ACCEPTANCE TESTING OF IMAGING SYSTEMS, REVIEW OF RECOMMENDATIONS

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Joint ICTP-IAEA Workshop on Radiation Protection in Image-Guided Radiotherapy (IGRT)
Trieste, Italy, 7-11 October 2024

Disclosures

- Nothing to disclose
- Any reference to commercial products does not imply endorsement

Outline

- Introduction
- Acceptance Testing and Commissioning of:
  - X-Ray Based Systems
  - Surface Guidance Systems
  - MR Guidance Systems
- Summary and Conclusions

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Introduction

- Acceptance testing of imaging systems is usually part of the acceptance of the entire radiotherapy unit
- This usually follows manufacturer procedures and recommendations
- Measured quantities often become “baseline” values for future quality assurance tasks

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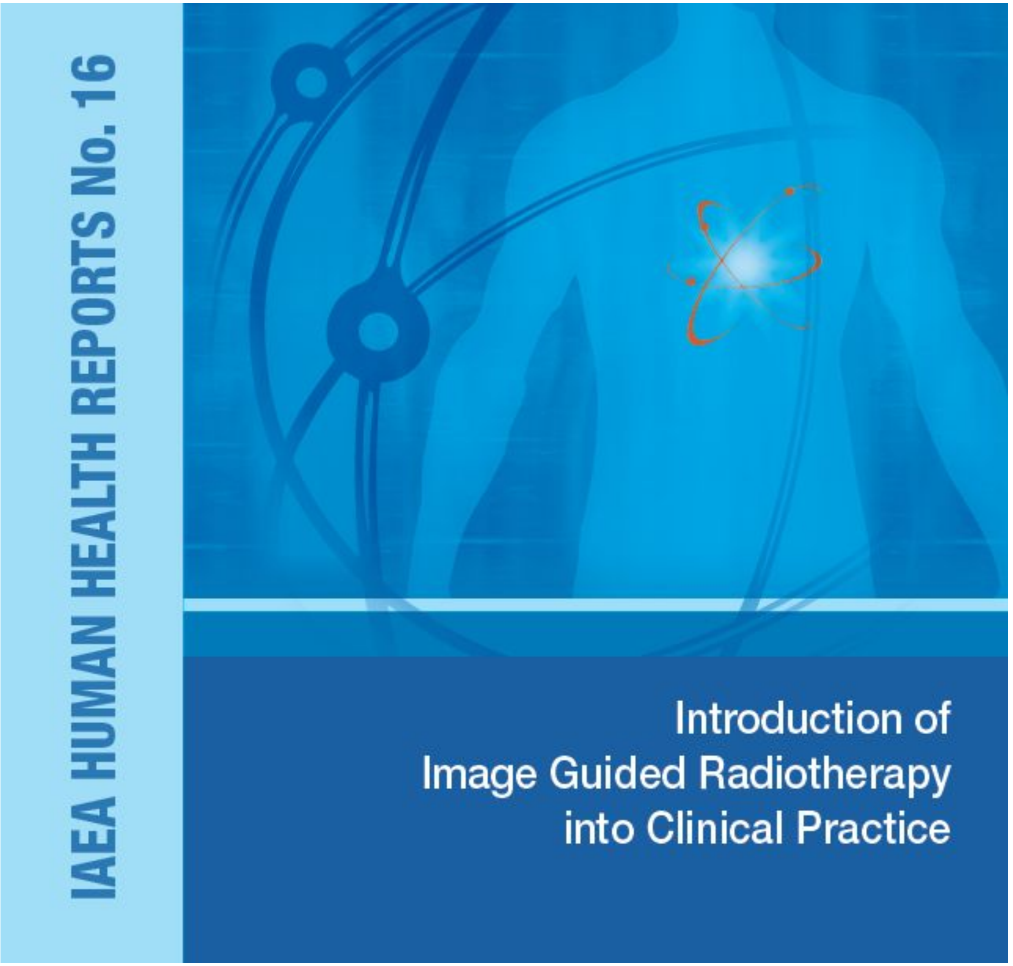

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RADIATION ONCOLOGY PHYSICS

JOURNAL OF APPLIED CLINICAL MEDICAL PHYSICS

AAPM MEDICAL PHYSICS PRACTICE GUIDELINE 2.b.: Commissioning and quality assurance of X-ray-based image-guided radiotherapy systems

Steven P. McCullough[1] | Hassaan Alkhatib[2] | Kyle J. Antes[3] | Sarah Castillo[4] | Jonas D. Fontenot[5] | Andrew R Jensen[6] | Jason Matney[7] | Arthur J. Olch[8,9]

Quality assurance of cone-beam CT for radiotherapy

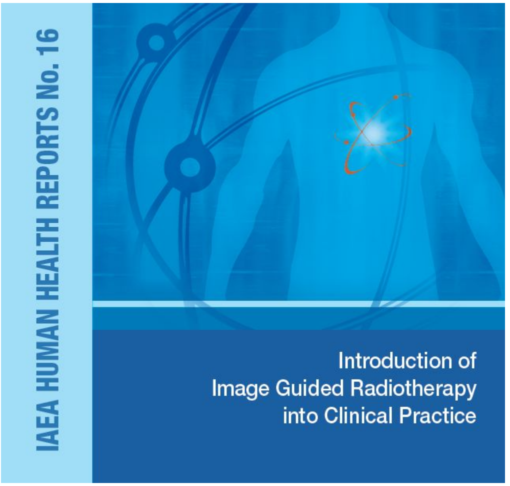
NEDERLANDSE COMMISSIE VOOR STRALINGSDOSIMETRIE

Report 32 of the Netherlands Commission on Radiation Dosimetry

March 2019

IAEA Report No.16

- Recommendations on starting an IGRT program:
  - Allow sufficient time for acceptance and commissioning
  - Allow sufficient time for training
  - Develop necessary guidelines and policies and procedures
  - Develop a comprehensive quality assurance program
  - …



Medical Physicist Knowledge

- An understanding of:
  - X ray imaging procedures, with particular emphasis on CT;
  - Other imaging modalities, including but not limited to ultrasound and magnetic resonance imaging;
  - Image quality parameters (e.g. modulation transfer function, signal to noise and spatial resolution) and the tools to assess them;
  - Common artefacts in CT and CBCT (e.g. motion, metal artefacts and ring artefacts);

Medical Physicist Knowledge

- An understanding of:
  - Radiation dose delivered in diagnostic procedures, the quantities used to determine it, and the tools required to assess the dose;
  - Cross-sectional anatomy of common radiotherapy treatment sites;
  - Organ motion as relevant to radiotherapy treatment;

Medical Physicist Knowledge

- An understanding of:
  - Quality control of image quality, including geometric accuracy and imaging dose;
  - Commissioning and acceptance of diagnostic imaging equipment, including CT and CBCT;
  - Image formats, including DICOM;
  - Image handling, including contrast enhancement and image matching

Acceptance Testing and Commissioning

- Acceptance testing is the process of verifying that the purchased and installed equipment fulfils the specifications agreed upon in the contract;
- Acceptance testing is often performed using test equipment and tools provided by the manufacturer;
- It may also include reference images provided by the manufacturer

Acceptance Testing and Commissioning

- Commissioning is the process of testing the system for the intended clinical application within the department;
- The commissioning activities not only depend on the actual IGRT equipment used, but also on the intended use and all other equipment (hardware and software) the IGRT tools are interfaced with

AAPM MPPG 2.b.-Commissioning Tasks

- Customer acceptance procedures
- TPS integration
- OIS integration
- Establish routine QA baselines
- QA documentation

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Commissioning Tasks

- Customer acceptance procedures
  - The physicist provides direct supervision during the acceptance procedure, ensuring that the imaging equipment satisfies performance requirements stated by the manufacturer. In some cases, measurements completed as part of the acceptance procedures may also serve as components in establishing the routine quality assurance program.

Commissioning Tasks

- TPS configuration and connectivity
  - Digitally reconstructed radiographs (DRR) of test objects in various orientations are created with the treatment planning system and transferred (typically via DICOM interface) to the image guidance system. Proper display of the DRR image within the image guidance software must be ensured.

Commissioning Tasks

- TPS configuration and connectivity
  - Reference CT image sets of test objects in various orientations are imported into the treatment planning system (TPS). Contours are added and the images and structures are transferred (typically via DICOM interface) to the image guidance system. Proper display of the reference CT images and structures within the image guidance software must be ensured.

Commissioning Tasks

- OIS integration
  - Setup fields created for a test patient within the oncology information system (i.e. Aria, Mosaiq, …) are properly recognized by the imaging hardware and software when loaded. Acquired images are then assigned to the correct patient, if applicable.

Commissioning Tasks

- OIS integration
  - Volumetric IGRT image setup fields created for a test patient within the oncology information system are properly loaded and recognized by the imaging hardware and software. Acquired images are assigned to the correct patient and are available for registration with the reference 3D image set.

Commissioning Tasks

- Establish routine QA baselines
  - Measurements taken at the time of IGRT system commissioning, which characterizes IGRT system performance will serve as reference values for the routine QA program.
    - <u>More on this in the next presentation</u>

Commissioning Tasks

- QA documentation
  - All acceptance and commissioning procedures and results must be contained within a formal report. Furthermore, a formal policy for routine IGRT QA programs and procedures for performing routine QA measurements must be developed.

NCS Report 32-Commissioning Tasks

- Geometric tests
- X-ray output measurements
- Image quality tests
- Safety tasks

Quality assurance of cone-beam CT for radiotherapy

NEDERLANDSE COMMISSIE VOOR STRALINGSDOSIMETRIE

Report 32 of the Netherlands Commission on Radiation Dosimetry
March 2019

Geometric Tests

- The coincidence of the kV and MV beamlines is essential for high precision IGRT
- This is typically achieved by aligning a ball-bearing phantom at the isocenter and acquiring a CBCT

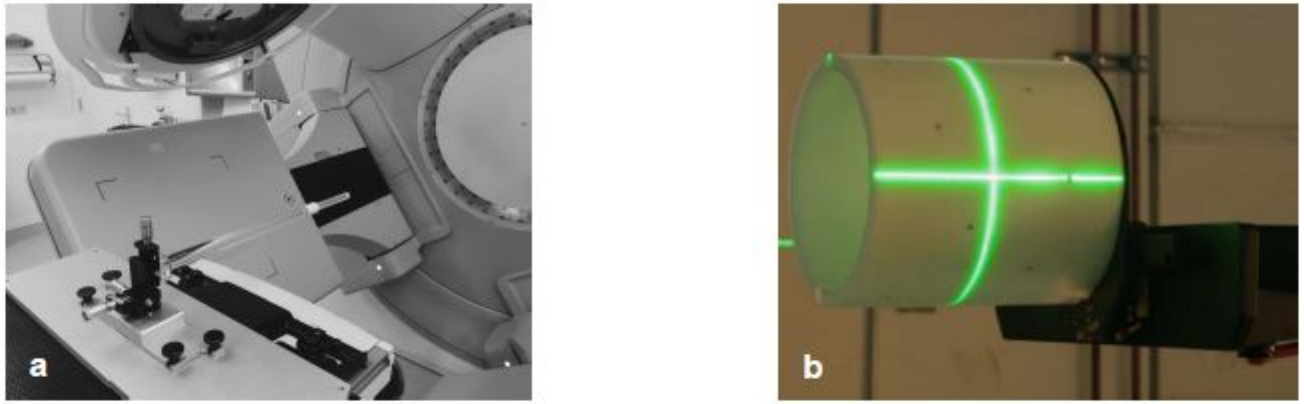

Figure 3.1. (a) Elekta ball-bearing phantom, (b) Varian IsoCal phantom.

Geometric Tests

- The apparent travel of the ball-bearing on the projection images, used for reconstruction of volumetric datasets, provides a measurement of the components' flexing as a function of the gantry angle (flexmap)

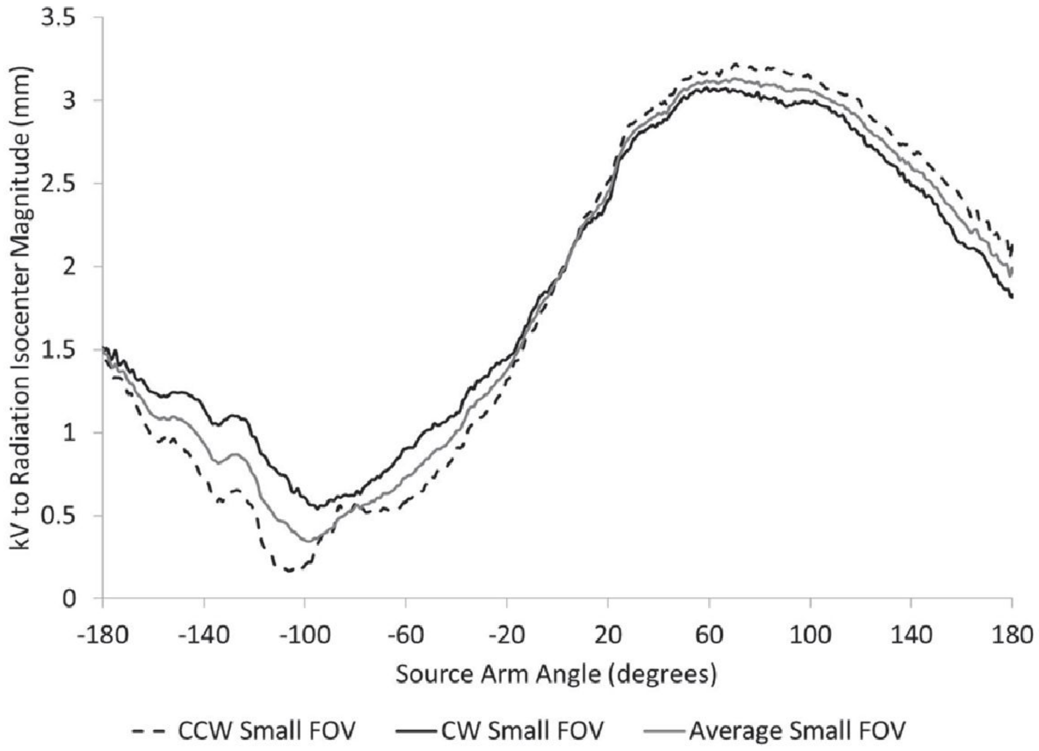

Image from AAPM 2018 Summer School proceedings, Chapter 4

Geometric Tests

- Correction for these flex motions is done digitally by the reconstruction software or by adjusting the robotic imaging arm

X-Ray Output Measurements

- X-Ray tube QA: Kilovoltage peak accuracy, HVL determination, tube current accuracy
  - Not commonly determined unless required by regulation
- Radiation dose
  - Commonly measured, methods described in the next presentation

Image Quality Tests

- Various image quality aspects evaluated
  - Spatial resolution
  - Low contrast detectability
  - Image uniformity
  - CT numbers
  - Geometric features (scaling, distortions, …)

Safety Tasks

- Mechanical safety interlocks (touch guards, laser guards)
- Warning lights
- X-ray tube radiation leakage
  - Not commonly done unless required by regulation

Other X-Ray Based Systems

- TomoTherapy/Radixact
- CyberKnife
- Halcyon
- …

System-specific recommendations available in
various reports and/or papers

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SGRT Commissioning-AAPM TG 302

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AAPM SCIENTIFIC REPORT

MEDICAL PHYSICS

AAPM task group report 302: Surface-guided radiotherapy

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TABLE 4 Summary of tests outlined in Section III.B. of AAPM's Task Group 147 for commissioning an SGRT system

Test category	Description	Tolerance
Interface with peripheral systems	• Integrity of data transferred from CT simulation, TPS, R&V systems for a variety of patient orientations to test coordinate systems • Confirm isocenter coordinate transfers accurately into SGRT system using a phantom • Beam delivery functionality (with/without gating) • CT triggering functionality for prospective/retrospective gating • Couch shift functionality	Passing/functional
Spatial drift and reproducibility	• Characterize warm-up period necessary prior to clinical use • Localization accuracy for a 90-min period or until stability is achieved[48]	• NA • ≤2 mm over 1 h; ≤1 mm after stabilizing
Static localization accuracy	• Localization accuracy of offset phantom over a reasonable clinical range (i.e., ±100 mm range from isocenter)	≤2 mm ≤1 mm for SRS/SBRT
Dynamic localization accuracy	• 4D spatial localization accuracy • Frame rate characterization for clinically reasonable scenarios • Latency threshold (may depend on clinical workflow)	• per TG-142 • per spec. • within 100 ms of expected value
Camera system characteristics	• Camera exposure settings are appropriate for a variety of skin tones • Measure localization FOV • Characterization of camera occlusion for variety of clinical scenarios (e.g., couch/gantry angles)	• NA • per spec. • NA
Imaging	• Isocenter coincidence with all imaging modalities that will be used in complement with SGRT	≤2 mm ≤1 mm for SRS/SBRT
End-to-end	• Characterization of localization and monitoring accuracy from CT to dose delivery including beam hold if available • Winston-Lutz including SGRT for SRS applications	• ≤1% dose change; ≤2% dose change for beam hold • <1 mm
Standard Operating Procedures	• Should include training guidelines for new personnel (either new to the department or new to the technology) • Should include intended use of the SGRT system, case-types, etc. • Should be updated as experience and technology evolves	Existing/Available

FOV, field-of-view; R&V, record and verify; SRS, stereotactic radiosurgery; SBRT, stereotactic body radiotherapy; TPS, treatment planning system.
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Data transfer integrity with TPS and R&V system (isocenter, surface map)

Interface with CT and Linac (gating and couch shift)

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Warm-up period necessary, stability localization accuracy (static and dynamic)

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Camera settings for different skin tones, camera occlusion, …

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Isocenter coincidence with other imaging modalities, end-to-end testing

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Standard operating procedures (intended use, training, etc.)

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MRI-Guided Radiation Therapy

ICRU REPORT 97: MRI-GUIDED RADIATION THERAPY USING MRI-LINEAR ACCELERATORS

Paul J. Keall *(Chair)*[1], Carri K. Glide-Hurst (Vice-Chair)[2], Minsong Cao[3], Percy Lee[4], Brad Murray[5], Bas W. Raaymakers[6], Alison Tree[7], and Uulke A. van der Heide[8]

Machine QA for the Elekta Unity system: A Report from the Elekta MR-linac consortium

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Radiotherapy and Oncology 181 (2023) 109504

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Radiotherapy & Oncology

Original Article

An ESTRO-ACROP guideline on quality assurance and medical physics commissioning of online MRI guided radiotherapy systems based on a consensus expert opinion

Check for updates

Stephanie Tanadini-Lang[a,*], Geoff Budgell[b], Omar Bohoudi[c], Stefanie Corradini[d], Davide Cusumano[e,f], Görkem Güngör[l], Linda G.W. Kerkmeijer[g], Faisal Mahmood[h,i], Simeon Nill[j], Miguel A. Palacios[c], Michael Reiner[d], Daniela Thorwarth[k], Lotte Wilke[a], Jochem Wolthaus[m]

ICRU 97

- Formal guidance and tolerances are under development (e.g. AAPM TG-352)
- However, many of the guidelines established for Linacs (i.e. TG-142), MRI scanners, and MR-simulators (i.e. TG-284) can be applied to MR-Linacs

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ESTRO-ACROP Guidelines

- A collection of Linac- and MR scanner-specific tasks, as well as those related to interactions of magnetic field and Linac beam
  - Field homogeneity
  - RF interference
  - Image quality checks
  - Dosimetric measurements
  - Safety checks
  - End-to-end testing
  - …

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Elekta MR-Linac Consortium

- Provides an overview of the QA equipment and techniques required for measurements on MR-Linac systems with a focus on Elekta Unity

Machine QA for the Elekta Unity system: A Report from the Elekta MR-linac consortium

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- Summary and Conclusions

Summary and Conclusions

- Acceptance testing of imaging systems is part of the overall acceptance and commissioning of radiation delivery unit
- There are a number of published guidelines but this usually follows manufacturer recommendations
- The measured values at the time of acceptance often become the baselines to which future performance of the system is compared to

Questions?