TG-210
Conventional Linac Acceptance Testing: Empowering the Physicist in the Linac Acceptance Process

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Disclosure

- TG 210 was submitted for final on December 2017
- The material on this presentation is a contribution from all the TG 210 members.
- No conflict of interest to disclose.

Outline

- Overview of the Acceptance Testing Process (ATP)
- TG 210 Survey Discussion
- Topics on TG 210
- Future of Acceptance Testing
- TG 210 Recommendations
Acceptance vs. Commissioning

- Acceptance testing – series of test to determine if the equipment meets the Manufacturer’s specifications.
- Commissioning tests – set of measurements to establish the machine performance and baselines to be used for the treatment planning systems and to evaluate future machine performance.

How does the ATP process usually work?

- Purchasing of a linac:
  - the vendor and the institutions agree to a given set of test that will be performed once the linac arrives.
- After installation:
  - ATP is performed by the physicist and companies’ installer
- After ATP
  - The medical physicist confirms that all contractual specifications are met
  - The ownership of the linac is transferred from the vendor the institution.

Survey Participants

How many days did the acceptance testing take?

- More than 10 days: 5.88%
- 5-10 days: 25.58%
- 1-5 days: 68.54%
Who performed the acceptance test?

- Both separately: 2.81%
- The vendor: 5.10%
- The physicist: 5.87%
- Both together: 86.22%

Was the onsite physicist trained by the vendor before the acceptance testing took place?

- No: 41.39%
- Yes: 58.61%

When did you (the physicist) provide the acceptance testing instructions for the vendor?

- During acceptance: 36.13%
- After acceptance: 0.25%
- Before negotiation: 7.89%
- After negotiation: 10.94%
- During installation: 44.78%

What documents were used as guidance for acceptance testing?

- Vendor provided material: 35.69%
- TG 106: 19.4%
- TG 142: 28.08%
- TG 45: 12.22%
- TG 108: 19.4%
- Other: 2.25%
- IAEA: 2.4%
What documents were used as guidance for acceptance testing

<table>
<thead>
<tr>
<th>Document</th>
<th>Notes</th>
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<tbody>
<tr>
<td>DIN 66089-2</td>
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<td>Older test protocols prior to TG 45</td>
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<td>Internal QA documents</td>
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<td>ISO 9186-1986</td>
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<td>vendors</td>
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<td>Swiss Recommendation</td>
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<td>Dutch NCS recommendations</td>
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<td>Professional judgement</td>
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<td>Institutional procedure</td>
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TG 210 Objectives

- Provide Recommendations for
  - Technical specifications that should be included in the purchase contract.
  - Consideration of technical aspects of purchase contract.
- To provide definition of performance specifications for major LINAC subsystems in ATP.
- To make recommendations on the tests to be performed during the LINAC ATP, including beam matching and subsequent major repair/upgrades including testing methods that complement vendor-suggested measurements.

TG 210 Objective v 2.0

- To empower the physicist to be meaningfully involved with the design and execution of comprehensive and effective LINAC ATP beginning with the purchase contract negotiation to the contractual handover of the LINAC to the department for clinical use.

TG 45: AAPM Code of Practice for Radiotherapy Accelerators

- Published in 1994.
- TG 45 ATP Overview
  - Checking the Treatment Area
  - Initial Checking of Mechanical and Radiation Systems
  - Console System Tests
  - Checking of Radiation Systems and Beam Parameters
  - Checking Interlock Systems
  - Multileaf Collimators
  - Checking Ancillary Equipment
Accepted Linac Capabilities

- IMRT: 25.62%
- VMAT: 22.34%
- Conical Collimators: 11.97%
- SRS with MLC shaping: 16.99%
- High Dose Rate Total Skin Electron mode (HDTSe): 8.56%
- Gating: 14.52%

TG 210 Sections

- Considerations for Technical Aspects of the Purchase Contract (Pre-Planning)
- Contract Technical Specifications and Installation Process
- General Acceptance Item Steps
- Imaging ATP
- Definition of Linac Beam Matching
- Major Component Replacement Tests/Upgrades
- Future of Acceptance Testing
- Summary and Recommendations

Considerations for Technical Aspects of the Purchase Contract (Pre-Planning)

1. Regulatory Requirements
2. Infrastructures
3. Planned linac technologies and integration
4. Clarification of ATP criteria
5. Outside Contractors

Regulatory Requirements

- Linac and associated equipment cleared by the Food and Drug Administration
- Understand State Regulations
- Initiate paper work for state approval
  - State might ask for safety survey before site approval
- Users should receive training before operating the machine
  - Will the vendor provide training to the users?
- Contact the Imaging and Radiation Oncology Core (IROC) in advance for the optically stimulated luminescent and thermoluminescent dosimeters (OSLD/TLD) irradiation kit.
Considerations for Technical Aspects of the Purchase Contract (Pre-Planning)

Infrastructure

- Important to have vendor required infrastructure specifications for the linac and the vault
  - Have sufficient clearance i.e. floor, walls height
- Plan for an in-house computer network
- Clean power source
- Chilled water cooling loop
- Appropriate shielding
- Consider vault design for extended source to surface distance (SSD) technique
- Any imaging device on ceiling or floor mounts
- Special lighting for optical surface tracking

Considerations for Technical Aspects of the Purchase Contract (Pre-Planning)

Planned linac technologies and integration

- Important to clarify with the vendor which techniques will be used for treatment and how will the integration will take place.
  - IMRT, IGRT, SRS/SBRT, gating treatments and the use of Flattening Filter Free (FFF)
- Ensure that the vendor knows beforehand about any linac that will be beam matched to an existing one
  - Both linacs should be similar or compatible to the reference linac model being matched.

Considerations for Technical Aspects of the Purchase Contract (Pre-Planning)

Warranty

- General items
- Specific components
- Service contract
- All licenses required

Outside Contractor

- Understand the consulting group process
- Ensure that the contractor will provide
  - A detailed report with the full acceptance testing procedures
  - Results of the final ATP
  - Additional data collected
Contract Technical Specifications and Installation Process

- The contract should include all the details to be in compliance with facility, vendor criteria, and governmental regulations.
- The contract should guarantee that the cleanliness and environmental conditions of the treatment area will be met.
- Before the linac arrives:
  - perform an onsite inspection
  - environmental issues, i.e. air conditioning
  - physics cable conduits
  - Make sure cables are properly installed before walls are closed.
  - patient monitor
  - Have good communication with the vendor site planner.
  - Go over all these details before the linac arrives to ensure a smooth installation process.

TG 210: Empowering the Physicist in the Acceptance Testing Process—The TG210 Perspective

If you (the physicist), where able to do your own test, when was the addition of your tests to the acceptance process negotiated?

- I did not perform my own test: 36.01%
- As part of the purchasing contract: 12.18%
- Onsite with the engineer: 51.81%

General Acceptance Items and Steps

1. Safety and Radiation Safety Test
2. Mechanical Tests
3. Dosimetrical Tests
   - X-Ray Beam Performance
   - Electron Beam performance
   - Arc Therapy mode
   - Monitor Chamber checks
   - Miscellaneous check
General Acceptance Items and Steps

Safety and Radiation Safety Test

- Audio-Visual equipment functioning
- Safety interlocks - Test functionality of door interlocks, Timers, 'Beam off' button, Radiation/beam-off button and any other safety interlocks
- Beam termination test based on timer or monitor unit (MU) delivered in all modes (clinical, service)
- Warning lights and sound indications
- Preliminary radiation shielding survey using the "worst case" scenario to all photon energies
- Head leakage test using films wrapped around the gantry head
- Collimator transmission
- Simulate a power failure while treatment beam is on and verify continuation of treatment when power comes back on

Safety and Radiation Safety Test

Taken from TG 210

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Mechanical Tests

- Alignment of mechanical isocenter with axis of rotation of gantry, collimator, couch, and any couch top assembly using a front-pointer tool and another pointed tool that can be attached to the couch
- Repeat mechanical alignment test for all imaging systems using an imaging phantom
  - Coincidence of light with radiation field
    - Test congruence of light field and radiation field using film exposures based on film marks placed at the center and edges of light field for the primary cardinal rotational angles of gantry, collimator, couch, and couch top. Film processed between light fields with addition exposure on single X-ray or kilovoltage images. Couch, couch rotations and translations
  - Coincidence of light with imaging fields:
    - Test congruence of light field and imaging field based on phantom images on MV and kV imaging systems. Agreement between light fields with imaging fields over a range of gantry, collimator, couch rotations and translations for all imaging systems
- Radiation isocenter test using starshot for the collimator, gantry, and treatment couch

Mechanical Tests

Taken from TG 210

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Dosimetrical Tests

Photon beam performance
- Output calibration based on TG-51
- Percent depth dose
- Radiation beam profile: Patterns and symmetry (in-plane and cross-plane)
- Penumbra
- Dose linearity with monitor unit (MU) and Dose Rate
- Dose reproducibility with gantry Angle

Electron beam performance
- Output verification based on TG-51
- Percent depth dose
- Radiation beam profile: Patterns and symmetry (in-plane and cross-plane)
- Penumbra

Arc therapy tests
- Output verification check with gantry rotation
- Dose per-arc gantry angle rotation check
- Output verification with gantry angle

Dosimetrical Tests

Taken from TG 210

TG 210: Empowering the Physicist in the Acceptance Testing Process- The TG210 Perspective

Miscellaneous checks

- Test functional status of electron cone applicator, stereotactic cones and trays
- Special modes of treatment:
  - Test functionality and perform output and beam profile tests on all special treatment modes such as high dose rate 3D, SRS, SBRT, IMRT, TBI, IMRT, and high dose rate electron (HD-3D) modes of treatment
- Test of ancillary systems:
  - Verify functionality of physical wedges and enhanced dynamic/virtual/universal wedges
  - Check integration of the linac with the 6 degrees of freedom (6DOF) couch, the respiratory gating system as well as the 3D or 4D thorax or pelvis imaging system as well as the 5-axis or 7-axis imaging system, the surface imaging system, the electromagnetic positioner system, and the external monitor system
  - Perform the Winston-Lutz test for linacs that will be used for SRS/SBRT treatments
- Measure the sag in treatment table
- Test Data transfer integrity:
  - Test integrity of the data transfer between CT simulator, treatment planning system (TPS), Record & Verify (R&V) and the treatment console. These tests also include any ancillary computer systems, including 4D CT, CT, MR images, and the treatment planning system, the treatment planning system, the surface imaging system, the external monitor system and the electromagnetic positioner system.
Did you use any documents for guidance regarding acceptance test tolerances?

No: 4.88%
Yes: 95.12%

If yes, what documents did you use?

- Vendor documents: 40.09%
- TG 142: 28.87%
- Training documents: 10.41%

Imaging ATP (1)

Section purpose:
- Provide guidelines to perform the necessary acceptance tests for the linac imaging systems.
- Provide alternative testing strategies if vendor-provided devices are not available.

Imaging ATP sub sections:
- Safety verification
- Mechanical, geometric, and localization calibrations
- Image quality
- Imaging dose and limitations
Beam matching

- Make sure that the new linac model is similar to the reference linac:
  - Flattening filter
  - Mechanical limits
  - Compatibility in the software versions
- Once the matching is completed
  - Absolute calibration of both machines
  - Same tolerances are used on the R&V system and the TPS

Major Component Replacement Tests / Upgrades
Examples of Major Repair / Replacement Items

- Waveguide and target
- Klystron / Magnetron
- Bending magnet
- Ion chamber
- Beam tuning
- MV or kV imaging system
- Collimation system (jaws, MLC)
- Gantry drive system
- Linac mounting or balancing (impact on isocenter)
- Couch / patient support
Major Component Replacement Tests / Upgrades

Examples of Minor Repair / Replacement Items

- Field light change
- Software update (for example, a maintenance release)
- Software parameter adjustment
- Position readout calibration
- Drive motor or position sensor adjustments
- Imager calibration
- Computer servicing, such as board replacement

- Ask the engineer about which system will they be working on
- Will there be any adjustments or modifications to any system that are not directly involved with the repair / replacement work
- Will the work change:
  - Beam generation, including beam energy or beam profiles (flatness, symmetry)?
  - Beam collimation, including primary jaw position or motion, MLC position or motion, or collimator position or motion?
  - Linac geometry, including isocenter, gantry position or motion?
  - Linac imaging systems, including positioning of the imaging source (kV only) or imaging panel, imaging performance, or imager dosimetry calibration? Couch positioning or motion for all degrees of freedom?
  - Accessory operation?
  - Interfaces to 3rd-party systems?
  - Safety features?
- What tests will the service engineer perform following the work
- What are the manufacturer’s recommendations for testing following this work

Future of Acceptance Testing

- Standardization of Linear Accelerators
  - Linac configurations will be simplified
  - Fewer options for Linacs
- Adoption of Advanced Measurement Devices
  - Ion chamber arrays
  - Diode arrays
  - EPIDs
- Adoption of Automated Testing Routines
  - EPIDs
  - AQUA, Acumyn, Inc.

Preliminary Recommendations

- The physicist should be involved in the negotiation process between the manufacturer and the institution.
- The physicist should make sure to understand and meet all regulatory requirements by the state early in the process.
- All Linac users should be trained before the Linac arrives to the institution.
- The physicist should be provided the ATP procedure and tolerances by the vendor with enough time before the Linac arrives to the institution.
- The physicist should be excluded from routine clinical duties when possible to ensure the projected timeline is met.
- The physicist should have good communication with the vendor service engineers during and after the ATP process.
- The physicist should understand the details involved in the beam-matching process to ensure that the right parameters and data are collected.
- The physicist should communicate with the vendor service engineers prior to any Linac minor or major component replacements in order to understand any work to be performed on the Linac and its implications.
Who owned the equipment that the acceptance test were done with?

- Independent contractor physicist: 4.50%
- Installer (vendor): 41.44%
- Clinic (Physics group): 52.07%
- Other: 1.98%

Would you (the physicist) prefer to use your own equipment for beam data acquisition during acceptance?

- Yes: 77.38%
- No: 22.62%

Acknowledgements

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