Image Guided Radiation Therapy Guidelines:
ATC QA subcommittee report
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This document represents work in progress within the Advanced Technology QA Consortium (ATC). Comments are welcome and should be directed to Marcia Urie, PhD or David Followill, PhD, co-chairs of the ATC Credentialing and QA Committee.

Introduction

Image guided radiation therapy (IGRT) is defined by this subcommittee as external beam radiation therapy with positional verification using imaging prior to each treatment fraction. Some imaging procedures can result in an additional significant dose to the patient, and are specifically excluded from consideration in these guidelines. For example, radiographic imaging each day of treatment is not considered to be an acceptable IGRT procedure. The definition of IGRT for this guideline is for a complete process that extends from the step of imaging a patient at the time of CT-simulation through the step of imaging the patient again at the treatment unit. This process includes the procedures for manually or automatically comparing these two datasets to determine a series of mechanical movements of the patient support system to correct for detected positioning errors. Although manual matching of the image information is acceptable, a computerized system for calculating shifts of the patient support system is a requirement for clinical trial IGRT. The possible variations in the way each step in this complex procedure can be handled results in a large number of different overall IGRT approaches. For example, orthogonal 2D images can be obtained each day to verify or correct the patient's position, or a full volume image dataset can be used. Techniques such as the use of ultrasound or fiducial markers placed on the patient's skin are not currently included in these guidelines.

At this point in time the majority of commercial systems for image registration are rigid-body based. Some academic centers have deformable registration available, but this approach is not included in these guidelines at this time for clinical trials. It is anticipated that these academic centers will assist in implementing this technology in the near future, and the guidelines will be amended when additional information is available. An example of the use of deformable technology is the use of image fusion for datasets that play a secondary role in the IGRT process. For example, deforming a Magnetic Resonance Imaging (MRI) study to transfer information from a study that was not performed with the patient in the treatment position to a CT-simulation study is considered to be an acceptable routinely-used IGRT procedure. These guidelines do not include a discussion of this step in the IGRT procedure.

Protocols are currently being developed that prescribe tight margins in order to spare normal tissues, often with high doses per fraction. To assure precise delivery of the dose, these protocols are including requirements for confirmation of correct patient/target positioning prior to each fraction. Many technologies are commercially available for this verification. These technologies are complex and integrated in the computer networks of the accelerators. They require training and expertise to use appropriately. *This committee believes that for multi-institutional clinical trials, authentication of the*

proper implementation of the IGRT by each participating institution is required. Below are the guidelines recommended by the Advanced Technology Consortium (ATC) for credentialing of institutions to participate in protocols requiring IGRT. It is strongly encouraged that the credentialing for IGRT be the same among all cooperative groups and protocols, such that an institution will be eligible to participate in all NCI sponsored clinical trials utilizing IGRT once it has been credentialed for IGRT.

IGRT Guidelines:

1. The treatment planning must be imaged (CT) based with the capability of transferring the treatment data to a verify/record system.

2. The treatment unit must have "on-board" imaging (which includes the placement of a diagnostic CT unit in the treatment room) that has a fixed frame-of-reference with an origin that is precisely related to the frame-of-reference origin for the treatment device.

3. The treatment unit must have software that allows registration of the desired and actual images and calculates required shifts.

4. A cooperative group protocol that uses IGRT should provide detailed instructions on how the IGRT system is to be used.
   a. Anatomy to include in the image registration process
   b. Type fusion algorithm to be used (e.g., bone vs. soft tissue or gray scale)
   c. Type of IGRT allowed (e.g., full volume imaging, orthogonal 2D matching)
   d. For protocols where IGRT is part of the study question, details of imaging procedure should be requested (e.g., full or half scan, bowtie, grid, etc.) for documentation

5. The protocol should request recording the dose resulting from the imaging procedures.
   a. Imaging dose should not be included in the therapy dose unless specifically requested by the protocol.

6. The institution must satisfactorily complete the IGRT Questionnaire (see Appendix I)

7. A Benchmark test must be performed to demonstrate correspondence of the treatment unit frame-of-reference origin (the treatment unit isocenter for most treatment devices) and the imaging system frame-of-reference origin. See the next subsection and Appendix II for a description of the *isocenter coincidence* test. Appendix III describes the procedures for completing the *isocenter coincidence* test.

The Isocenter Coincidence Test

The use of image guidance to more accurately position treatment fields is a major component of stereotactic radiosurgery (SRS) as a special procedure radiation therapy treatment. The significant improvement in the accuracy of this new targeting approach was obtained through a QA procedure called the Winston-Lutz test (needs reference). More recently, there has been a transition from rigidly mounted head frames that fix to a patient's cranium to a frameless approach that relies on the imaging being performed with the patient in the treatment position on the patient position system at the time of treatment. During this transition, it is not clear that the strict reliance on a Winston-Lutz type test has been maintained as part of the required QA. Although this test is still considered essential for SRS treatments, it has not been universally applied to frameless IGRT treatments for stereotactic radiation therapy (SRT), stereotactic body radiation therapy (SBRT), 3D-CRT or IMRT. At least one recent QA document (AAPM Task Group 142) has emphasized the importance of periodically guaranteeing that the two separate frames-of-reference (imaging system and treatment system) properly communicate. That is, that the transformation from one origin to the other frame-of-reference origin is correct so that calculated shifts accurately adjust the position of treatment fields relative to a patient's anatomy.

Although the "modified" Winston-Lutz QA procedure to be used for frameless IGRT systems is identified in the AAPM Task Group 142 report as the *isocenter coincidence* test, the exact method for this testing is not described. Like the original Winston-Lutz test, the *isocenter coincidence* test is an end-to-end QA procedure in that it must start with the planning imaging process and end with the treatment step. In this case the last step is the use of the treatment beam to both irradiate and image markers using the treatment beam.

The *isocenter coincidence* test should also verify the ability of 6-degree-of-freedom to correct for rotational errors in the patient's position. This is accomplished by targeting off-axis markers in addition to markers placed at the center of the frame-of-reference.

Recommendations for guaranteeing acceptable communication between the IGRT and imaging systems

A major contribution of the ATC is to implement a guideline that requires appropriate testing for each treatment unit equipped with IGRT that will be used for NCI sponsored protocols. To accomplish this goal, the recommendations of the ATC Subcommittee on IGRT are as follows:
1) clearly describe the required test for verifying *isocenter coincidence*,
2) make this test a one-time requirement for each treatment unit equipped with IGRT, and have institutions forward the results to the protocol group for review,
3) Provide documentation that this test is performed, without protocol group review of the results, with the frequency recommended in the AAPM TG 142 report
4) when a protocol allows the use of IGRT to correct for rotational errors, the *isocenter coincidence* test must be extended to verify the accuracy of this mathematical transformation, and
5) .

Appendix I : FACILITY QUESTIONNAIRE   -   PART II (IGRT)

If you have credentialed previously for any protocols involving IMRT or IGRT, do not fill in this part of the form until you have updated informatio currently on record. Please contact the Image-Guided Therapy QA Center (ITC) to obtain a copy of that information. IGRT is defined here to inclu only those procedures where the imaging technique checked below is used in combination with some form of computer-assisted manual or automati registration with the image information obtained during the patient's planning CT procedure. The standard use of MV EPID images as a visual comparison to DRRs does not fall under this definition. Also, the use of silver halide film radiographs alone is not accepted under this definition of IGRT. Part I questionnaire should be reviewed and updated before completing this form.

Table 1 - List the different types of IGRT systems you have in your department.

ID #	Vendor & Type	Treatment unit identification # column of Table I	Enter the let footnote 1 tl describes yo system	How is the i registration accomplishe footnote 2 a letter here)	How is the succ image registrati verified? (See f and enter letter	Do any of these u robotic couches c correcting angula deviations? (yes c	How often do y the position of t imaging system isocenter? (See 4 and enter lette	RTOG Protocol identif (enter one or more #s i space below)
1								
2								
3								
4								

FOOTNOTES
  1 - a. kV cone-beam (2D or 3D match),   b. Dual kV imaging panels (eg, ExacTrac, Cyberknife),   c. Helical MV tomography,   d. MV cone-beam
      e. In-room diagnostic CT scanner,   f. kV or MV Stereoscopic images using EPID,
      g. other (describe)_____
  2. a. automatic registration,   b. manual click drag and rotate,   c. other (describe) _____
  3. a. split screen, b. spy glass, c. color fade d. other (describe)_____
  4. a. each day, b. each week, c. each month, d. yearly, e. not done, f. other _____

Table 2 - How do you use IGRT for different disease sites?

	Head and Neck	Prostate	Thorax	Upper GI	GYN	Other*
System or systems used for each site. Use ID # designation from first column of Table 1.						
Number of patients where this technology was used in the last 12 months						
IGRT frequency (enter letter from footnote 1)						
Do you perform a second IG study after patient position is adjusted? (yes or no)						
Estimate the patient dose in cGy due to imaging. (see footnote2)						
What tolerance levels in mm are used for x, y and z adjustments of the patient position?						
What are your rotational tolerances before repositioning the patient?						
If the system has a robotic couch, what are your tolerance levels for rotational corrections?						
Who approves these changes at the time of treatment? (see footnote 3)						
Are fiducial markers used for this disease site? (enter yes or no)						

*Please write the site name under the word "other"

FOOTNOTES

1. – a. IG is used each fraction, b. IG is used for the first five fractions and once each week thereafter, c. other _____

2. – This should be the dose in cGy due to a single IG procedure. For example, if orthogonal images are used for IGRT this number should be the combined dose for the two images. If a second imaging procedure is used to check the patient's position, this amount should NOT be included.

3. - a. therapist, b. radiation oncologist, c. physicist, d. other _____

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Appendix II

Modern IGRT techniques are different than earlier techniques that use imaging for patient setup. This statement applies to both traditional verification imaging and to SRS treatments that use a rigidly attached head frame to position the patient for both treatment planning and treatment. In comparison, modern IGRT incorporates specialized computer techniques to register image datasets to precisely monitor and/or correct setup deviations.   As a result of this major difference, IGRT requires a modification of traditional QA procedures. This, in turn, requires an additional step that demonstrates that the treatment and image guidance systems accurately communicate to fall within stated tolerance. The complete image guidance process includes the imaging (CT), the treatment-planning that assigns field positions and creates the images that are used to verify the match that is achieved through the image registration step. This appendix describes the *isocenter coincidence* test that guarantees acceptable communication and information transfer for all aspects of the process that extends from treatment plan imaging, planning, to treatment.

The *isocenter coincidence* test can be thought of as a simple 2-step process. The first step uses the CT simulation process to reproducibly position markers in space relative to, for example, the surface of a phantom in which they are embedded. The second step uses the IGRT system to reposition the markers relative to the treatment unit frame-of-reference so that they can be irradiated and imaged with the treatment beam. The communication between these 2 steps involves the treatment planning system and the data transfer from this system to the treatment machine including its IGRT component. Any detected difference in the position of the markers relative to the planned treatment beams (usually on orthogonal pair) quantifies the overall error in the system.

There are different ways of accomplishing the test described above and two examples are included in this guideline.

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Appendix III

Image Guided - Adaptive Radiation Therapy

Positional Verification   Benchmark

Purpose:

      This benchmark is a sample case used to validate that your process and system for image guided adaptive radiotherapy has acceptable accuracy for participation in clinical trials. The aim is to demonstrate the precision and accuracy of your system, from CT scan to treatment planning to treatment delivery with image guided adaptive positioning. There are two options to perform this benchmark. You may chose either Method 1 using your solid/plastic water calibration equipment or Method 2 using your diode/ion chamber array. You need do only Method 1 or Method 2.

Method 1:   Solid Water (see below)

      Using the water-equivalent slab calibration equipment in your physics/radiation oncology department, you will CT scan a phantom, transfer the CT scan to your treatment planning system, create a beam with isocenter at a specific point, set up the phantom for treatment delivery, adjust the position of the phantom according to your adaptive- image guided system, and verify that the adjustment is correct.

Method 2: diode/ion chamber array (see Page 5)

      Using the diode/ion chamber array available in your physics/radiation oncology department, you will CT scan the array, transfer the CT scan to your treatment planning system, create a beam with isocenter at a specific point, set up the phantom for treatment delivery, adjust the position of the array according to your adaptive- image guided system, and verify that the adjustment is correct.

Details for Method 1:

      a) Create a phantom approximately 10 cm thick using your "water equivalent" slabs routinely used for linac QA. These may be "plastic water", 'virtual water", or comparable

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material.   Place a slab with a cavity to accommodate an ionization chamber on the top of the slab.

Most of these slabs are 2 cm thick, with the cavity center at midplane (i.e. 1 cm from the surface). If available, use a slab with the cavity to accommodate a 0.6 cc Farmer type chamber. A smaller cavity for a smaller chamber may be used if a 0.6 cc chamber slab is not available.

b) Obtain a CT scan of this phantom. Align the cavity pathway perpendicular to the

<div style="border:1px solid black; display:inline-block; padding:4px">Phantom positioned for CT scan</div>

travel of the table so that the entire length of the cavity appears in an axial slice. Obtain fine ($\leq$ 3mm thick slices) CT scan of the phantom that extends at least 5 cm on either side of the cavity.

Make sure that the center of the ion chamber cavity is indicated on the external slab. (This is usually scribed by the manufacturer or already marked by the physicist).

c) Transfer the CT scan to your treatment planning system. Carefully mark the tip of the air chamber (as a mark, structure, reference point, or whatever your planning system allows) as a single point marker. Create another marker point in the center of the air cavity and 10 cm toward the entrance from the tip.


d) Create a field with isocenter at the tip of the air cavity (the same point as your marker point). Make it a 22 cm (in the direction of the chamber cavity) x 10 cm field.

e) Transfer the setup information to your treatment delivery system as you would for a patient.

f) Take the slab with the air cavity to the treatment room and place it on the treatment table. Adjust the isocenter height to the center of the air cavity. Adjust the scribe of the chamber slab to approximately the corner of a 3 x 3 cm light field. The exact location and rotation are not critical.
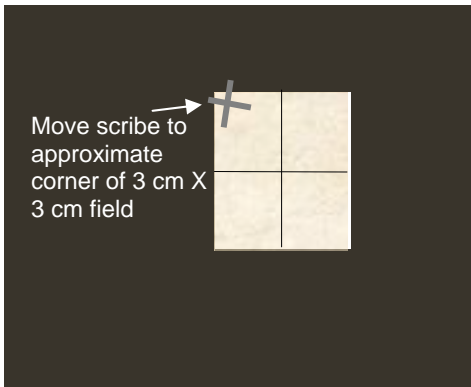
Slab with air cavity positioned at isocenter height ready for position adjustment techniques.

Move scribe to approximate corner of 3 cm X 3 cm field

Example of position of scribe in light field before registration.

g) Obtain a radiographic image of the positioning of the ion chamber cavity with respect to the central axis of the field using portal imaging, film, MV CT, KV on-board, or other system used for positional adaptation.
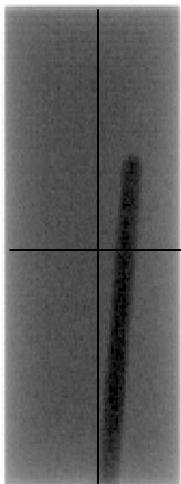

EPID image of initial positioning of air cavity slab

MV cone beam image of initial positioning of air cavity slab

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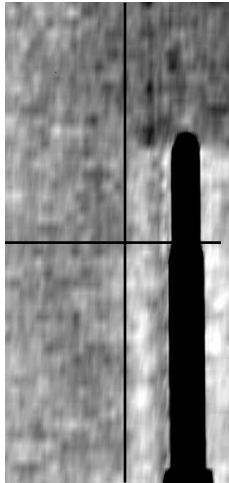
h) Using the techniques and software you use for image-guided adaptive therapy position adjustment, correct the position of the tip of the air cavity, i.e. the point you marked on the planning system, to isocenter and the adjust the rotation of the slab to that planned. Print out the shifts and rotation performed.

h) Obtain an image demonstrating the position of the air cavity tip following this movement (i.e. demonstrating correct positioning).
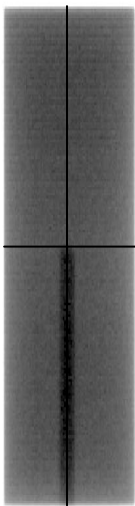
EPID image following image registration, computerized calculation of required shifts and rotation, and movement to the correctly aligned position.	Cone beam MV image following registration, computerized calculation of required shifts and rotation, and movement to the correctly aligned position.
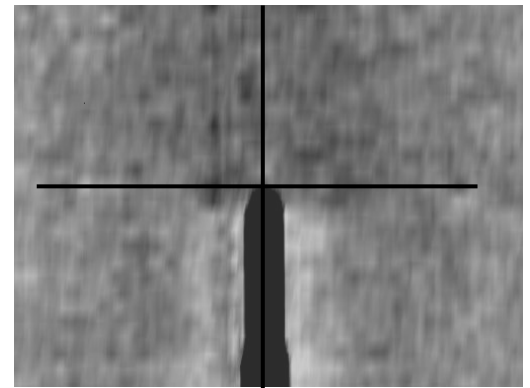
Results to be submitted:

1). Complete the questionnaire in Appendix I.

2). Axial CT slices through the center of the air cavity.

3) Images from the planning system showing the point marked to be isocenter and the field.

4) Image of the original position of the air cavity on the treatment table (prior to adaptive therapy adjustment).

5) Output of the adaptive therapy software indicating required shifts to the correct positioning.

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6) Image of the position of the air cavity on the treatment table after position adjustment.

Details for Method 2:

a) CT scan your diode array device (e.g. MapCheck) or ion chamber array device (e.g. MatrixX). Use thin ($\leq$ 3 mm thick) slices.


CT scan of MatrixX array

b) Transfer the CT scan to your treatment planning system.   Select a chamber (diode) approximately 3 cm (x and y) from center and at the depth of the detectors to be isocenter. Create a 10 x 10 AP field to treat with this isocenter.
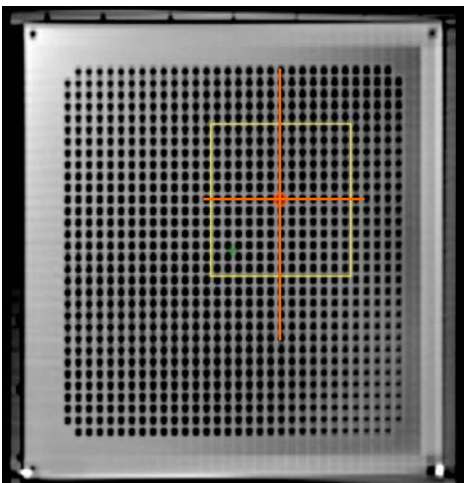
Beam's Eye View of a 10 X 10 cm field with isocenter indicated by the crosshairs.

c) Transfer the setup information to your treatment delivery system as you would for a patient.

d) Take the array device to the treatment room and align it on the treatment table. Adjust the isocenter height to the center of the detectors. Adjust the x and y positions so that the crosshair is approximately in the center of the device.   The exact location and rotation are not critical.

e) Obtain a radiographic image of the positioning of the ion chamber cavity with respect to the central axis of the field using portal imaging, film, MV CT, KV CT or other system used for positional adaptation.
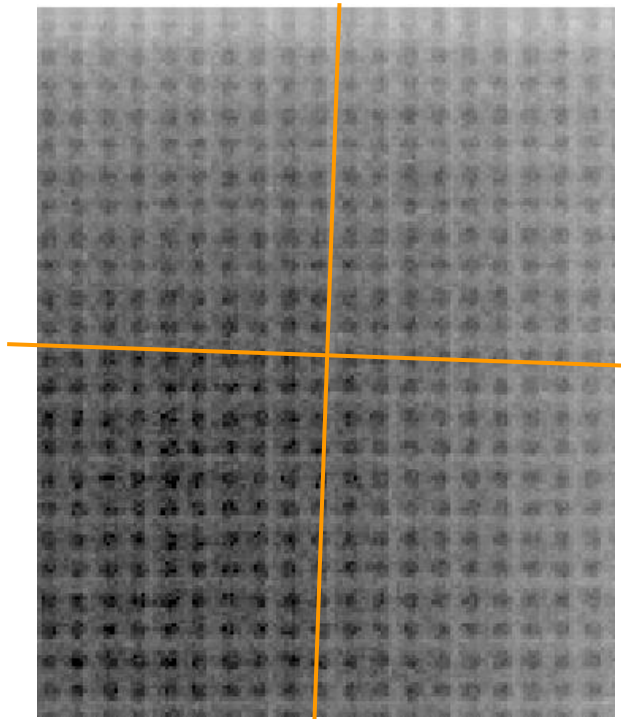
EPID image of initial positioning of array on the treatment table.

f) Using the techniques and software you use for image-guided adaptive therapy position adjustment, correct the position of the array device to the isocenter you planned.

g) Print out the adjustments as calculated by the registration software.

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g) Obtain an image demonstrating the position of the isocenter with respect to the chamber or diode array.
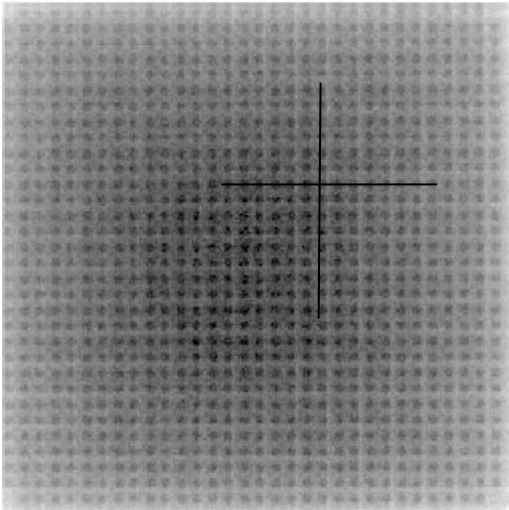
Results to be submitted:

1). Complete the questionnaire in Appendix I.

2). CT slices showing the array.

3) Images from the planning system showing the point marked to be isocenter and the treatment field.

4) Image of the original position of the array device on the treatment table (prior to adaptive therapy adjustment).

5) Output of the adaptive therapy software indicating shifts required for correct positioning.

6) Image of the position of the array device on the treatment table after position adjustment.

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