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# Tools and Techniques for Efficiently Implementing the Recommendations of Task Group 142

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University of Michigan

# Disclosures

I have a faculty appointment at the University of Michigan Department of Radiation Oncology and I am employed by the Department of Veterans Affairs.

I'm part of a consortium investigating how Varian Developer Mode can be used to automate linac QA.

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I’m not endorsing any commercial or non-commercial product.

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# Outline

1. TG-142 Highlights
2. Preliminaries
3. Commercial Solutions
4. If you DIY
5. Other TG reports
6. Beyond the Recommendations

# Objective

To convey a variety of tools, references, and ideas that may enhance your TG-142 based linear accelerator quality assurance program.

# But first…..

## Top 5 reasons TG-142 should be followed:

5. Since you perform QA you might as well follow the latest AAPM guidelines.

4. The tests to perform, the tolerances, and the frequency are spelled out for you – the easy button!!

3. Some accrediting organizations require compliance with TG-142.

2. Some states are mandating it (not the intent!!).

1. TG-142 represents consensus guidelines from a panel of experts.

# Review of TG-142

1. TG-142 was charged with updating the **recommendations** of TG-40 Table II AND adding asymmetric jaws, MLCs, and dynamic/virtual wedges.
2. The task group also recommended QA for linac imaging devices and respiratory gating systems.
3. The type of treatment (IMRT, SRS/SBRT, TBI, TSET, etc.) was a factor considered by the TG.
4. VMAT was not included in the recommendations.

# Review of TG-142

4. Includes tables describing daily, monthly, and annual QA with tolerances for non-IMRT, IMRT, and SRS/SBRT.
5. Specifically mentions detector arrays in the context of annual testing.
6. Includes machine specific guidance (Varian, Elekta, Siemens).
7. Recommend adhering to tests / frequencies unless analysis (FMEA?) justifies another approach.

# Review of TG-142

8. Acceptance and commissioning are used to set baselines.
9. Describes 3 action levels to respond to deviations from recommended tolerances (levels 1, 2, and 3, with 3 representing a stop treatment).
10. Outlines roles of QMP, QA team, other personnel.
11. Refers to, and builds on, other task group reports besides TG-40.

# Preliminaries

## Tools - Dosimetry

Single Ion chambers+ electrometer - daily, monthly, annual

*ADCL cal 'd local standard, "field" chamber for linearity, etc*

Diode, diamond detectors – specialized annual tests

Ion chamber / diode detector daily check devices

Ion chamber and diode arrays – monthly and annual testing

*Great for constancy, including energy (Gao et al 2013)*

1D scanning water tank – monthly, annual

3D scanning water tank – annual

*Detector arrays more efficient, less prone to setup errors*

EPID – monthly and annual

*Multi-use, great for response vs gantry angle*

# Preliminaries

## Tools - Mechanical

Levels, rulers, graph paper - daily, monthly, annual

*Old school still works*

Specialized test tools – daily, monthly, annual

*Increased efficiency*

*Available in a variety of configurations to hold films, align lasers, etc.*

Detector arrays – monthly and annual

*Some detector arrays come with a variety of options*

Radiochromic / radiographic film – monthly and annual

*EPID very efficient when available and appropriate*

EPID – daily, monthly, annual

# Preliminaries

## Tools - Imaging

Linac vendor supplied phantoms - daily, monthly, annual

*Often the vendor supplies useful phantoms.*

*Acceptance documents may provide baselines.*

Specialized phantoms – daily, monthly, annual

*Can enable increased efficiency, automated analysis.*

*Capture your own baselines.*

# Preliminaries

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## What about redundancy in TG-142?

1. TG- 142 includes overlap on the frequency of certain tests (daily, monthly, and annual have same test listed). *Example – output tested daily, monthly, and annually with tolerances of 3%, 2%, and 1% respectively. Different test methods and uncertainties are appropriate.*
1. Per TG-142: *"This overlap in frequency should have some level of independence such that the monthly check would not simply be a daily check."*
3. The protocol further clarifies that the QMP should determine the extent of the independent measurements.

# Preliminaries

## Timing

**When is the question!**

1. Perform the entire annual in a short block of time.

   ***Which definition of annual do you use?***

   *(food for thought…..MQSA defines annual as within 14 months)*
2. Break it up into components (mechanical, dosimetry,and imaging components, for example) and spread out the pain.
3. Distributed annual – nibble away at it each month

   *(Don Roberts at U of Michigan has efficient breakdown)*

# Commercial Solutions

1. I'm going to run through some commercial options for performing, documenting, and tracking TG-142 results.
2. I will convey PORTIONS of what these products can do based on information readily available to me – consider it a sneak preview!
3. If you're selecting software or tools, talk to the vendors for the full details and capabilities.
4. No endorsements here....

# Commercial Solutions

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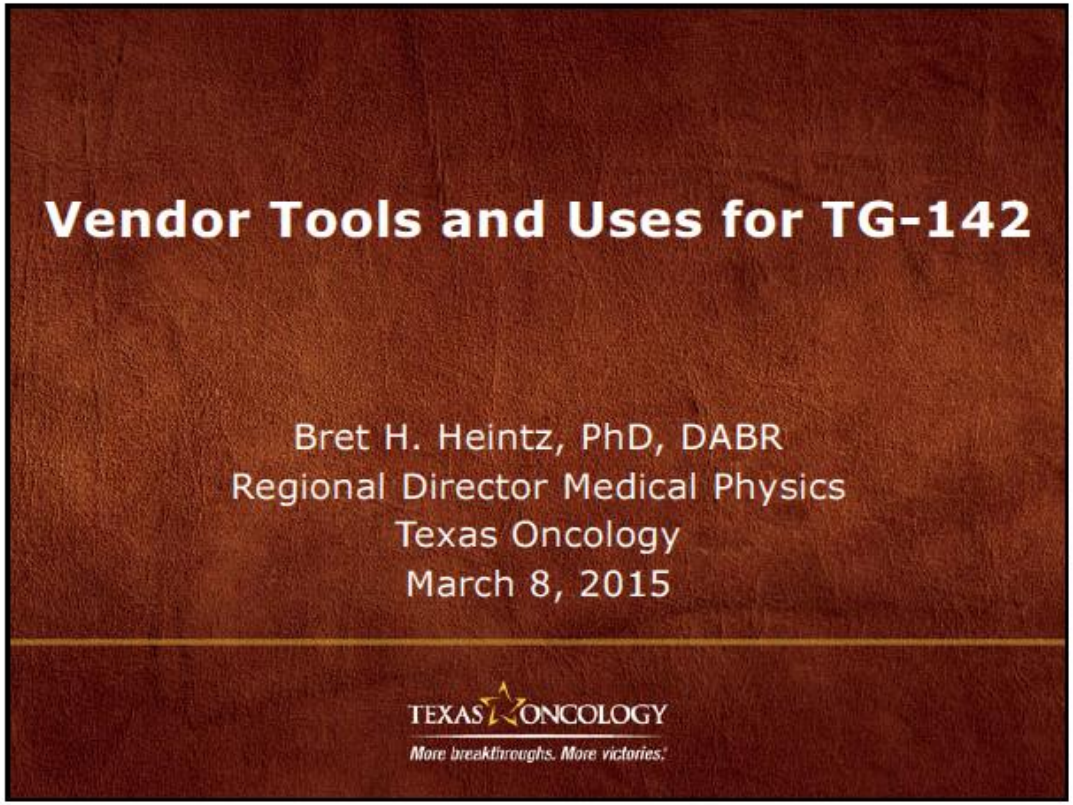
This reference from the 2015 AAPM Spring Clinical Meeting describes the evaluation of commercial software. (*multiple TG-142 presentations from this meeting were excellent!)*



# Commercial Solutions

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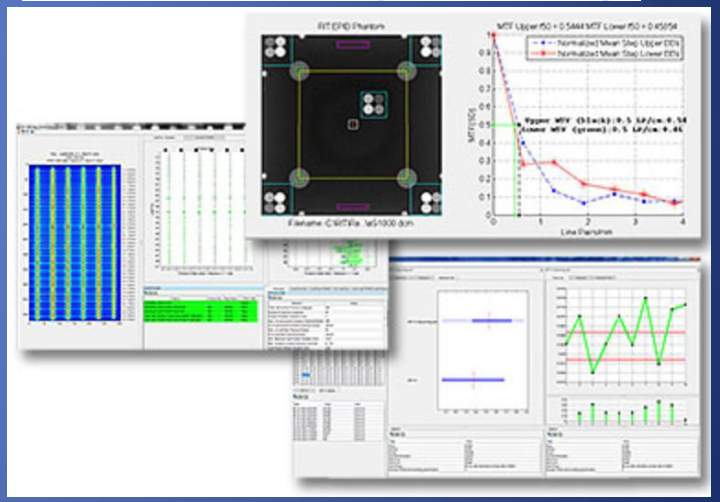
**Radiological Imaging Technology (RIT) software packages:**

1. Automated software accomplishes all TG-142 tests that use an image.
2. Stores, trend tracks, and analyzes results of other TG-142 tests.
3. Can be customized.
4. Includes QA plan files.
5. Supports multiple phantoms, arrays, scanner outputs, and image formats.
6. Cloud-based comparison service.

RIT G142



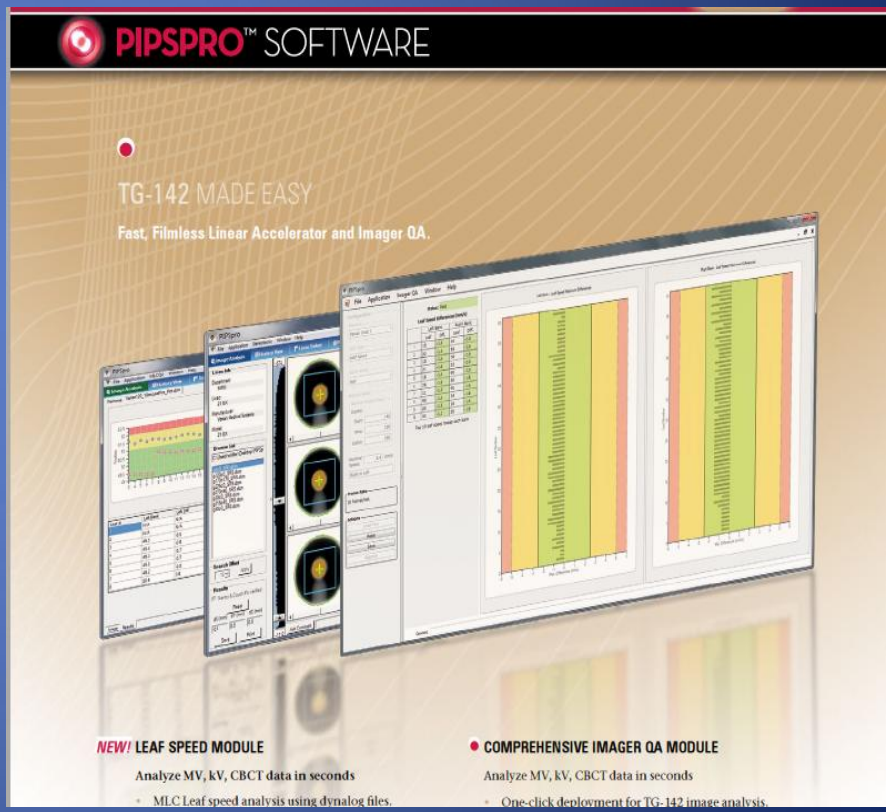
RITCognition™ (patent pending)

RITtrend
For Electronic QA Record Keeping

# Commercial Solutions

**Standard Imaging PIPSpro:**

1. Automated software performs extensive TG-142 imaging and MLC QA, plus mechanical QA.
2. Automatic log file analysis.
3. Customizable.
4. Includes special phantoms and supports other phantoms.
5. Analysis and trend track tools.
6. QA Pilot cloud tool available.



# Commercial Solutions

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**Sun Nuclear:**

1. Offers both MachineQA and ATLAS for TG-142 QA.
2. Automatic image analysis for MLC, imager, and mechanical QA.
3. MachineQA supports a variety of phantom platforms including Sun Nuclear ImagePro.
4. ATLAS is customizable for storing, analyzing, and trend tracking QA data.
5. Other QA devices / arrays available.

SUN NUCLEAR corporation

**Imaging and Mechanical QA Tests**

- CBCT Image Quality & Accuracy
- kV Image Quality & Accuracy
- MV Image Quality & Accuracy
- MLC Picket Fence
- MLC Log File Positioning & Leaf Speed
- VMAT Tests:
  - Dose Rate versus Gantry Speed
  - Leaf Speed
  - Arc Point Dose
  - DMLC Point Dose
- Winston-Lutz Radiation Isocenter
- Winston-Lutz Machine Isocenter
- Gantry Starshot
- Couch Starshot
- Collimator Starshot
- Light / Radiation Field Congruence
- Field Size
- Beam Flatness
- Beam Symmetry

# Commercial Solutions

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**IBA myQA:**

1. Automatically analyzes images for imager, MLC, and mechanical QA.
2. Also automatically imports and analyzes results from IBA StarTrack or MatriXX chamber array devices.
3. Flexible –can store any other manually entered QA result for analysis and tracking.
4. Supports any phantom platform.

# Commercial Solutions

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**Mobius Medical Systems**

**DoseLab:**

1. Performs automatic analysis of images for a spectrum of QA tests.
2. Automatic log file analysis.
3. Customizable to store, analyze, and trend track manually entered QA data.
4. Can be used with Mobius phantoms or phantoms from other vendors.

DoseLab

# Commercial Solutions

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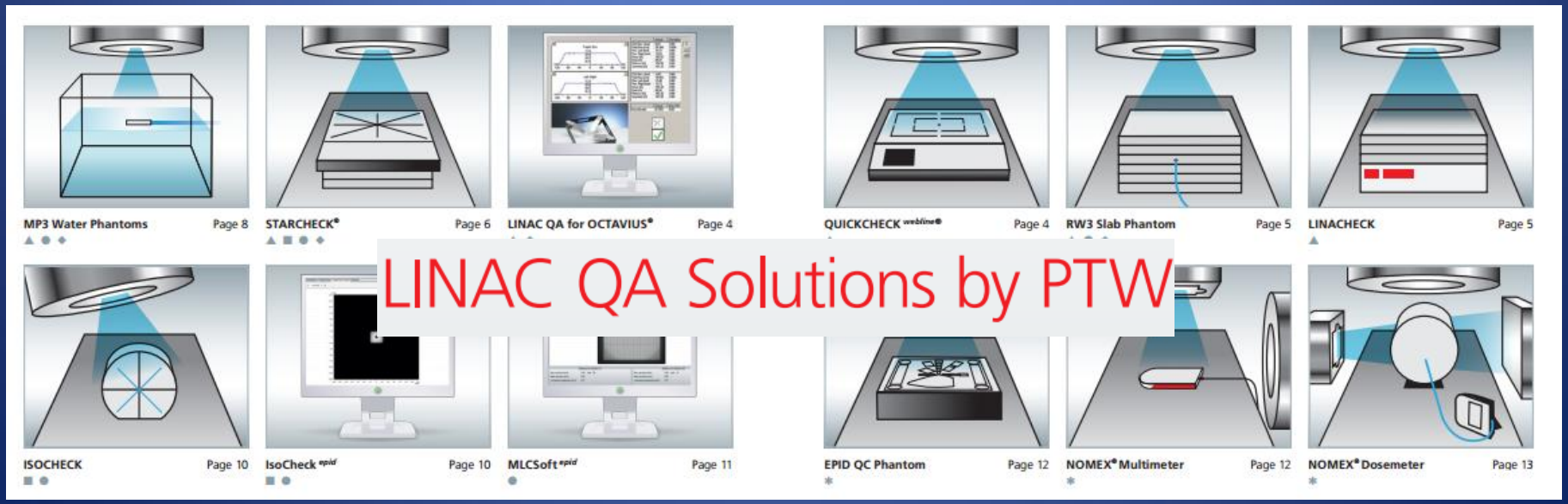
**PTW:**

1. Offers a variety of tools, phantoms, and arrays that have associated software for performing QA.
2. Modules for mechanical, dosimetry, MLC, and imager QA.
3. Automatic comparison of images to baseline.
4. Trend tracking included in many of the options.



# Commercial Solutions

**ZapIT! Medical:**

1. Offers a cloud based software solution for managing TG-142 and other QA testing.
2. Can record results, set and manage baselines, and trend track.
3. Includes a physics manual with a standard library describing how to perform tests.


ZapIT! QA

# Commercial Solutions

**Raven by LAP:**

1. A CCD-based QA device that records light and radiation field images.
2. Includes software for recording and analyzing results.
3. Can perform mechanical, MLC, and dosimetry QA per TG-142.

RAVEN
LINAC QA BY LAP

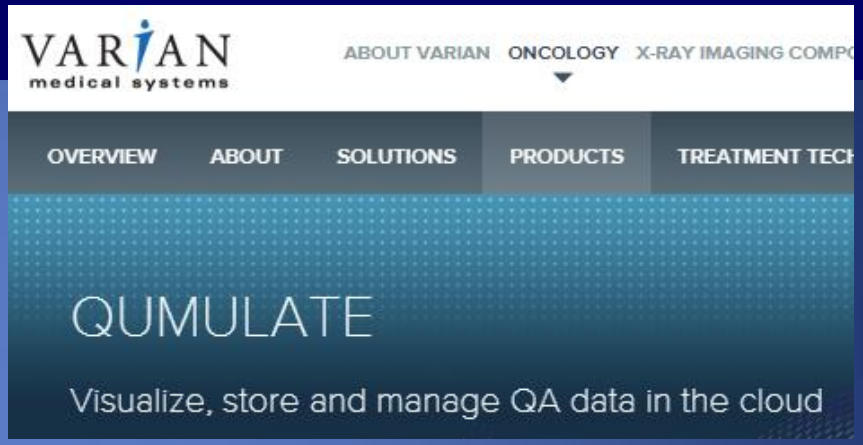

One device measures, verifies and records your LINAC's optical, mechanical, and radiation parameters.

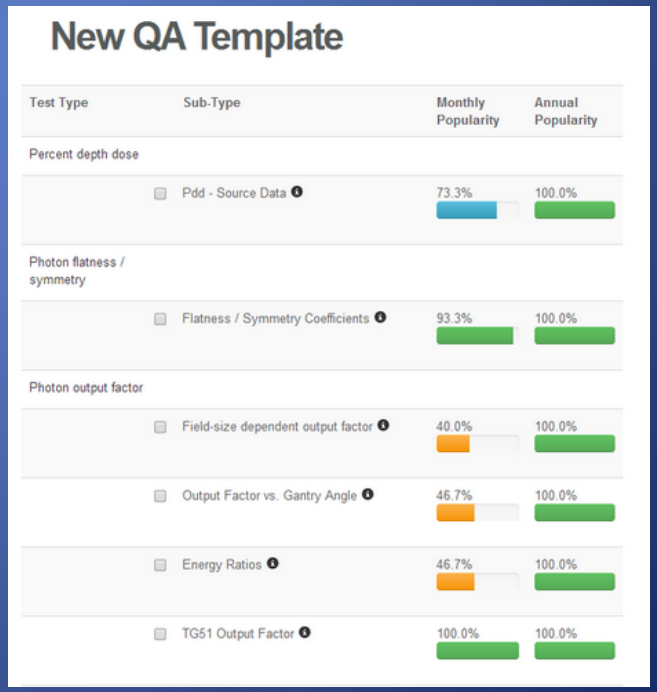
| TECHNICAL DATA | |
|---|---|
| Screen Size | 25 × 25 cm |
| Resolution | 0.25 mm |
| Detector Type | CCD Camera with phosphor screen |
| Dimensions (W × H × D) | 294 × 434 × 761 mm<br>11.6 × 17 × 30 inch |
| Weight | 16.7 kg |
| PC / Software | included |
| Interface | USB, Ethernet |

# Commercial Solutions

**Varian Qumulate *(on the horizon)*:**

1. According to the web site a post beta release is coming soon……
2. A software tool for managing QA results in one location.
3. Enables not only analysis but comparisons to other machines.



# Commercial Solutions

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**One more disclaimer:**

Other vendors offer test tools and phantoms that can assist with accomplishing TG-142 QA.

See the vendors at this conference for current and complete information!

# If you DIY

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**If you use "home-grown" software …….**

1a. Perform QA on your software / spreadsheet.

1b. Double-check critical calculations.

2. Make it easy to ID when tolerances exceeded:

- explicitly list baselines, tolerances next to results
- automatic analysis with flags, color coding

3. KISS principle.

4. Trend results and revisit tolerances.

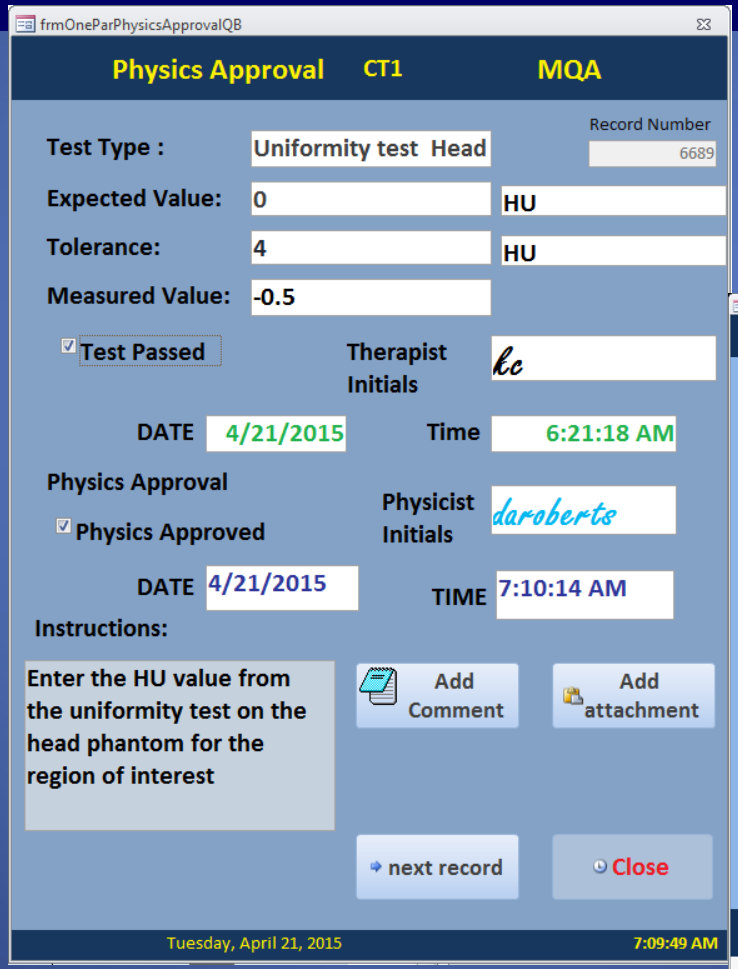
5. Track revisions and changes.

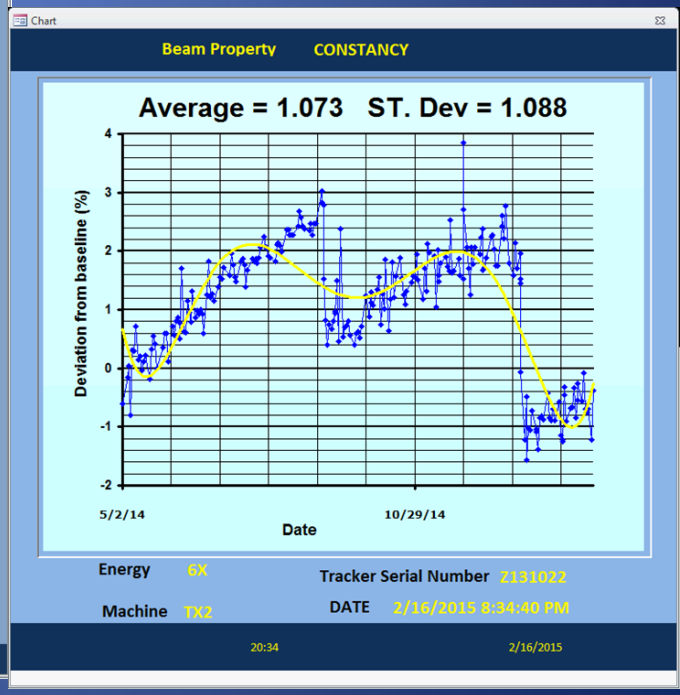
6. Seek out QA team approval and/or peer review.

7. "Lock" results (annual, monthly) or make a pdf.

# If you DIY

Example of a sophisticated TG-142 software solution from Don Roberts at the University of Michigan



# If you DIY

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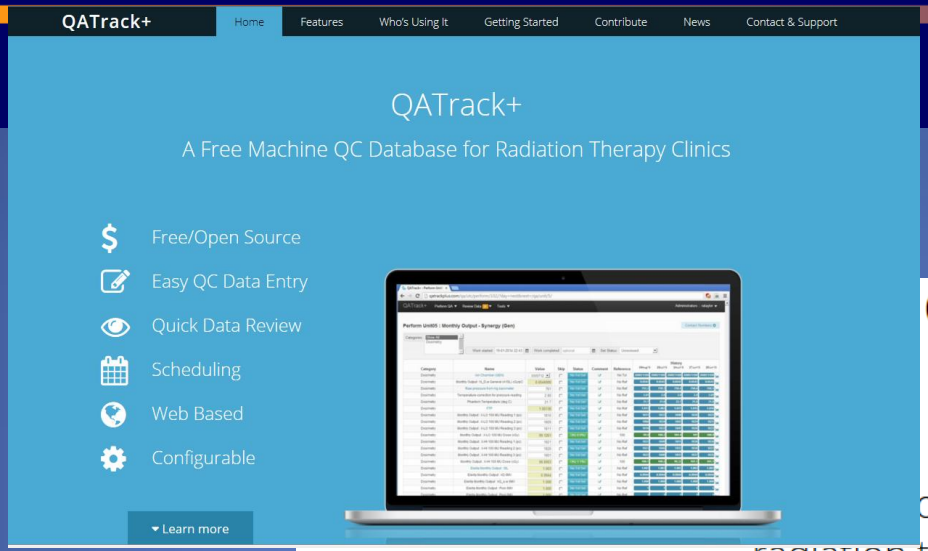
QATrack+ software may aid in scheduling, recording, and tracking results.

*http://qatrackplus.com*




QATrack+

d for the needs of a modern radiation therapy clinic

QATrack+ has many features to make your life easier:

- ✔ Replace paper forms & spreadsheets with a unified system
- ✔ QC test types including numerical, boolean, calculated, file upload & analysis, and more
- ✔ Multiple user groups (Physicists, Therapists, etc.) and group specific permissions via a configurable authorization system
- ✔ Built in review & approval functionality for QC data
- ✔ Fast and easy data trending
- ✔ Scheduling system to keep on top of your QC program.
- ✔ Did we mention it's free?.

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# If you DIY

A free TG-142 guide on MedPhys Files

# If you DIY

There are other free references available on the web.

*One example, a free guide to TG-142 currently available on the Standard Imaging web site.*

STANDARD IMAGING®

User's guide to TG-142

R. K. Fulkerson, Ph.D. and S. M. Holmes, Ph.D.

Contents

# Other TG Reports

**Other TG reports interplay with TG-142, partial list:**

1. TG-51 (Protocol for Clinical Ref Dosimetry)
   *Of course.....ensure you use the 2014 addendum with recommendations on chambers, new $k_Q$ values, and special considerations and corrections for FFF beams.*
2. TG-179 (QA for IGRT Utilizing CT)
   *Imaging QA recommendations in Table II*
3. TG-75 (Management of Imaging Dose During IGRT)
   *Includes dose comparison levels, also provides detailed information on calculating effective dose.*

# Other TG Reports

4. TG-76 (Management of Resp Motion in Rad Onc)
   *Besides being a great reference on managing respiratory motion, the TG-76 report provides QA recommendations for a variety of respiratory management approaches.*
5. TG-100 (Methods for Evaluating QA in Radiotherapy)
   *Implements a risk-assessment method to approach QA, likely to substantially change what we do and how often.*
6. TG-40 (Comprehensive QA for Rad Onc)
   *Still very relevant and useful! Table IV describes QA for measurement equipment (all QA gear needs QA as well!)*

# Other TG Reports

7. TG-111 (Methodology for Eval of Rad Dose in X-ray CT)
   *Detailed description of how to measure dose for CBCT*
8. TG-106 (Accelerator Beam Data Commissioning Equipment and Procedures)
   *Provides excellent details on performing precision measurements on linacs*
9. TG-226 (Commissioning and QA of X-ray IGRT Systems)
   *Recommendations on acceptance testing and commissioning of IGRT systems as well as methods for measuring dose*

***And many others, including modality specific reports.***

# Beyond TG-142

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**Entering a dangerous area……opinions!**

Ideas above and beyond TG-142 to consider:

1. Dosimetric leaf gap
2. File and directory checks
3. Complex VMAT or IMRT reference plan
4. Small field output or penumbra test
5. Winston-Lutz style alignment test
6. Entrance skin exposure as a path to imaging dose
7. Absolute couch positions (daily vs monthly)
8. Daily symmetry or off-axis ratio
9. Backup daily QA method and baselines

# Beyond TG-142

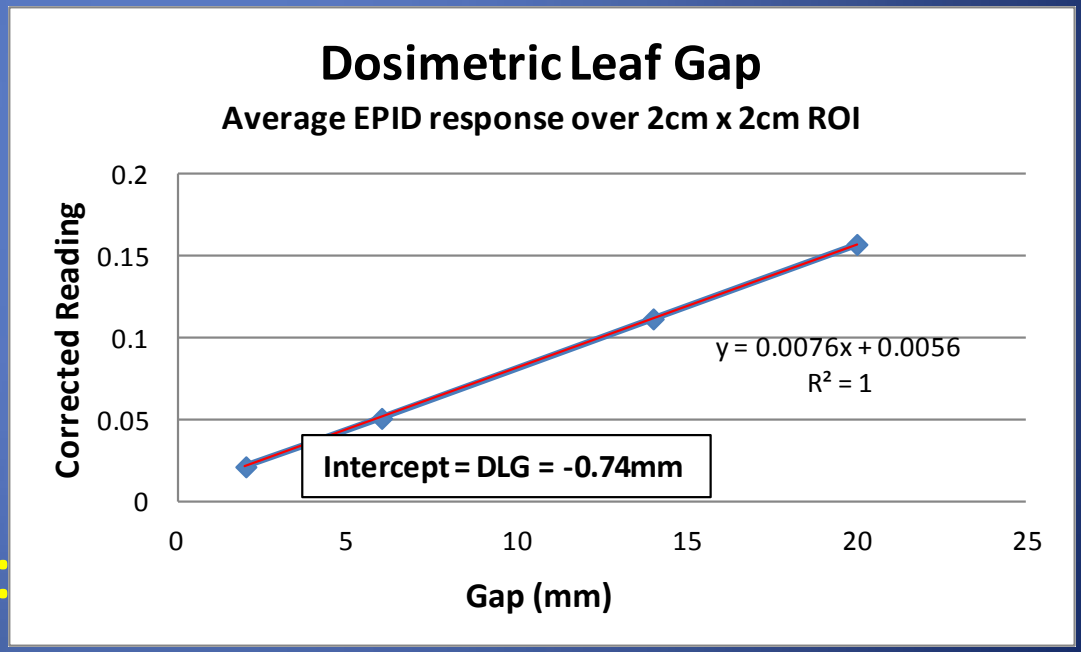
## Dosimetric Leaf Gap

1. TG-142 monthly MLC leaf position tolerance is 1mm.
2. Rangel and Dunscombe (2009) showed that a systematic 0.3mm MLC gap error can correlate to a 2% EUD deviation in dynamic IMRT delivery.
3. Can use a sliding gap test as a constancy tool and deliver daily or less frequently.
4. Can measure the dosimetric leaf gap offset periodically (ion chamber, detector array, EPID, pick your tool of choice).

# Beyond TG-142

## Dosimetric Leaf Gap

1. LoSasso et al (1998) describes method for measuring leaf gap offset, applied to EPID by Mei et al (2011).
2. If measure with an EPID will typically see a value less than ion chamber result.
3. Sample DLG results:
Ion chamber = 1.14mm
EPID = 0.74mm



# Beyond TG-142

## File and Directory Checks

1. Checking for corrupt or changed files is a good idea.
2. TG-142 discusses in context of scrutinizing embedded tables that map jaw positions for dynamic wedges.
3. Need assistance of the vendor to implement meaningful, automated checks on files and directories that aren't already checked during boot up.

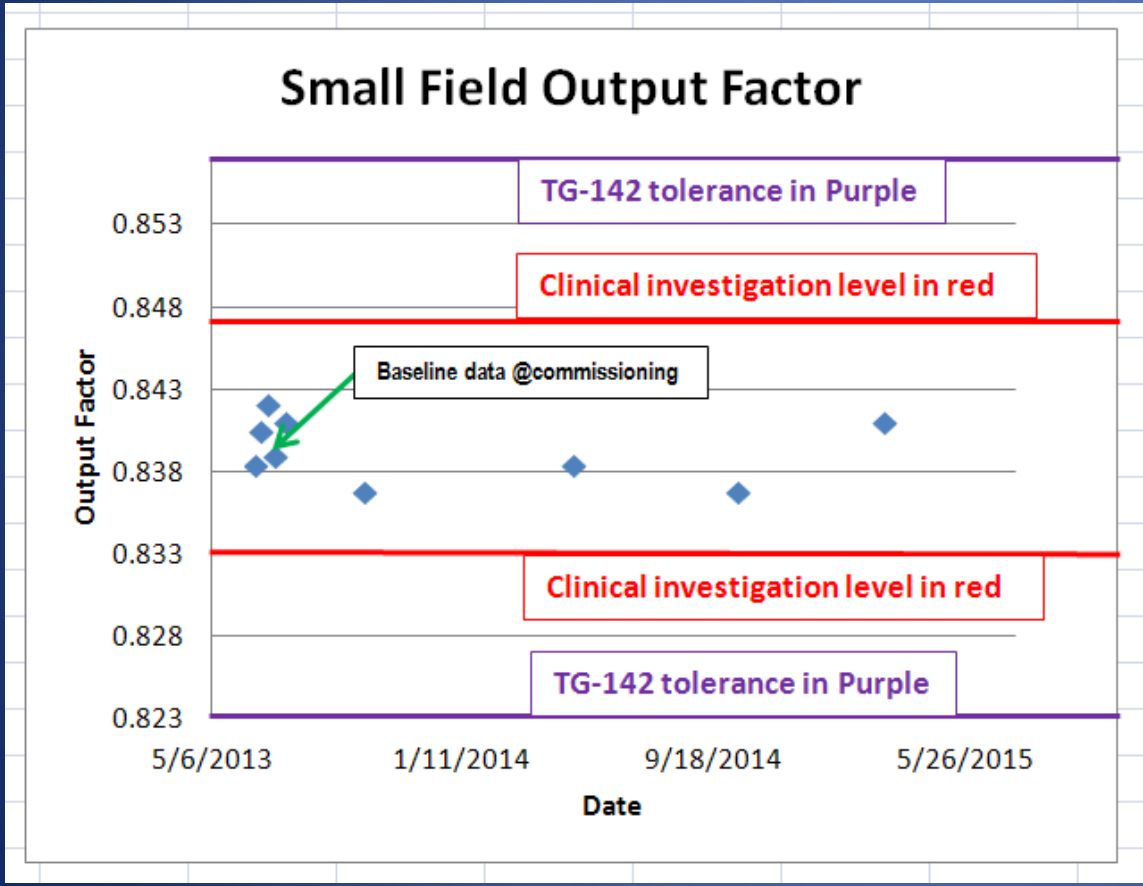
# Beyond TG-142

## Complex IMRT or VMAT delivery

1. Constancy checks are a BIG part of TG-142 linear accelerator QA.
2. A particularly complex IMRT or VMAT plan can be measured on one of your test devices (2D or 3D array) and saved as a constancy test case (ref V. Feygelman).
3. This case can then be re-measured periodically and after upgrades, with the results compared to baseline to re-affirm performance.

# Beyond TG-142

## Small Field Output and/or Penumbra Measurement

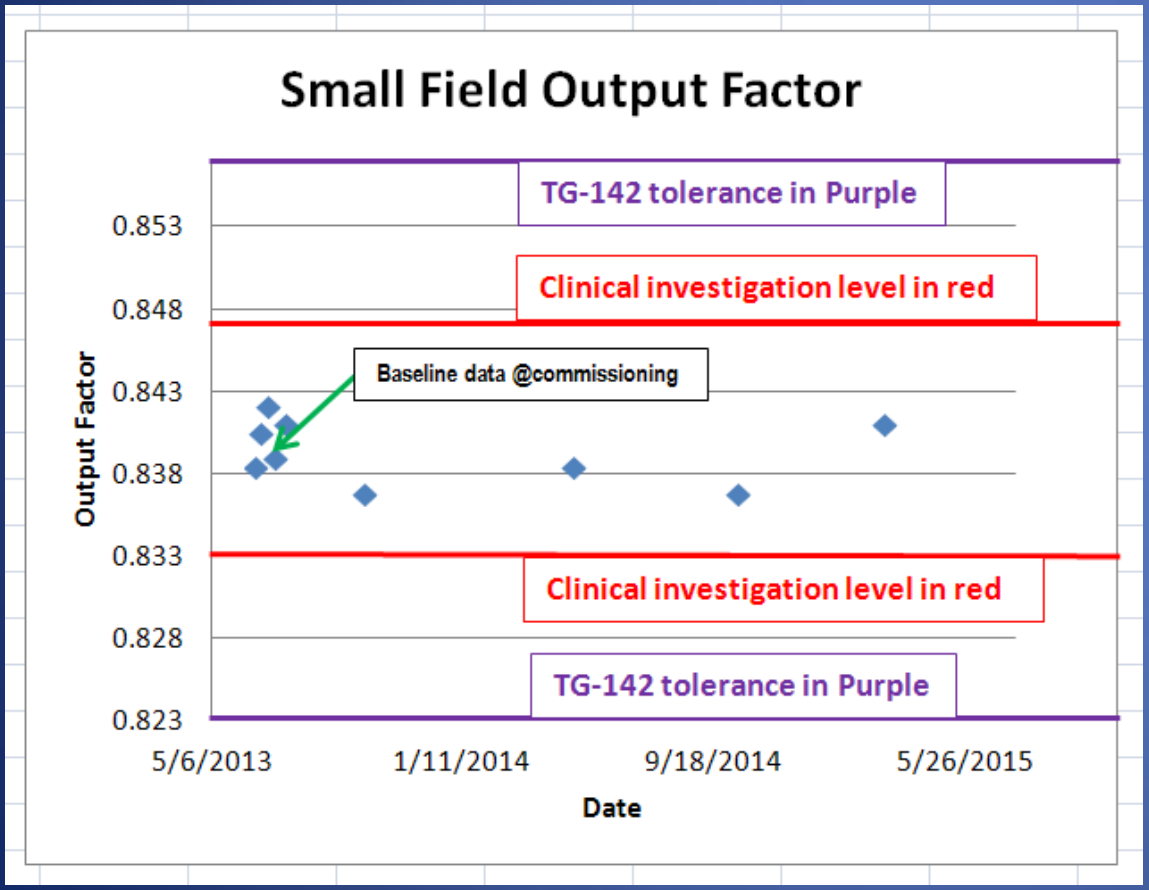



Small field output and penumbra are influenced by the primary focal spot size, shape, and location.

Both small field output and penumbra can be used as constancy checks for focal spot properties.

# Beyond TG-142

## Side Note: Customized Tolerances




A constancy check with careful baselines may allow tolerances smaller than TG-142.

This example demonstrates investigation levels of 0.8 %, vs 2% from TG-142 recommendations.

# Beyond TG-142

## Winston-Lutz Style Test

1. Systems used for SRS are often checked more frequently than TG-142 recommends.
2. ASTRO SRS/SBRT white paper recommends daily Winston-Lutz test (Solberg et al, 2011).
3. Y. Huang et al described experiences with daily Winston-Lutz style testing at 2015 AAPM Spring Clinical meeting.

**Daily quality assurance of coincidence between imaging and radiation isocenter**

Yimei Huang, Bo Zhao, Indrin J. Chetty, James Gordon, Ning Wen

Henry Ford Health System, Detroit, Michigan


- Purpose: The targeting accuracy of an image guided treatment depends crucially on the coincidence between imaging and radiation isocenter. In this study, we developed and implemented an efficient quality assurance (QA) procedure that measures the coincidence between imaging and radiation isocenter daily.
- Methods: A two-step procedure was implemented on a Novalis® Tx. First, four Winston Lutz (WL) portal images at gantry angles of 0, 90°, 180°, and 270° are acquired of a BB that is positioned according to laser or light field close to machine isocenter, the analysis of which provides the offset of the BB relative to the average radiation isocenter ($\vec{r}_1$). Next, the BB was imaged with the ExacTrac® X-Ray (V6.0.5, BrainLAB AG) or cone beam computed tomography (CBCT) of the OBI® system (V1.5, Varian Medical Systems), the analysis of which provides the offset of the BB relative to imaging isocenter ($\vec{r}_2$). The vector, $\vec{r}_2$- $\vec{r}_1$, is then the deviation between the imaging and radiation isocenter.
- Results: Averaged over a period of 4 months, the overall deviation to the average radiation isocenter is 0.18±0.05 mm (mean±SD) for the ExacTrac system and 0.50±0.09 mm (mean±SD) for the CBCT on the Novalis Tx.

# Beyond TG-142

## kV Imaging Entrance Skin Exposure

Can create a table of free in-air entrance skin exposure for kV imaging using the two point measurement method of **Harpen (Med Phys, 1996)**, then compare to baselines.

**Entrance Skin Exposure and Dose Chart - 15 cm Above Isocenter**

Machine: xxxx  Physicist: xxxx

Date: xxxxx

NOT A TECHNIQUE CHART - USE ONLY FOR REFERENCE

| PROJECTION | Technique kVp | Technique mAs | Setup SID (cm) | Distance Above Iso (cm) | Iso to Detector distance (cm) | Entrance Skin Exp (mR) for 10 mAs |
|---|---|---|---|---|---|---|
| Reference @ 10 mAs | 50 | 10 | 150 | 15 | 50 | **34** |
| Reference @ 10 mAs | 60 | 10 | 150 | 15 | 50 | **49** |
| Reference @ 10 mAs | 70 | 10 | 150 | 15 | 50 | **66** |
| Reference @ 10 mAs | 80 | 10 | 150 | 15 | 50 | **87** |
| Reference @ 10 mAs | 90 | 10 | 150 | 15 | 50 | **110** |
| Reference @ 10 mAs | 100 | 10 | 150 | 15 | 50 | **137** |
| Reference @ 10 mAs | 110 | 10 | 150 | 15 | 50 | **166** |
| Reference @ 10 mAs | 120 | 10 | 150 | 15 | 50 | **198** |

If you measure HVL #'s, add your technique information, then you can estimate effective doses using the FDA handbook **(doc FDA 89-8031)**.

# Beyond TG-142

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## Daily check of symmetry or off axis response

1. Many daily check test tools test off axis as well as central axis dose constancy.
2. A vendor recently issued customer notices regarding potential photon AND electron symmetry problems
3. Simple daily tests of symmetry are fast and efficient with modern tools and may be appropriate.

# Beyond TG-142

## Couch Position Indicators

1. Most centers use some sort of couch tolerances for their treatments as a safety check.
2. Some setups require the therapists to set couch positions, especially couch vertical.
3. Conclusion: couch values can be important.
4. TG-142 recommends monthly checks of couch position indicators.
5. Daily checks may be called for depending on how you use couch positions and your hardware.

# Beyond TG-142

## Backup Daily QA Method

1. Monthly and annual testing generally does not impact whether daily treatments are performed.
2. If the daily QA check device is non-operational, treatments are delayed while physics sets up alternative test methods.
3. Develop a fast backup daily test method, document it, and train multiple people.

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Last bit of advice:  Stay tuned for TG-198!

Thank you for your attention!