# Medical Physics Practice Guideline #8
# Linac QA
# TG265

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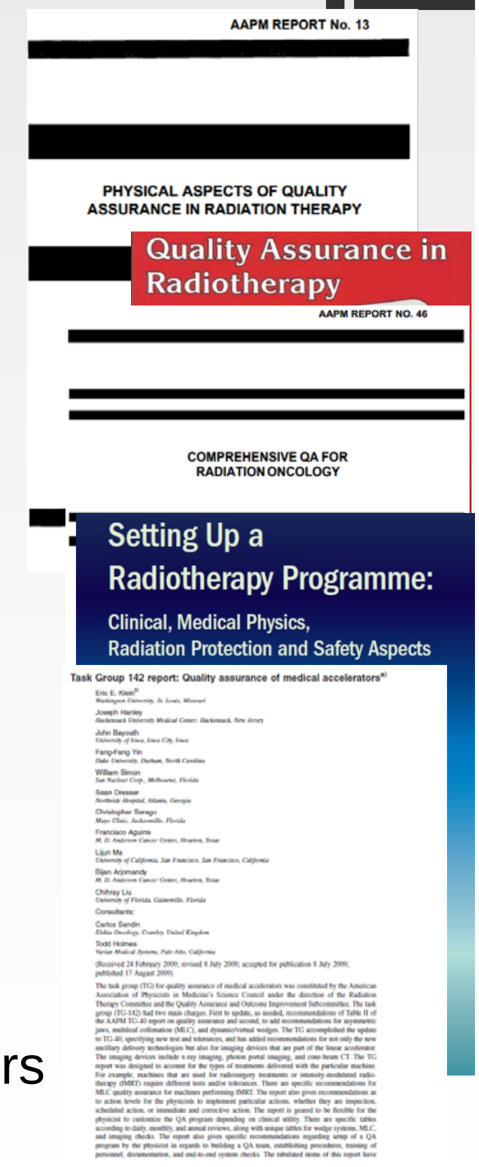
# Outline

- Current Resources for Linear Accelerator Quality Assurance Protocols –
  - TG40 & TG142
- Motivation for Practice Guideline on Linear Accelerator Quality Assurance
- MPPG #8 TG265 –
  - Committee Members
  - Timeline
  - Initial Discussion and Results

# Numerous Publications on Quality Assurance Tests for Linear Accelerators

- AAPM TG24, Physical Aspects of Quality Assurance in Radiotherapy (1984)
- World Health Organization, Quality Assurance in Radiotherapy (1988)
- AAPM TG40, Comprehensive QA for Radiation Oncology (1994)
- IAEA, Setting Up a Radiotherapy Program (2008)
- AAPM TG142, Quality Assurance of Medical Accelerators (2009)



# Protocols for Specialized Equipment and Procedures

- **IMRT**
  - AAPM, Guidance document on delivery, treatment planning and clinical implementation of IMRT
- **Electron Beams**
  - AAPM TG25 and TG70, Recommendations for clinical electron beam dosimetry
- **Stereotactic Radiosurgery/Stereotactic Body Radiation Therapy**
  - AAPM TG42, Stereotactic Radiosurgery
  - AAPM TG101, Stereotactic body radiation therapy
- **Cyberknife**
  - AAPM TG135, Quality assurance for robotic radiosurgery
- **Tomotherapy**
  - AAPM TG148, QA for helical tomotherapy

# Overall Goal for Quality Assurance Program

- ICRU recommends that the dose delivered to the patient be within ± 5% of the prescribed dose.

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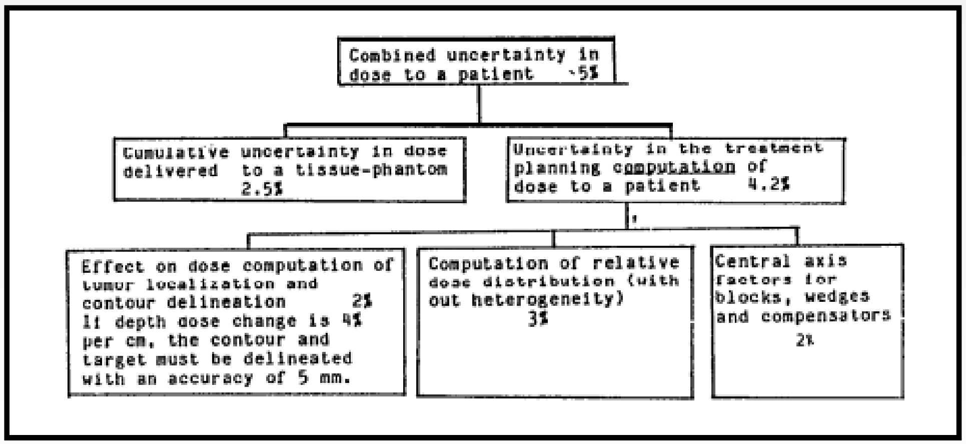


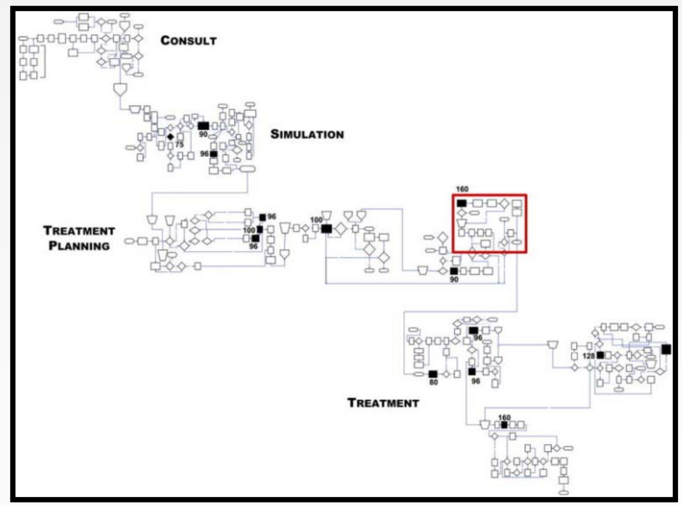


(1) ICRU "Determination of absorbed dose in a patient irradiated by beams of x- or gamma-rays in radiotherapy procedures," ICRU Rep. 24, International - Commission on Radiation Units and Measurement, Bethesda, MD (1976)
(2) G. Svensson et al., "Physical Aspects of Quality Assurance in Radiation Therapy." AAPM TG24 (1984)
(3) E.C. Ford, R. Gaudette, L. Myers, B. Vancouver, L. Engineer, R. Zellars, D.Y. Song, J. Wong, T.L. Deweese, "Evaluation of safety in a radiation oncology setting using failure mode and effects analysis" Int J Radiat Oncol Biol Phys (2009)

# Common Protocols for Traditional Linear Accelerator Quality Assurance Tests

- **TG40**
- **TG142**

# TG 40 → TG142

- TG142 is smaller in scope in that it only contains tests for linear accelerators. TG40 was comprehensive to include tests for Co-60 units, CT Simulators, radiotherapy equipment, etc.
- TG142 expanded on linear accelerator tests to provide guidance for tests on MLCs, asymmetric jaws, dynamic and virtual wedges, EPIDs, CBCT and static kV imaging.
- TG142 also considers increased precision needed and increased demand on an accelerator with the increased use of IMRT, TBI, SRS and SBRT

Daily Tests

| TG40 | → TG142 |
| --- | --- |
| X-Ray Output | X-Ray Output |
| Electron Output | Electron Output |
| Lasers | Lasers |
| ODI | ODI |
| Door Interlock | Door Interlock |
| Audiovisual | Audiovisual |
| | Door Closing Safety |
| | Collimator Size Indicator |
| | Stereotactic Interlocks |
| | Radiation Area Monitor |
| | Beam On Indicator |
| | Wedge Check Run Out |

# Monthly Tests

## TG40 → TG142

**TG40**

- X-Ray Output
- Electron Output
- Backup Monitor Chamber
- Electron Energy
- Xray Energy
- Xray Beam Flatness
- Electron Beam Flatness
- Xray Beam Symmetry
- Electron Beam Symmetry
- Light/Rad Field
- Gantry/Collimator Indicators
- Wedge position
- Tray position
- Applicator Position
- Field Size Indicators
- Jaw Symmetry
- Cross Hair Centering
- Treatment Couch Position Indicators
- Latching of Wedges, Blocking tray
- Emergency Off Switches
- Wedge, Cone Interlocks
- Field Light Intensity

**TG142**

- X-Ray Output
- Backup Monitor Chamber
- Electron Energy
- Xray Profile Constancy
- Electron Profile Constancy
- Light/Rad Field (Sym)
- Light/Rad Field (Asym)
- Gantry/Collimator Indicators
- Wedge Placement
- Accessory Trays
- Jaw Position Indicators (Sym)
- Jaw Position Indicators (Asym)
- Cross Hair Centering
- Treatment Couch Position Indicators
- Latching of Wedges, Blocking Trays
- Lasers/ODI w/ Front Pointer
- Lasers
- Laser Guard Interlock Test
- Wedge Factor for All Energies
- [MLC] Setting vs Radiation Field
- [MLC] Backup Diaphragms (Elekta)
- [MLC] Travel Speed
- [MLC] Leaf position Accuracy
- Compensatory Placement
- [Respiratory Gating] Beam Output
- [Respiratory Gating] Phase, Amplitude
- [Respiratory Gating] In Room Respiratory Monitoring
- [Respiratory Gating] Gating Interlock

# Monthly Tests

## TG40 → TG142

### TG40

- X-Ray Output
- Electron Output
- Backup Monitor Chamber
- Electron Energy
- Xray Energy
- Xray Beam Flatness
- Electron Beam Flatness
- Xray Beam Symmetry
- Electron Beam Symmetry
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- Electron Profile Constancy
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- Light/Rad Field (Asym)
- Gantry/Collimator Indicators
- Wedge Placement
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Monthly Tests

## TG40 → TG142

**TG40**

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- Electron Beam Flatness
- Xray Beam Symmetry
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# Monthly Tests

## TG40 → TG142

| TG40 | TG142 |
|---|---|
| X-Ray Output | X-Ray Output |
| Electron Output | Backup Monitor Chamber |
| Backup Monitor Chamber | Electron Energy |
| Electron Energy | Xray Profile Constancy |
| Xray Energy | Electron Profile Constancy |
| Xray Beam Flatness | Light/Rad Field (Sym) |
| Electron Beam Flatness | Light/Rad Field (Asym) |
| Xray Beam Symmetry | Gantry/Collimator Indicators |
| Electron Beam Symmetry | Wedge Placement |
| Light/Rad Field | Accessory Trays |
| Gantry/Collimator Indicators | Jaw Position Indicators (Sym) |
| Wedge position | Jaw Position Indicators (Asym) |
| Tray position | Cross Hair Centering |
| Applicator Position | Treatment Couch Position Indicators |
| Field Size Indicators | Latching of Wedges, Blocking Trays |
| Jaw Symmetry | Lasers/ODI w/ Front Pointer |
| Cross Hair Centering | Lasers |
| Treatment Couch Position Indicators | Laser Guard Interlock Test |
| Latching of Wedges, Blocking tray | Wedge Factor for All Energies |
| Emergency Off Switches | [MLC] Setting vs Radiation Field |
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# The ICRU recommends that the dose delivered to the patient be within what percentage of the prescribed dose?

| | | |
|---|---|---|
| 20% | 1. | ± 1% |
| 20% | 2. | ± 2% |
| 20% | 3. | ± 3% |
| 20% | 4. | ± 4% |
| 20% | 5. | ± 5% |

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# Answer

- **Answer: (5) ±5%**
- **Reference:** “Determination of absorbed dose in a patient irradiated by beams of x- or gamma-rays in radiotherapy procedures,” International Commission on Radiation Units and Measurement Bethesda Report 24 (1976)

# TG40 includes tests for:

| | | |
|---|---|---|
| 20% | 1. | Asymmetric Jaws |
| 20% | 2. | Co-60 units |
| 20% | 3. | CBCT Equipment |
| 20% | 4. | Dynamic Wedges |
| 20% | 5. | IMRT |

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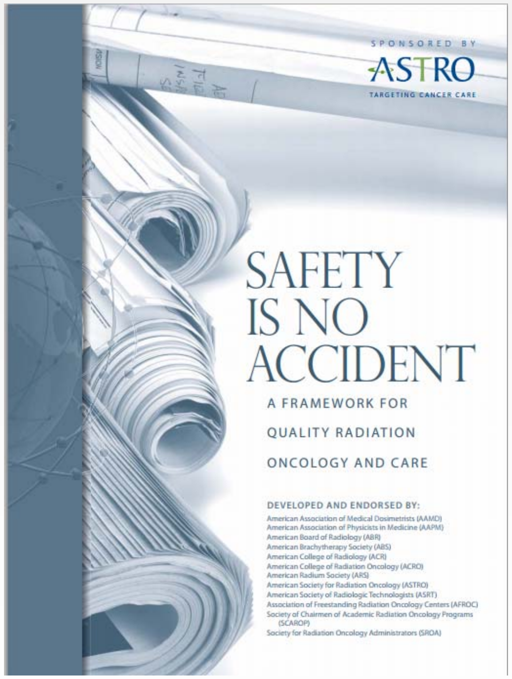
# Answer

- **Answer: (2) Co-60 Units**
- **Reference:** G.J. Kutcher et al., “Comprehensive QA for radiation oncology: Report of AAPM Radiation Therapy Committee Task Group 40,” Med. Phys. 21, 581-618 (1994)

# Motivation for TG265

## Qualified Medical Physicist

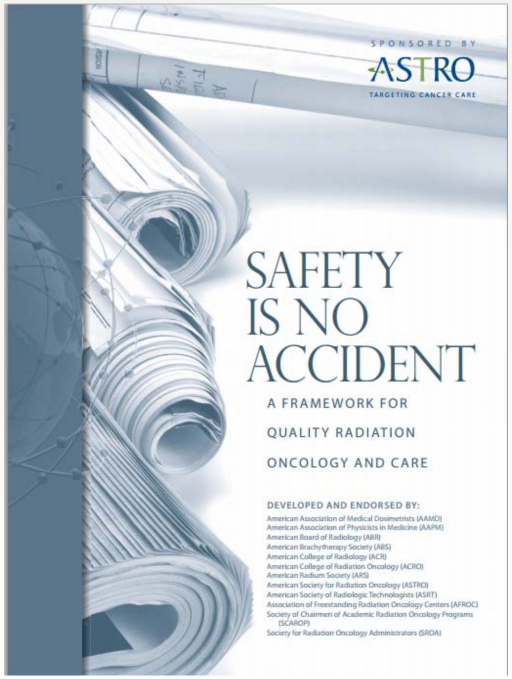
- Qualified Medical Physicist is ultimately responsible for a QA program.
- Safety Is No Accident (2012), Qualified Medical Physicists:
  - Are responsible for ensuring the safe and effective delivery of radiation as prescribed
  - As the field evolves, we are also responsible for:
    - Incorporating technological innovations to improve patient/staff safety
    - Assessing the safety of treatment processes, (e.g., with statistic processes, failure mode analysis, fault trees, etc.)



# Motivation for TG265

## Qualified Medical Physicist

- Safety Is No Accident (2012), Challenges for Qualified Medical Physicist:
  - There is a role shift to increase emphasis on safety-related work
  - Must seek education in advanced process analysis tools for patient safety

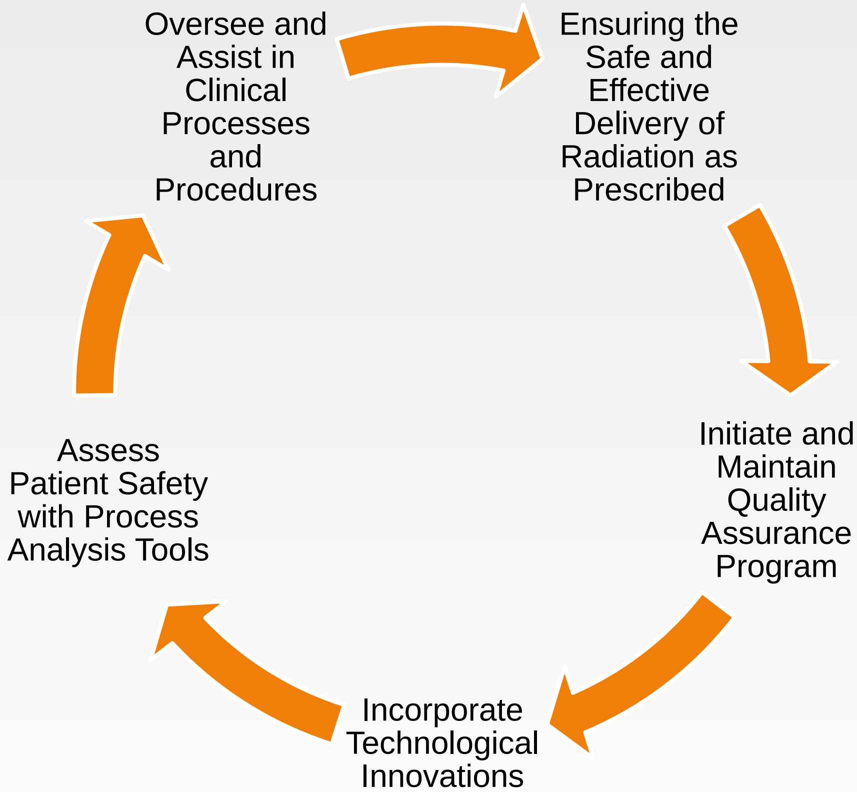


# Motivation for TG265

## Qualified Medical Physicist

- Many responsibilities for the average medical physicist to juggle…

# Motivation for TG265



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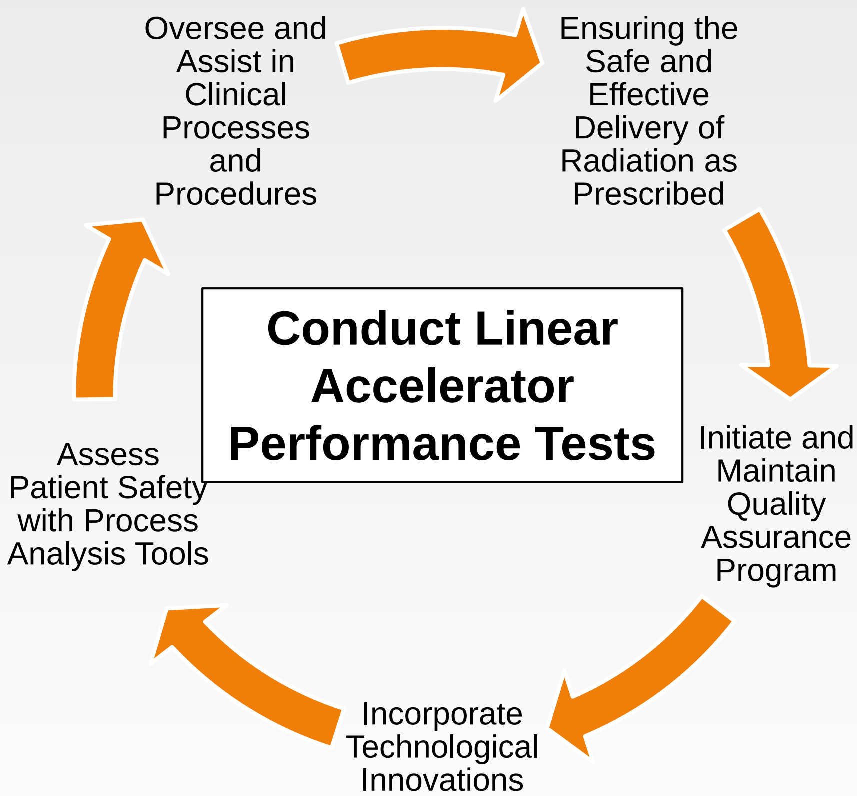
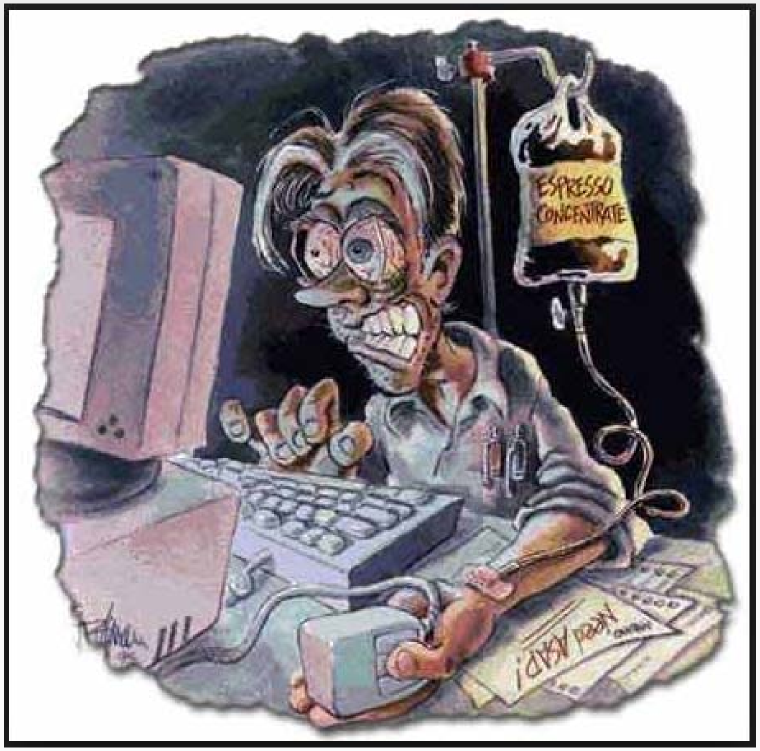


# Motivation for TG265

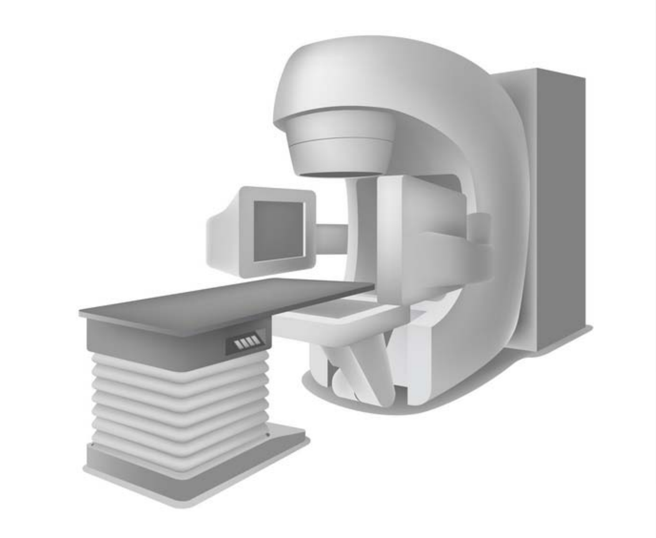



- We need to make sure we are not unduly taxing medical physicists.

# Motivation for TG265

- Rather than continually adding to an already long list of QA tests, we should revisit and “redesign the process to reflect the characteristics of modern equipment.”
  - Point/Counterpoint - H. I. Amols, E. E. Klein and C. G. Orton, “QA procedures in radiation therapy are outdated and negatively impact the reduction of errors,” Med. Phys. 38, 5835 (2011)

# TG265



- The task group is charged with reviewing the current recommendations for C-arm based linear accelerator quality assurance and determining the minimum test procedures that should be performed to ensure safe and effective treatment deliveries without unduly taxing clinical staff.

TG265

# Regulatory and Accrediting Agencies

- Regulatory and accrediting agencies may expect protocols to be followed exactly.
- Must ensure that recommended performance tests are necessary and relevant.

# TG265

**Dosimetry**

**Mechanical**

**Safety**

- Considers only dosimetry, mechanical and safety performance tests.
- Imaging tests are outlined **Medical Physics Practice Guideline (TG225): "Commissioning and quality assurance of X-ray-based image-guided radiotherapy systems"**
- TG 265 is not a "how-to" document.

# TG265
# Committee Members

- Combination of experience from large, academic centers to small community centers to consulting groups.
- Representation from TG142

Northwest Medical Physics Center
A Washington based non-profit Organization

OncoLogics
TREATING CANCER PERSONALLY

# TG265
# Committee Members

- Committee Members:
  - Koren Smith (Chair) – Johns Hopkins Hospital
  - Peter Balter – UT MD Anderson Cancer Center
  - Robin Miller – Northwest Medical Physics Center
  - John Duhon – Oncologics
  - David Vassy – Gibbs Cancer Center
  - Gerald White – Colorado Associates in Medical Physics
  - Francisco Aguirre – UT MD Anderson Cancer Center

# TG265
# Elements of Guideline

- Introduction
  - Goals and Rationale
  - Intended Users
  - Definitions and Abbreviations
- Staff Qualifications and Responsibilities
- Performance Test Review
  - FMEA Methodology
  - Minimum Required Resources and Equipment
  - Regulatory Considerations
  - Other Important Considerations
- Recommended Performance Tests
- Conclusions

# TG265 Timeline

- 7/1/2014 – TG265 Charge Accepted
- 8/1/2014 – TG265 Committee Formed
- 8/19/2014 – Conference Call
  - Data Collection on Linac Tests Performed at Committee Member's Institutions
- 9/9/2014 – Conference Call
  - Data Review for Daily/Weekly Tests
- 10/16/2014 – Conference Call
  - Data Review for Daily/Weekly Tests
- 11/3/2014 – Draft Outline Submitted to SPG
- 11/20/2014 – Conference Call
  - Data Review for Daily/Weekly Tests
- 1/15/2015 – Conference Call
  - Data Review for Monthly Tests
- 1/29/2015 – Conference Call
  - Data Review for Monthly Tests
- 2/12/2015 – Conference Call
  - Data Review for Monthly Tests
- 2/27/2015 – Working Draft of Report Initiated

# What is a principle ingredient of TG265?

| | | |
|---|---|---|
| 20% | 1. | Minimum Linac Performance Tests |
| 20% | 2. | “How-To” Descriptions |
| 20% | 3. | ALARA Principles |
| 20% | 4. | State Regulatory Requirements |
| 20% | 5. | Accreditation Standards |

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# Answer

- **Answer: (1) Minimum Linac Performance Tests**
- **Reference:** "TG265" Unpublished Manuscript. (2015)

# What kind of linear accelerator tests does TG265 describe?

| | | |
|---|---|---|
| 20% | 1. | On-Board Imaging Tests |
| 20% | 2. | Software Upgrade Tests |
| 20% | 3. | Preventative Maintenance Tests |
| 20% | 4. | Dosimetry, Mechanical and Safety Tests |
| 20% | 5. | Immobilization Equipment Tests |

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# Answer

- **Answer: (4) Dosimetry, Mechanical and Safety Tests**
- **Reference:** “TG265” Unpublished Manuscript. (2015)

# TG265 Approach

- Review current list of possible performance tests for linear accelerators.
  - Majority of the tests reviewed are from TG142.
- Review each test for necessity (based on experience with failure rates) and relevance (based on current available technology).
- For each test, Committee Members note:
  - Risk Assessment (FMEA Risk Priority Number)
  - Time to Complete Test
  - Test Performed After Specific Maintenance
  - Proceed after Failure?

# TG265
# Risk Assessment

- FMEA methodology to assign a RPN value to each test
- RPN = Severity * Occurrence * Detectability
  - Severity
    - Rank the potential severity of harm if a clinical parameter is not tested and were to fall out of tolerance (e.g., what would be the severity of harm to a patient if the ODI is off by a few millimeters and goes undetected?)
  - Occurrence
    - Rank the test for frequency of occurrence of a failure. (e.g., how many times have the gantry angle indicators been known to fail?)
  - Detectability
    - Rank the test for difficulty in detecting a failure. Use knowledge of other tests being performed. (e.g., wedge placement accuracy may be detected by a wedge factor output check or profile check).

# TG265
# Risk Assessment

- FMEA methodology to assign a RPN value to each test
- RPN = Severity * Occurrence * Detectability
  - The higher the score:
    - the more severe the potential of harm is, if the test is not performed,
    - the test is likely to fail more frequently, and
    - the harder it is to detect a failure

# TG265
# Initial Discussion and RPN Results

- Daily/Weekly Performance Tests
- Monthly Performance Tests

# TG265
# RPN Results – Daily/Weekly Tests

- RPN Scores (Average of 5 Committee Members)
- Highest to Lowest
  - **82**: Wedge Checkout Run
  - **76**: X-Ray and Electron Output Constancy
  - **75**: Collimator Size
  - **55**: Picket Fence
  - **43**: Stereotactic Interlocks
  - **40**: Laser Localization
  - **39**: Door Closing Safety
  - **29**: ODI @ iso
  - **21**: Audio/Visual Monitors
  - **8**: Door Interlock (beam off)
  - **7**: Beam On Indicator
  - **6**: Radiation Area Monitor

# TG265
# Discussion – Daily/Weekly Tests

- X-Ray and Electron Output Constancy

  - Time to Perform Test (Average): 11 Minutes
  - Performed after Maintenance: Monthly Output Test is Done after Any Adjustments to Output
  - Proceed after Failure: No; Machine is Down

  - Additional:
    - It is more critical to verify daily output for hypofractionated treatments.
    - An ion chamber fail or leak may cause output variations but may be seen by other interlocks such as symmetry faults.
    - The timing of daily output check should be considered – we currently assume the greatest risk of failure occurs in the morning.
    - May detect any mishaps/changes if work was done the night before.

# TG265
# Discussion – Daily/Weekly Tests

- Laser Alignment

  - Time to Perform Test (Average): 4 Minutes
  - Performed after Maintenance: Any Adjustment/Movement of Lasers
  - Proceed after Failure: Proceed with IGRT Patients

  - Additional:
    - Stability of lasers can depend on how they are mounted.
    - If relying on lasers alone for setup, there is a low severity for patient mis-alignment for regular fractionated patients.

# TG265
# Discussion – Daily/Weekly Tests

- ODI

  - Time to Perform Test (Average): 3 minutes
  - Performed after Maintenance: Monthly ODI Check is Done after Any Adjustments
  - Proceed after Failure: Proceed with IGRT Patients

  - Additional:
    - ODI is very stable and typically does not drift.
    - Daily Test is at one position.
    - In certain types of machines, it may be easy to move the ODI if work is being done on the head of the accelerator.

# TG265
# Discussion – Daily/Weekly Tests

- Collimator Size Indicator

  - Time to Perform Test (Average): 2 Minutes
  - Performed after Maintenance:
  - Proceed after Failure: No; Machine is Down

  - Additional:
    - Tolerance is tight for SRS/SBRT. Tested by comparing the light field to an etching on a device – difficult to detect 1 mm errors from the therapists checking daily.
    - Winston-Lutz Type Test is more appropriate test for collimator size indicators for SRS/SBRT treatments.

# TG265
# Discussion – Daily/Weekly Tests

- The lowest ranking RPN scored tests may be required for regulatory purposes in some states.
  - **21** Audio/Visual monitors
  - **8** Door Interlock
  - **7** Beam On Indicator
  - **6** Radiation Area Monitor
- A couple of daily tests become more critical if the linear accelerator was subject to maintenance the night before.
- Overall the average time reported for all of the TG142 Daily/Weekly recommended tests is:
  - 25 Minutes for Daily Tests
  - 5 Minutes for Weekly Tests

What process analysis tool is used rank possible performance tests?

| | | |
|---|---|---|
| 20% | 1. | Six Sigma |
| 20% | 2. | Incident Learning System |
| 20% | 3. | Root Cause Analysis |
| 20% | 4. | FMEA Process Maps |
| 20% | 5. | FMEA Risk Priority Numbers |

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# Answer

- Answer: (5) FMEA Risk Priority Numbers
- **Reference:** “TG265” Unpublished Manuscript. (2015)

# TG265
# RPN Results – Monthly Tests

- RPN Scores (Average of 5 Committee Members)
- Highest to Lowest
  - **144**: Leaf Travel Speed
  - **122**: Leaf Position Accuracy (IMRT)
  - **105**: X-ray, electron and chamber output constancy
  - **89**: Jaw Position Indicators (Asymmetric)
  - **83**: Photon and Electron Beam Profile Constancy
  - **72**: Electron Beam Energy Constancy
  - **72**: Jaw Position Indicators (Symmetric)
  - **71**: Digital Graticule
  - **69**: Light vs Radiation (Symmetric and Asymmetric)
  - **57**: Wedge Factor for All Energies
  - **56**: Typical IMRT Dose Rate Output Constancy
  - **56**: Backup Diaphragm Settings (Elekta Only)
  - **53**: Cross-hair Centering
  - **48**: Wedge Placement Accuracy
  - **43**: Treatment Couch Position Indicators
  - **40**: Gantry/Collimator Angle Indicators
  - **40**: Laser / ODI Check with Front Pointer
  - **36**: Accessory Trays (i.e., Graticule or Dot Tray)
  - **31**: Localizing Lasers
  - **13**: Latching of Wedges, Block Trays
  - **6**: Laser-Guard Interlock Test

# TG265
# Discussion – Monthly Tests

- <u>Jaw Positions Indicators/Light vs Radiation Field</u>

  - Time to Perform Test (Average): 35 Minutes
  - Performed After Maintenance: Bulb Replacement, Mirror Adjustment, Jaw Adjustment or Potentiometer Adjustment; Any Mechanical Adjustment in the Head

  - Additional:
    - Traditional ‘Jaw Position Indicator’ test and ‘Light vs Radiation Field’ test may be considered together. The user may test the accuracy of jaw positions using the light field (at 3 clinically relevant positions including across the central axis). This is the error most commonly seen from a Light vs Radiation Field test.
      - The jaw position may need to be adjusted slightly or is not tracking linearly across the field.
    - After the jaw positions are verified, the light field may be checked against the radiation field for 1 field size. Do not expect light vs radiation to change with different jaw positions.

# TG265
# Discussion – Monthly Tests

- Photon and Electron Profile Constancy

  - Time to Perform Test (Average): 15 Minutes
  - Performed After Maintenance: Any Work on Ion chamber, Dosimetry or Beam Production System

  - Additional: Some centers check this daily with a device that has multiple off axis detectors. Is it possible to closely monitor daily tests from a comprehensive daily check device and still be able to detect small changes in the profile shape?

# TG265
# Discussion – Monthly Tests

- <u>Electron Beam Energy Constancy</u>

  - Time to Perform Test (Average): 13 Minutes
  - Performed After Maintenance: Any Work on Ion chamber, Dosimetry or Beam Production System

  - Additional: This test is a good indicator of how well electron beams are performing, particularly if electrons are not used frequently in the clinic. Some centers check this daily with a comprehensive daily check device. Is it possible to detect small changes in energy (fraction of a mm change in depth dose) by closely monitoring daily tests?

# TG265
# Discussion – Monthly Tests

- <u>Treatment Couch Position Indicators</u>

  - Time to Perform Test (Average): 7 Minutes
  - Performed After Maintenance: Any work on Couch; Any Work on Couch Position Potentiometers

  - Additional:
    - Should check the absolute position for at least one point (daily couch positions within treatment fields rely on the absolute position of the couch being correct). If you check two absolute positions, then a relative check is inherently done as well.
    - Table Angle Indicators and Table Walkout are important too. Winston-Lutz Type Test is more sensitive at picking up errors in table walkout with rotation.

# TG265
# Discussion – Monthly Tests

- <u>Wedge Placement Accuracy/Wedge Factor</u>

  - Time to Perform Test (Average): 22 Minutes
  - Performed After Maintenance: Wedge Position Adjustment/Wedge Stuck; Adjustment to Wedge Mount (Varian), Y Jaw Work for EDW (Varian)

  - Additional: The placement of the wedge (or the profile shape creation with the wedge) is the most important aspect to test. Do not expect the wedge factor (transmission through the wedge) to change over time.
    - Physical Wedge – Test the placement accuracy monthly.
    - Universal/EDW wedge – Test the wedge profile shape and position monthly against a baseline. The easiest way to verify this is to measure the wedge profile.

# TG265
# Other Considerations

- Role of Vendor Provided Tests
- Role of TG100

- Presentation of List of Recommended Tests:
  - Include Possibilities for Decision Making
  - Include Guidance for Tests

# Conclusions

- Qualified Medical Physicists must make many decisions in regard to establishing or maintaining an effective quality assurance program for linear accelerators.

- TG265
  - Minimum test requirements for traditional linear accelerators.
    - Include decision making guidance based on individual clinical practice.

# Thank You!

- Peter Balter
- Robin Miller
- John Duhon
- David Vassy
- Gerald White
- Francisco Aguirre

- Lynne Fairobent - AAPM
- Russell Tarver – Chair of Subcommittee on Practice Guidelines