discernible critical normal structures
2. Ensuring proper orientation of volumetric patient image data from CT and other fused image data sets on the radiation treatment planning system (TPS)
3. Designing and generating the treatment plan under the direction of the radiation oncologist and medical physicist
4. Generating all technical documentation required to implement the IGRT treatment plan
5. Being available for the first treatment and assisting with verification for subsequent treatments as necessary

D. Radiation Therapist

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

1. Understanding the proper use of the patient immobilization/repositioning system and fabricating and understanding the proper use of devices for IGRT
2. Under the supervision of the radiation oncologist and medical physicist, performing initial (planning) simulation of the patient and generating the medical imaging data appropriate for the TPS
3. Implementing the IGRT treatment plan under the supervision of the radiation oncologist and the medical physicist or of the medical dosimetrist under the direction of the medical physicist
4. Acquiring verification images for review by the radiation oncologist
5. Performing evaluation of the stability and ongoing reproducibility of the immobilization/repositioning system and reporting inconsistencies immediately to the radiation oncologist and the medical physicist

E. Continuing Medical Education

Continuing medical education programs should include radiation oncologists, medical physicists, medical dosimetrists and radiation therapists.

The continuing education of the physician and medical physicist should be in accordance with the ACR Practice Parameter for Continuing Medical Education (CME) [7].

F. Staffing Levels

It is the responsibility of an institution to ensure appropriate staffing levels for the support of clinical practice. Staffing levels will be dependent on, among other things, the complexity of treatment and number of new technologies introduced in the clinic and supported for clinical use. Institutions should review their staffing levels before and after new technologies are introduced to ensure quality and safety in their standard of care.

III. IGRT IMPLEMENTATION

Introducing IGRT in clinical application includes comprehensive device operation evaluation, acceptance/commissioning, establishment of routine QA procedures, identification of appropriate disease sites, and creation of disease site and/or technique specific policies/procedures. Enforcement of sufficient initial and ongoing staff training is essential for a safe and efficient IGRT program for targeting and reduction in margin.
As IGRT technology evolves, it is the responsibility of all staff to keep an up-to-date knowledge on the technology and operational details of newly introduced and updated IGRT devices, eg, MRI guidance, more sophisticated fiducial markers with electromagnetic localization and dose tracking, and better imaging techniques with CT, ultrasound and/or camera-based systems [8].

The commissioning/acceptance for these IGRT systems should follow technical recommendations from national professional organizations. IGRT has been routinely implemented for various disease sites, such as: brain; head and neck; lung/thorax; breast; liver; prostate/pelvis; pelvis/gynecologic tumors; spine; and for techniques such as IMRT and SBRT/SRS. The frequency of IGRT usage should be carefully balanced between the needs of the disease/technique, imaging dose and resource requirements.

A. Patient Dose

One of the undeniable benefits of IGRT is the minimization of irradiation of surrounding tissues (organs at risk and other nontarget tissues). However this generally comes at the cost of increased dose due to increased imaging, eg, fluoroscopic imaging or MV cine imaging.

As discussed in the ACR–AAPM Technical Standard for Medical Physics Performance Monitoring of Image-Guided Radiation Therapy (IGRT), imaging parameters and associated doses for different IGRT applications should also be carefully assessed as defined by AAPM TG-75. It is important to have a clear picture about the imaging dose to the whole imaging volume for each IGRT procedure, especially when applied to motion imaging. Note that the imaging volume is much larger than the treatment volumes [9]. IGRT offers the possibility of significantly enhancing the accuracy and precision of radiation therapy methods and is an important advance in terms of margin reduction to better limit the dose to critical structures.

B. Fiducial Markers

When the target is not clearly visible and bony anatomy is not sufficient for adequate target alignment, fiducial markers may be needed.

With megavoltage or kilovoltage X-ray imaging, fiducial markers (either already present or specifically implanted) can be used as surrogates to target areas. Fiducial markers are needed when bony alignment or soft tissue imaging quality is inadequate. The use of implanted fiducial markers in small lung and liver lesions has also enabled real-time tracking using in-room X-rays, particularly improving the accuracy of radiosurgical types of approaches [10,11]. Use of other marker based techniques such as electromagnetic tracking without the acquisition of images is an extension of the use of implanted fiducial markers where only a 3D coordinate is generated to perform the guidance [9,12]. Helical or cone beam CT scans or planar X-ray alignments are also efficient and reliable image guidance methods.

C. Moving Targets

Although the patient may be immobilized relative to an external reference system, the reproducibility of target position will vary due to the motion of internal organs during a given treatment fraction, and also due to the displacement, deformation, or alteration of targets and other tissues between fractions. Both of these factors – intrafraction motion and interfraction motion – must be taken into account when determining the margins around the clinical target volume (CTV) that will define the PTV for a given course of treatment.

Several methods may be employed using IGRT to help assess and account for such target motion, thereby leading to better coverage of the target volume and less exposure of nontarget surrounding normal tissues. Which specific method will be chosen in a given clinical situation will depend on a number of factors, such as: the technologies available; the appropriate imaging technology for the target tissue in question; the relative levels of potential intrafraction and interfraction organ motion; and the deployment of fiducial markers or other tracking devices.
At the time of patient simulation for IGRT, the radiation oncologist must decide how, if at all, both intrafraction and interfraction target motion will be taken into account.

1. **Intrafraction organ motion**
   Several methods may be helpful in determining the extent of potential intrafraction organ motion, including slow or multiple acquisition of CT images; 4-D CT imaging; 4-D positron emission tomography (PET) imaging; and dynamic fluoroscopic imaging of targets or fiducial markers. Assessment of the extent of internal organ motion, including organ excursion, deformation, speed, frequency, and the presence of phase shifts, may be useful in determining which techniques, if any, would be most appropriate to compensate for or control organ motion.

   Several validated forms of motion monitoring and control exist, such as respiratory gating, abdominal compression, tumor tracking, or active breath control. A QA program for the methodology should exist for the procedure, and the clinical tolerances should be predetermined.

2. **Interfraction organ motion**
   Displacement of internal organs may occur, lessening the accuracy and reproducibility of the external reference system at the time of treatment delivery. Methods for compensating for this problem include those that directly image the internal target in question, or those that indirectly image the target through the use of fiducial markers or other tracking devices.

   Direct imaging may include MV radiographs acquired with either radiographic film or an electronic portal imaging device (EPID); planar kV imaging for better differentiation of bony anatomy; ultrasound images; MRI; or CT imaging at the time of treatment delivery for better delineation of soft tissues, either offline, such as the adaptive-radiation-therapy (ART) strategy, or online, such as the in-room cone-beam CT (CBCT) approach.

3. **Planning target volume definition**
   Definition of PTV, in terms of the margins used to expand the CTV, must take into account the interfraction and intrafraction motion characteristics of the target, the mechanical tolerances of the imaging modalities and treatment unit, the associated uncertainties of imaging methods used at the time of simulation and treatment delivery, and the position uncertainties of fiducials or other tracking devices relative to the target in question, as well as any residual immobilization and setup uncertainties.

**Soft Tissue**

Fiducial markers do not provide information about changes in the size and shape of tumors that may occur during a several-week course of radiation therapy [13-17]. Various modalities, including orthogonal imaging, ultrasonography, or MRI/CT, can be used for real-time imaging of the tumor and surrounding tissues during radiation therapy. Using the tumor itself or the surrounding bony anatomy as a surrogate for the target, these techniques incorporate specialized software to determine positional deviations relative to pretreatment CT simulation images and to adjust patient positioning. Applications of various IGRT systems may be tumor-specific and/or site-specific depending not only on the properties of the imaging modality, but also on the type of tumor and its anatomical relation with the surrounding healthy tissues [14].

Conventional CT or CBCT using kilovoltage X-rays (kVCT) can be used to identify most superficial or deep-seated tumors [15,16]. Ultrasonography depicts echogenicity differences between tumors and the surrounding tissues and has been used for several years, mainly for localizing the prostate and other superficial tumors [13]. Ultrasonography may also be used to localize tumors that are found to be isodense or hypodense by unenhanced CT, such as certain tumors in the liver, to obviate the need for contrast-enhanced CT. Recently, megavoltage X-ray CT (MVCT) and in-room MRI have become available for IGRT. Even though MVCT provides images of inferior resolution compared to kVCT, this modality results in better soft tissue imaging in anatomic regions adjacent to metallic prostheses, such as dental fillings in patients with head and neck cancers, and hip prostheses in patients with pelvic tumors [17].
E. Patient Positioning

Patient immobilization could improve accuracy and reproducibility in patient positioning relative to the IGRT device and treatment unit. This can be achieved with the use of immobilization devices and is especially important when the IGRT unit is separate from the treatment unit.

F. Image Acquisition and Imaging Dose

The IGRT system needs to be calibrated to ensure high quality of imaging. The calibration ensures system performance characteristics such as slice thickness uniformity, image contrast, and spatial resolution. The IGRT system must also be accurately aligned to the reference point, which may be the isocenter, of the linear accelerator and registered with the treatment planning system. The software used to identify and correct couch misalignments needs to be assessed for accuracy. Orthogonal images should be obtained and compared to digitally reconstructed radiographs (DRRs) for coincidence when applicable. Each facility needs to develop QA procedures to ensure reliability and reproducibility of the IGRT process.

Imaging dose needs to be carefully evaluated for imaging protocols used. Extensive efforts have been engaged to reduce imaging dose while maintaining image quality when radiation-based IGRT systems are used. At the time of this report, the imaging dose per-image ranges from 0.1 to 0.6 mGy for planar kV imaging, 1 to 3 mGy for MV planar imaging, and 10 to 50 mGy for 3D X-ray imaging. For 4-D image acquisition or tracking with radiation-based systems, accumulated dose from these imaging should be evaluated, e.g., imaging dose from fluoroscopy can reach over 1,000 mGy/hour [8].

G. Treatment Verification

IGRT images need to be reviewed by the physician initially and then periodically to ensure treatment accuracy and reproducibility. Each facility, under the direction of the radiation oncologist, should consider establishing a threshold above which the physician is required to review the patient setup and images before treatment is delivered.

IV. DOCUMENTATION

Reporting should be in accordance with the ACR–ASTRO Practice Parameter for Communication: Radiation Oncology [18]. Successful IGRT implementation includes specification of the type of imaging modality used, its frequency, and the anatomical or fiducial targets employed. As noted above, various verification methodologies of IGRT implementation are in current use, and one or more appropriate methodologies should be incorporated into the patient’s record, as part of documentation of treatment parameters.

V. QUALITY CONTROL AND IMPROVEMENT, SAFETY, AND PATIENT EDUCATION

Policies and procedures related to quality, patient education, infection control, and safety should be developed and implemented in accordance with the ACR Policy on Quality Control and Improvement, Safety, Infection Control, and Patient Education appearing under the heading Position Statement on QC & Improvement, Safety, Infection Control, and Patient Education on the ACR website (http://www.acr.org/guidelines).

IGRT images acquired at time of radiation delivery to ensure its adherence to the planned treatment. The use of IGRT requires additional QA procedures to demonstrate that the treatment and image guidance systems are geometrically related to fall within a stated tolerance. Such QA testing should be designed by the medical physicist and performed daily.

IGRT is a complete process; a complex interaction of different systems must be monitored through a comprehensive QA procedure or set of procedures. This end-to-end test must start with the CT simulation procedure and go through all steps that are required until reaching the final step treatment.
There are different tests that have been developed, however; one of the simplest that can be applied to most IGRT systems uses a plastic block phantom with a few embedded radio-opaque fiducial markers. The position of these markers is determined during CT simulation process. The treatment planning step places a series of small fields that hit each of these markers from at least 2 orthogonal directions, and creates digitally reconstructed radiographs (DRRs) showing the expected position of the markers in the treatment fields. The phantom is then placed on the treatment couch with intentional setup errors. After IGRT correction of the position of the phantom position, the treatment beam is used to irradiate and image the markers. Any detected difference in the position of the markers quantifies the overall error in the system.

A. Fiducial Markers

To serve as adequate surrogates, implanted fiducial markers need to be stable. The stability of intraprostatic fiducials has been well documented [19,20]. However, for lung and liver lesions treated with small margins, fiducial migration needs to be ruled out [10,21]. If more than 1 fiducial marker is implanted, intermarker distances are simple measures of migration. However, if migration is suspected, a CT scan should be obtained to document and reestablish the correlation between the target areas and the implanted fiducial marker. This is particularly important in situations where image interpretation as part of the image registration process during the guidance is minimal, or when an image is not obtained at all (eg, electromagnetic tracking). It is also important to avoid the mistake of interpreting deformation of target areas rather than migration. The larger the magnitude of intermarker distances or the magnitude of bone versus fiducial distances, the more migration is the likely explanation of positional variations.

B. Moving Targets

At the time of patient simulation for IGRT, the radiation oncologist must decide how, if at all, both intrafraction and interfraction target motion will be taken into account.

1. Intrafraction organ motion
   Several methods may be helpful in determining the extent of intrafraction organ motion, including 4-D CT imaging, 4-D PET imaging, and dynamic fluoroscopic imaging of fiducial markers in or proximal to the target volume or other visible surrogate. Assessment of the extent of internal organ motion – including organ excursion, deformation, speed, frequency, and the presence of phase shifts – may be useful in determining which techniques, if any, would be most appropriate to compensate for or control organ motion.

   Several forms of motion monitoring and management exist, such as respiratory gating, abdominal compression, tumor tracking, or active breath control. The QA procedures being used should be relevant to the motion management system that is clinically implemented in their institution.

2. Interfraction organ motion
   Displacement, deformation, or growth or shrinkage of targets or other organs may occur over time, lessening the accuracy and reproducibility of the external reference system over a course of treatment. Methods for compensating for this problem include those that directly image the internal target in question, or those that indirectly image the target through the use of fiducial or other tracking devices.

   Direct imaging at time of treatment may include: MV radiographs acquired with either radiographic film or EPID, planar kV or CT imaging for better delineation of soft tissues and bony anatomy.

   Imaging of fiducial or other tracking devices may be used to provide indirect information regarding the position of the target at the time of treatment delivery, particularly when imaging technologies provide lower resolution or greater uncertainty about the position of the tissues in question.
Deployment of a fiducial marker system, however, requires assessment of potential uncertainties of the position of the fiducials relative to the position of the target, including the potential motion of the fiducial markers relative to the target volume over the entire time period of the treatment course.

Any imaging system, whether direct or indirect, should have an associated QA program with its clinical tolerances explicitly determined and parameter limits clearly defined.

3. Target definition
Definition of PTV, in terms of the margins used to expand the CTV, must take into account several constraints including, but not limited to: the interfraction and intrafraction motion characteristics of the target; the mechanical tolerances of the imaging modalities and treatment unit; the associated uncertainties of imaging methods used at the time of simulation and treatment delivery; and the position uncertainties of fiducial markers or other tracking devices relative to the target in question, as well as any residual immobilization and setup uncertainties.

C. Soft Tissues
Since IGRT is used in conjunction with highly conformal radiotherapy techniques, the accurate implementation of IGRT technologies and workflow are extremely important in ensuring adequate tumor coverage and avoidance of organs at risk. Moreover, IGRT may detect changes in the shape and/or size of tumors, which may necessitate modifications of the initial radiation dose distribution. The radiation oncologist must review the IGRT images and may need to revise the initial plan according to the individual patient’s clinical situation.

Verification of accuracy in treatment delivery requires understanding of the individual IGRT system and the ability to interpret the IGRT images in relation to those acquired at treatment planning. This process should include verification of patient positioning and documentation of the required couch shifts. It should result in congruence between portals, CT, or ultrasonographic images and DRRs created from the planning CT or other initial imaging. IGRT images should be reviewed and approved by the radiation oncologist to ensure that the radiation doses will be delivered to the designated clinical volumes as planned.

Each facility should develop its own clinical guidelines for the initial and ongoing implementation and documentation of IGRT throughout a course of radiation treatment. In particular, consideration should be given in establishing a threshold of couch positioning changes that requires the radiation oncologist’s involvement before the treatment is delivered, to verify the patient/tumor positioning and assess whether any couch adjustments are warranted. IGRT should be used in combination with other QA processes such as those employed to ensure proper gantry, jaw, and multileaf collimator settings or those used to verify IMRT plans.

The Medical Director of Radiation Oncology is responsible for ensuring that there is an appropriate continuing quality improvement (CQI) program as described in the ACR–ASTRO Practice Parameter for Radiation Oncology and the ACR Technical Standard for the Performance of Radiation Oncology Physics for External Beam Therapy [5,22]. It is the director’s responsibility to respond to identified problems, see that the actions are taken, and evaluate the effectiveness of the actions.

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