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

Angelica Perez-Andujar, PhD, DABR
University of California San Francisco
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TG 210 members


Ellen Xiaoyan Huang
ellenhuang111@gmail.com
8/23/2016-12/31/2018 Member
COI


Andrew N. Morrow, MSc
andrew.n.morrow@gmail.com
1/1/2017-12/31/2019 Task Group Vice Chair
COI


Angelica , Perez-Andujar, PhD
perezandujara@radonc.ucsf.edu
12/19/2016-12/31/2018 **Task Group Chair**
COI


Ching-Chong Jack Yang, PhD
jack.yang@rwlsh.org
10/4/2010-12/31/2018 Member
COI


Dharanipathy . Rangaraj, PhD
dharanipathy@cruvop.com
1/1/2017-12/31/2018 Consultant *(nonvoting)*
COI


Hua Li, PhD
huli@radonc.wustl.edu
8/23/2016-12/31/2018 Member
COI


Ganesh Narayanasamy, PhD
nganesh76@hotmail.com
8/23/2016-12/31/2018 Member
COI


Guanghua Yan, PhD
yan@ufl.edu
3/24/2017-12/31/2019 Member
COI


Todd Holmes
todd.holmes@varian.com
8/30/2016-12/31/2018 Consultant *(nonvoting)*
COI


Nicholas D. Schupp, MS
ndschupp@yahoo.com
8/23/2016-12/31/2018 Consultant *(nonvoting)*
COI


Sridhar . Yaddanapudi, PhD
sridhar-yaddanapudi@uiowa.edu
8/23/2016-12/31/2018 Guest *(nonvoting)*
COI

2 Presentation Title

TG 210

Disclosure

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

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Outline

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

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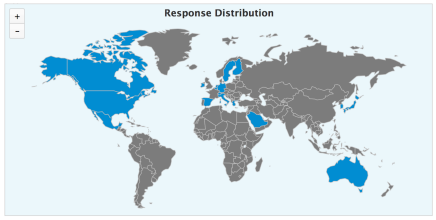
Acceptance vs. Commissioning

- 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 works?

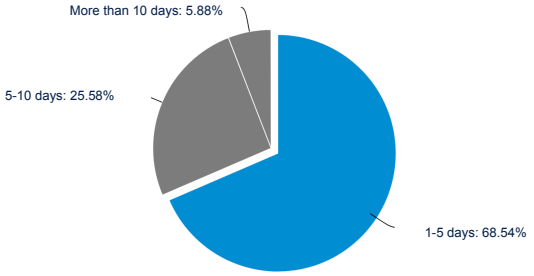
- Purchasing of a linac:
  - the vendor and the institutions agree to a given set of test that will be performed once the lina arrives.
- After installation:
  - ATP is performed by the physicist and companies' installer
- After ATP
  - The medical physicist confirms that all contractual specifications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

Survey Participants

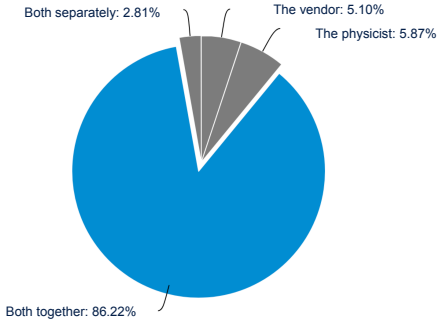


Countries	Responses
US	89.03%
CA	4.30%
Unknown	1.31%
AU	0.86%
SE	0.65%
SA	0.43%
IE	0.43%
JP	0.22%
IT	0.22%

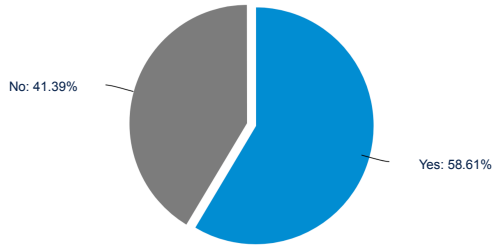
How many days did the acceptance testing take?



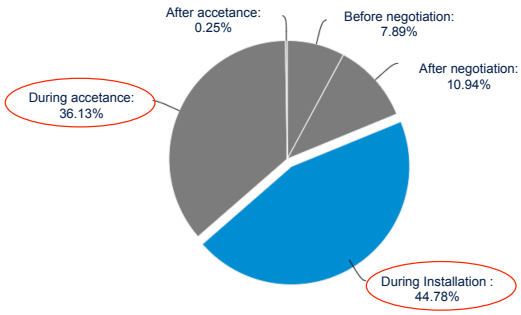
Who performed the acceptance test?



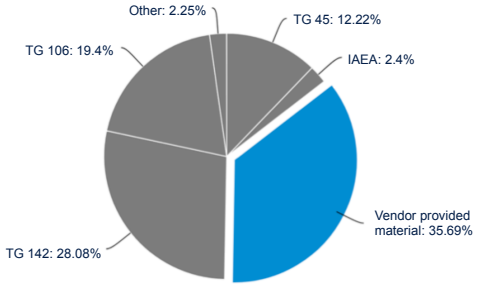
Was the onsite physicist trained by the vendor before the acceptance testing took place?



When where you (the physicist) provided the acceptance testing Instructions for the vendor?



What documents were used as guidance for acceptance testing?



What documents were used as guidance for acceptance testing

DIN 6800-2	Physicist had knowledge of other procedures (ie. TG 45,142 & 106)
older test protocols prior to TG 45	IPSM Report 81 and ACPSEM QA documents
Internal QA documents	Different papers on specific aspects not yet included in various TGs
iec 976, 977	in house acceptance test document which evolves
venders	own previous data
Swiss Recomendation	none
Dutch NCS recommendations	tg-51
Professional Judgement	Ontario HARP testing requirements
Institutional procedure	MPPG 5a
	CQPR TQC on linacs

experience

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.

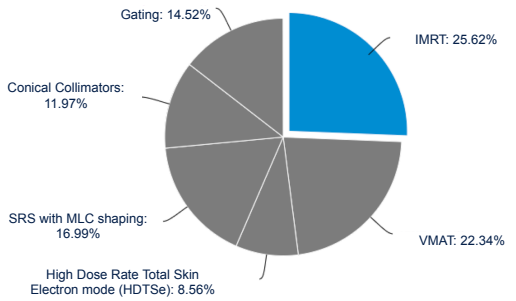
TG 210 Objective v 2.0

- 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



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

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

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 before hand 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)

Clarification of ATP criteria

- Possible to negotiate
  - Acceptance test and associated tolerances
  - Tighter acceptance criteria
  - For stereotactic linacs might want to ask tighter mechanical tolerances
    - tighter isocenter coincidence
- Physicist should request ATP documentation with the list of tolerances before hand.

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

Warranty and Outside contractor

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

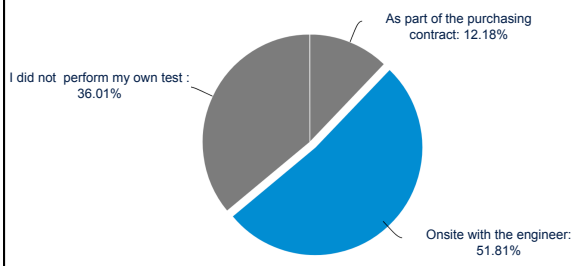
Contract Technical Specifications and Installation Process

- The contract should includes 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.

Contract Technical Specifications and Installation Process

- The physicist should be present during any discussion with the vendor site manager before the linac arrives to ensure that the clinical workflow won't be impacted.
- Physics should be present during the installation process.
- The physicist should supervise the installation process
- Perform a radiation shielding survey as soon as the the linac is installed and a consistent beam could be delivered
  - Repeat this survey as part of the ATP process and before signing the final ATP documents.
  - Survey should include head leakage test
- During ATP make sure to document all your work.
- If a consulting group will be involved in the ATP process make sure to understand their process and that a written report will be provided with all the data collected.

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



General Acceptance Items and Steps

1. Safety and Radiation Safety Test
2. Mechanical Tests
3. Dosimetrical Tests
   a. X-Ray Beam Performance
   b. Electron Beam performance
   c. Arc Therapy mode
   d. Monitor Chamber checks
   e. Miscellaneous check

General Acceptance Items and Steps
Safety and Radiation Safety Test

- **Audio-Visual equipment** functioning
- **Safety interlocks** - Test functionality of door interlock, Timer, "Beam off" button, Radiation "emergency off" button, "Power 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**
- **Anti-collision system performance** for treatment couch, linac's head and imaging components
- **Preliminary radiation shielding survey** using the "worst case" scenario on 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

Taken from TG 210

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General Acceptance Items and Steps
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**. Test agreement between light fields with radiation exposure over a range of gantry, collimator, **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

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General Acceptance Items and Steps
Dosimetrical Tests

Photon beam performance
- Output calibration based on TG-51
- Percent depth dose
- Radiation beam profile: Flatness 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: Flatness and symmetry (in-plane and cross-plane)
- Penumbra

Arc therapy mode
- Output constancy check with gantry rotation
- Dose per unit gantry angle rotation check
- Output constancy with gantry angle

Taken from TG 210

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General Acceptance Items and Steps
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 SRS, FFF, total body irradiation, and high-dose total skin electron (HD-TSE) 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 X-ray and non X-ray based imaging system, the surface imaging systems, the ultrasound system, and the electromagnetic transponder 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, 2nd check software, imaging registration software, medical records software among others.

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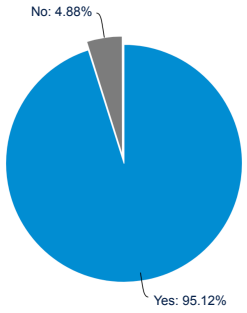
Did you used any documents for guidance regarding acceptance test tolerances?



If yes, what documents did you use?

DIN 6847-5	in house documents as above	Many older AAPM Reports, IEC976 and IEC 977
MPPG2a for imaging	in-house documents	In house comparisons with performance of comparable machines
AAPM puplications	IAEA review of RO physics	CQPR TQC on linacs
iec 976, 977, tg 50	TG 45	
Swiss docs	TG-40	
early truebeam publications	BJR	
Dutch NCS recommendations	TG40	
state regs	Canadian CPQR documents	
Institutional procedure	TG40	

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

Mechanical

Equipment: Front pointers, millimeter graph paper, spirit level, a machinist's dial indicator, calibrated digital level, radiochromic film, phantom with different thicknesses/heights, stereotactic phantom with inner BB marker, solid water blocks, tape measure

Test	Tolerance
Front pointer alignment with lasers	± 2mm
Mechanical isocenter coincidence with collimator, gantry and table axis of rotation	≤ 1 mm radius
Front pointer agreement with ODI at 100 cm SSD	0.5 mm
Cross-hair wallout	≤ 1 mm radius
Isocenter alignment with imaging systems	≤ 1 mm
Jaw symmetry test X and Y position accuracy	< 1 mm
Light and radiation field coincidence	< 2 mm
Radial crosshair and X-jaw parallelism	< 2.5 mm over 35 cm (<0.41°)
Transverse crosshair and Y-jaw parallelism	< 2.5 mm over 35 cm (<0.41°)
Gantry, collimator and table rotation isocenter	<1 mm radius
Winston Lutz Test	≤ 1 mm
Radiation and mechanical isocenter coincidence	< 1mm diameter
ODI at isocenter	≤ 2mm
Gantry, collimator and table angle indicator accuracy	< 0.5°
Collimator field size indicator	< 2mm
Asymmetric jaw position readout	< 1mm
Split field test	< 1mm
Jaw rotation symmetry test	< 1mm
Table position accuracy (longitudinal, vertical, lateral and rotation)	< 2 mm/1°
Table position accuracy: 6DOF pitch and roll	< 0.3°
Table sag	< 2 mm
MLC position accuracy	±1.0 mm
MLC position repeatability	±0.5 mm

- Vendors ATP documentation
- BJRs and other publications …
- IEC - IEC/TR 60977
- IAEA
- TG 25
- TG 40
- TG 45
- TG 142
- TG 101
- TG 51

Taken from TG 210

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

Taken from TG 210

Radiation Safety and Signs	
Test	Equipment
Room door interlocks	Visual checks
Imaging beam on lights indicator Imaging beam on indicator sound	
Collision interlock system (KVS) Collision interlock system (KVD)	
Collision interlock system (MVD)	

Mechanical (These test might only be applicable to certain linac models)	
Test	Equipment
KV image detector mechanical positioning accuracy	Ruler
KV source mechanical positioning accuracy	Ruler
kV collimator blade- jaw size accuracy	Film or FC-2 phantom
MV image detector mechanical positioning accuracy	Ruler
MV full range of travel SSD	Ruler

Image Geometry Accuracy	
Test	Equipment
KV imaging and imaging isocenter coincidence	Cube phantom with internal marker or IsoCal phantom
MV imaging and treatment isocenter coincidence	Cube phantom with internal marker or IsoCal phantom
kV, MV scaling	Blade calibration tool or FC-2 phantom

KV planar image quality	
Test	Equipment
Low contrast sensitivity	KV Leeds phantom
High contrast resolution	KV Leeds phantom
Spatial resolution	KV Leeds phantom

Taken from TG 210

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

Taken from TG 210

Photon Measurements (all energies)				
Test parameters on match machines	Equipment	SSD	Depth	FS
Absolute Dosimetry	Farmer Chamber	100	10	10
PDD 10x	Farmer Chamber	100	10	10
Output Factors open in water	Waterproof farmer chamber	90	10	5 field sizes
PDD open field	Scanning tank and small volume ion chamber	10		5 field sizes
Inline and Crossline profiles open fields	Scanning tank and small volume ion chamber	90	5, 10 15	5 field sizes
2D Distribution open fields	Diode array or film	100	5, 10, 15	5 field sizes
2D Distribution EDW (3 wedge angles)	Diode array or film	100	5,10,15	5 field sizes
Head Scatter Factors	Farmer chamber with buildup cap			Multiple

Electron Measurement matching test (all energies and applicators)				
Absolute Dosimetry		100	d_{ref}	Reference applicators
Output factors	Electron diode	100	d_{ref}	All applicators
Inline and crossline profiles	Electron diode	100	d_{ref}	All applicators

IMRT/VMAT 2D/3D verification				
IMRT Plans delivered on both machine	2D Dosimetry or 3D Dosimetry	--	--	---
MLC – Transmission, rounded leaf and Tongue and groove		--	--	---

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

Taken from TG 210

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

Taken from TG 210

Major Component Replacement Tests / Upgrades

- 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

Taken from TG 210

Future of Acceptance Testing

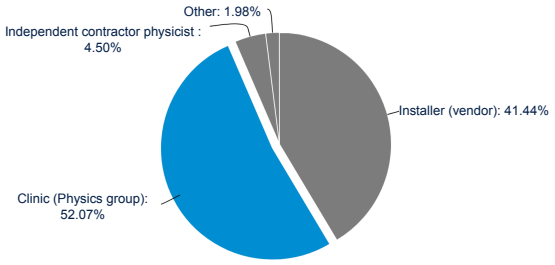
- Standardization of Linear Accelerators
  - linac configurations will be simplified
    - fewer options for linacs
- Adoption of Advanced Measurement Devices
  - ion chamber arrays
  - diode arrays
  - EPIDs
- Adoption of Automated Testing Routines
  - EPIDs
  - AQUA, Acumyn, Inc.

Preliminary Recommendations

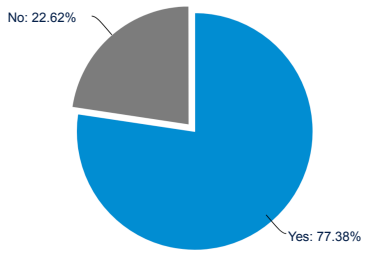
- The physicist should be involved in the negotiation process between the manufacturer and the institution.
- The physicist should make sure to understand and meet all regulatory requirements by the state early in the process.
- All linac users should be trained before the linac arrives to the institution.
- The physicist should be provided the ATP procedure and tolerances by the vendor with enough time before the linac arrives to the institution.
- The lead physicist for the ATP should be excluded from routine clinical duties when possible to ensure the projected timeline is meet.
- 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.

Taken from TG 210

Who owned the equipment that the acceptance test were done with?



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



Acknowledgements

Ellen Xiaoyan Huang
ellenhuang111@gmail.com
8/23/2016-12/31/2018 Member

Andrew N. Morrow, MSc
andrew.n.morrow@gmail.com
1/1/2017-12/31/2019 Task Group Vice Chair

Ching-Chong Jack Yang, PhD
jack.yang@rwjbh.org
10/4/2010-12/31/2018 Member

Dharanipathy , Rangaraj, PhD
dharanipathy@viewpi.com
1/1/2017-12/31/2018 Consultant (nonvoting)

Sridhar , Yaddanapudi, PhD
sridhar-yaddanapudi@uiowa.edu
8/23/2016-12/31/2018 Guest (nonvoting)

Hua Li, PhD
huli@radonc.wustl.edu
8/23/2016-12/31/2018 Member

Ganesh Narayanasamy, PhD
nganesh76@hotmail.com
8/23/2016-12/31/2018 Member

Guanghua Yan, PhD
yan@ufl.edu
3/24/2017-12/31/2019 Member

Todd Holmes
todd.holmes@varian.com
8/30/2016-12/31/2018 Consultant (nonvoting)

Nicholas D. Schupp, MS
ndschupp@yahoo.com
8/23/2016-12/31/2018 Consultant (nonvoting)

Sonja Dieterich, PhD
Steven Stutlief, PhD
Robin Stern, PhD
Kathy Molnar- Kimber, PhD
Members WGEBQA