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THE UNIVERSITY OF NEWCASTLE AUSTRALIA

# Improving MPC and alignment with TG-142


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# Overview

- My colleague has just introduced the Varian Machine Performance Check (MPC) daily check device.

- My talk today will concentrate further on MPC and include two sections:

1. MPC Vs TG-142
    - A look at how MPC currently complies with TG-142 QA recommendations.

2. How can MPC be improved?
    - Some ideas on how the current MPC could be improved from the literature.

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# MPC Vs TG-142 Requirements

Where do we currently stand?

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# TG-142 General Daily Linac QA Requirements

TABLE I. Daily.

| Procedure | Machine-type tolerance: Non-IMRT | IMRT | SRS/SBRT |
|---|---|---|---|
| **Dosimetry** | | | |
| X-ray output constancy (all energies) | | | |
| Electron output constancy (weekly, except for machines with unique e-monitoring requiring daily) | | 3% | |
| **Mechanical** | | | |
| Laser localization | 2 mm | 1.5 mm | 1 mm |
| Distance indicator (ODI) @ iso | 2 mm | 2 mm | 2 mm |
| Collimator size indicator | 2 mm | 2 mm | 1 mm |
| **Safety** | | | |
| Door interlock (beam off) | | Functional | |
| Door closing safety | | Functional | |
| Audiovisual monitor(s) | | Functional | |
| Stereotactic interlocks (lockout) | NA | NA | Functional |
| Radiation area monitor (if used) | | Functional | |
| Beam on indicator | | Functional | |

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Evaluation of the Machine Performance Check application for TrueBeam Linac

Alessandro Clivio[1], Eugenio Vanetti[1], Steven Rose[2], Giorgia Nicolini[1], Maria F Belosi[1], Luca Cozzi[3], Christof Baltes[2] and Antonella Fogliata[3*]

RADIATION ONCOLOGY PHYSICS WILEY

Evaluation of the TrueBeam machine performance check (MPC) beam constancy checks for flattened and flattening filter-free (FFF) photon beams

Michael P Barnes[1,2,3] | Peter B Greer[1,3]

RADIATION ONCOLOGY PHYSICS WILEY

Independent validation of machine performance check for the Halcyon and TrueBeam linacs for daily quality assurance

Yuting Li[1,2] | Tucker Netherton[1,3] | Paige L. Nitsch[3] | Song Gao[3] | Ann H. Klopp[3] | Peter A. Balter[3] | Laurence E. Court[3]

RADIATION ONCOLOGY PHYSICS WILEY

A multi-institutional evaluation of machine performance check system on treatment beam output and symmetry using statistical process control

Diana Binny[1,2] | Trent Aland[1,2] | Ben R. Archibald-Heeren[3] | Jamie V. Trapp[2] | Tanya Kairn[2,4] | Scott B. Crowe[2,4]

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What does MPC test from this list?

So what doesn't MPC test?

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X No safety checks

Its not really fair to expect MPC to do these checks

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# TG-142 Wedge and MLC Daily QA Requirements

TABLE IV. Dynamic/universal/virtual wedges.

| Dynamic-including EDW (Varian), virtual (Siemens), universal (Elekta) wedge quality assurance | | | | |
|---|---|---|---|---|
| | | Tolerance | | |
| Frequency | Procedure | Dynamic | Universal | Virtual |
| **Daily** | Morning check-out run for one angle | | Functional | |

TABLE V. Multileaf collimation (with differentiation of IMRT vs non-IMRT machines).

| Procedure | Tolerance |
|---|---|
| **Weekly** (IMRT machines) | |
| Qualitative test (i.e., matched segments, aka "picket fence") | Visual inspection for discernable deviations such as an increase in interleaf transmission |

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| **Weekly** (IMRT machines) | |
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✓ MPC includes an MLC static position test

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# TG-142 Imaging Daily QA Requirements

TABLE VI. Imaging.

| Procedure | Application-type tolerance: non-SRS/SBRT | Application-type tolerance: SRS/SBRT |
|---|---|---|
| **Daily[a]** | | |
| **Planar kV and MV (EPID) imaging** | | |
| Collision interlocks | Functional | Functional |
| Positioning/repositioning | ≤2 mm | ≤1 mm |
| Imaging and treatment coordinate coincidence (single gantry angle) | ≤2 mm | ≤1 mm |
| **Cone-beam CT (kV and MV)** | | |
| Collision interlocks | Functional | Functional |
| Imaging and treatment coordinate coincidence | ≤2 mm | ≤1 mm |
| Positioning/repositioning | ≤1 mm | ≤1 mm |

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# TG-142 Imaging Daily QA Requirements

TABLE VI. Imaging.

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| Imaging and treatment coordinate coincidence (single gantry angle) | ✓ MPC isocenter checks m | $\leq 1$ mm |
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| Imaging and treatment coordinate coincidence | ✓ MPC isocenter checks ı | $\leq 1$ mm |
| Positioning/repositioning | $\leq 1$ mm | $\leq 1$ mm |

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**Evaluation of the truebeam machine performance check (MPC) geometric checks for daily IGRT geometric accuracy quality assurance**

Michael P Barnes[1,2,3] | Peter B Greer[1,3]

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# Summary

- So MPC is doing a fairly good job at meeting our daily TG-142 requirements.
- But I would suggest that these requirements aren't setting a very high bar for MPC to meet.
- How does MPC compare to a current standard daily check device?

# Current standard Daily QA devices

- Our standard Daily QA devices already exceed TG-142 recommendations
- For example, Sun Nuclear Daily QA3 as an example tests:
  - Output constancy
  - Symmetry constancy (both planes)
  - Flatness (both planes combined)
  - Energy
  - Field size (both planes)
  - Field shift (both planes)

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Yes, all three should cause an MPC Uniformity fail, however, indirect and not all demonstrated as yet in the literature

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    Yes, all three should cause an MPC Uniformity fail, however, indirect and not all demonstrated as yet in the literature
  - Field size (both planes) ✓
  - Field shift (both planes) ✓

    Jaw positions are tested and so is the beam center shift.

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# So does MPC go even further?
# TG-142 Monthly QA tests (Dosimetry and Mechanical)

Table II. Monthly.

| Procedure | Machine-type tolerance | | |
|---|---|---|---|
| | Non-IMRT | IMRT | SRS/SBRT |
| **Dosimetry** | | | |
| X-ray output constancy | | | |
| Electron output constancy | | 2% | |
| Backup monitor chamber constancy | | | |
| Typical dose rate[a] output constancy | NA | 2% (@ IMRT dose rate) | 2% (@ stereo dose rate, MU) |
| Photon beam profile constancy | | 1% | |
| Electron beam profile constancy | | 1% | |
| Electron beam energy constancy | | 2%/2 mm | |
| **Mechanical** | | | |
| Light/radiation field coincidence[b] | | 2 mm or 1% on a side | |
| Light/radiation field coincidence[b] (asymmetric) | | 1 mm or 1% on a side | |
| Distance check device for lasers compared with front pointer | | 1mm | |
| Gantry/collimator angle indicators (@ cardinal angles) (digital only) | | 1.0° | |
| Accessory trays (i.e., port film graticle tray) | | 2 mm | |
| Jaw position indicators (symmetric)[c] | | 2 mm | |
| Jaw position indicators (asymmetric)[d] | | 1 mm | |
| Cross-hair centering (walkout) | | 1 mm | |
| Treatment couch position indicators[e] | 2 mm/1° | 2 mm/1° | 1 mm/0.5° |
| Wedge placement accuracy | | 2 mm | |
| Compensator placement accuracy[f] | | 1 mm | |
| Latching of wedges, blocking tray[g] | | Functional | |
| Localizing lasers | ±2 mm | ±1 mm | < ±1 mm |

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Beam center and Uniformity should assure these, but its not very direct.

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# MPC Philosophy

- So …
  - Its not difficult for MPC to meet Daily TG-142 recommendations
  - MPC already meets some TG-142 Monthly requirements
  - MPC does provide similar tests to current daily check devices

- Therefore:
  - its mainly a question of whether MPC can perform some of these tests better and potentially meet more TG-142 monthly requirements.

- Current MPC: Minimal number of fields.
  - Quick, but the tests are often influenced by multiple linac parameters

- This philosophy makes MPC quick, but difficult to diagnose fails.
  - Personally, id prefer it to take a little longer, but be easier to diagnose.

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# So how can MPC be improved?

Concentrating on the Uniformity test

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# MPC Uniformity - The Problem

- The MPC Uniformity check:
  - Non-flood field corrected (raw) images
  - Ratioed with the baseline image.
  - Smoothed to remove high frequency noise.
  - Uniformity is presented as the variation between the two pixels on the ratio image with lowest and highest values within approximately 75 % of field width.

- The MPC Uniformity test doesn't present results differentiated by plane.

- The Uniformity is theoretically influenced by multiple linac parameters including:
  1. Changes in beam steering (flatness and symmetry)
  2. Changes in beam energy (flatness is sensitive to energy)
  3. Changes in EPID pixel responses

- We want an individual test for each parameter.
  - This can be resolved using PSM corrected EPID imaging

# Introducing the Pixel-Sensitivity-Map (PSM)

- The PSM is the 2D matrix of pixel sensitivities (gains) across the EPID panel.

- PSM removes the EPID detector non-uniformities while preserving the incident beam non-uniformities. I.e. the Dosimetric information (Beam profile shape).

- Methods for determining PSM have been published in the literature.
  - The process is analogous to the detector array calibrations procedures performed on 2D arrays.

**Correction of pixel sensitivity variation and off-axis response for amorphous silicon EPID dosimetry**

Peter B. Greer[a)]

JOURNAL OF APPLIED CLINICAL MEDICAL PHYSICS, VOLUME 14, NUMBER 6, 2013

**A new approach for the pixel map sensitivity (PMS) evaluation of an electronic portal imaging device (EPID)**

Alberto Boriano,[1a] Francesco Lucio,[1] Elisa Calamia,[1] Elvio Russi,[1] Flavio Marchetto[2]

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# How can we use it?

- Once PSM is determined then it can be stored in the MPC application and removed from the raw EPID images on a daily basis.

- We can then apply standard flatness and symmetry metrics to test the incident beam.
  – Note: this is not possible on flood field corrected EPID images because the flood field removes the dosimetric information to provide a uniform image suitable for IGRT.

- Proof of concept and methods have been provided in these publications:

RADIATION ONCOLOGY PHYSICS
WILEY

**A proposed method for linear accelerator photon beam steering using EPID**

Michael P. Barnes[1,2,3] | Frederick W. Menk[3] | Bishnu P. Lamichhane[3] | Peter B. Greer[1,3]

**Rapid acceptance testing of modern linac using on-board MV and kV imaging systems**

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# Beam Energy Check

**Rapid acceptance testing of modern linac using on-board MV and kV imaging systems**


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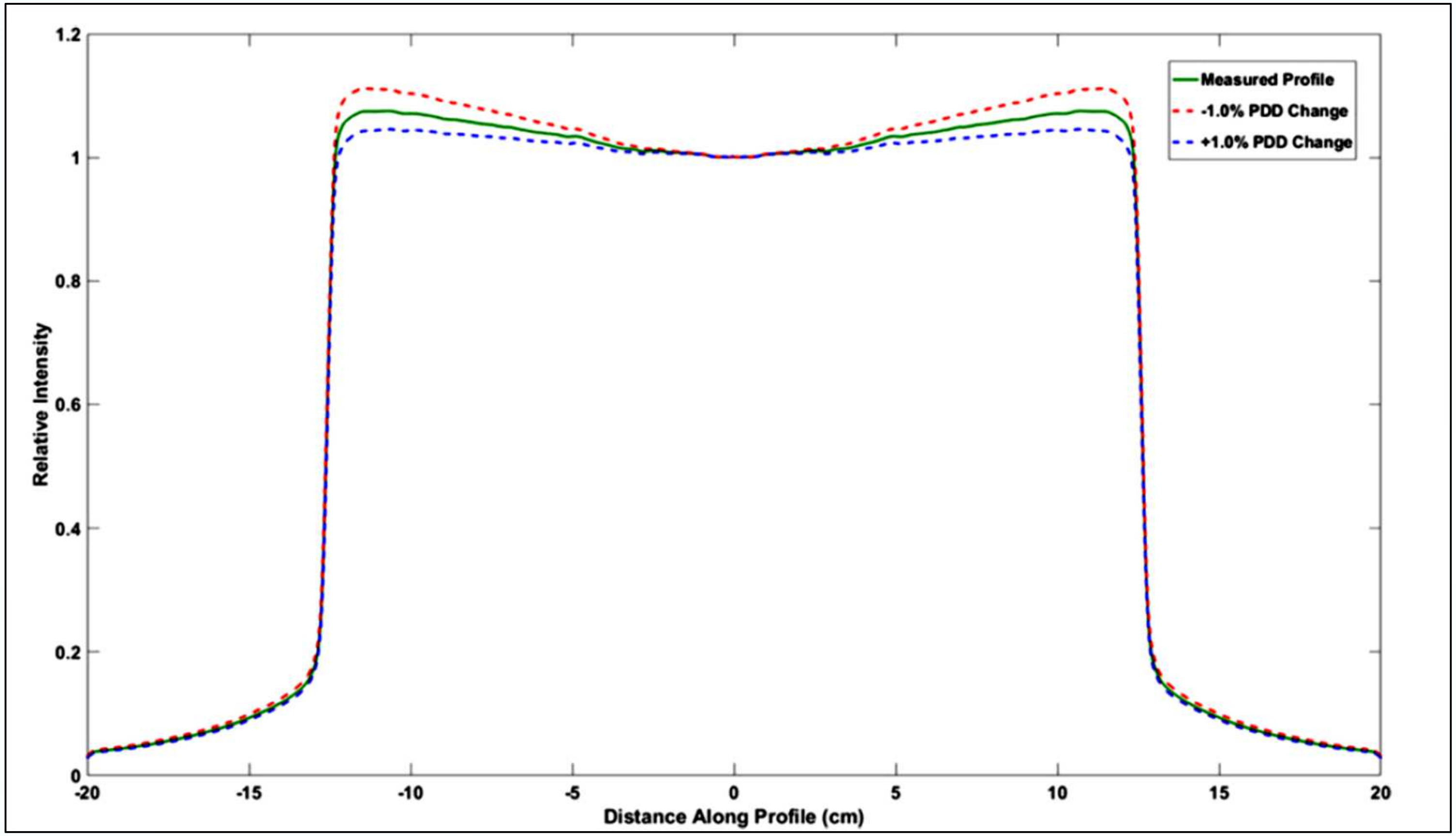


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# Beam Symmetry Check

RADIATION ONCOLOGY PHYSICS

WILEY

A proposed method for linear accelerator photon beam steering using EPID

Michael P. Barnes[1,2,3] | Frederick W. Menk[3] | Bishnu P. Lamichhane[3] | Peter B. Greer[1,3]

- From these profiles we can also measure absolute symmetry.
  - not just change compared to baseline
- This was done in this paper,
  - Simplified PSM at two off axis points (in both planes) to provide two-point symmetry.
  - equivalent to Daily QA3
- Measured symmetry results
  - Compared against SNC IC Profiler
  - Sensitivity assessed via adjustment of the beam steering.
- It may be possible to use this 2-point method for the energy check also
  - Use Off-Axis-Factor instead of flatness, which has been described in the literature as a better metric for photon beam energy

**TABLE 2** Wide field IEC symmetry as measured with EPID and IC Profiler for all four available photon beams.

| Beam | Plane | IC Profiler symmetry (%) | EPID symmetry (%) | % difference |
|---|---|---|---|---|
| 6 MV | In-plane | 100.4 | 100.46 | −0.06 |
| | Cross-plane | 100.3 | 100.34 | −0.04 |
| 10 MV | In-plane | 100.6 | 100.38 | 0.22 |
| | Cross-plane | 100.5 | 100.38 | 0.12 |
| 6 MV FFF | In-plane | 100.4 | 100.23 | 0.17 |
| | Cross-plane | 100.4 | 100.00 | 0.40 |
| 10 MV FFF | In-plane | 100.7 | 100.40 | 0.30 |
| | Cross-plane | 100.4 | 100.00 | 0.30 |
| | | Mean difference | | 0.19 ± 0.18% (1 SD) |

**TABLE 3** Sensitivity of EPID measured wide field IEC symmetry to beam angle steering of the 6 MV beam.

| | Plane | IC Profiler symmetry (%) | EPID symmetry (%) | % difference |
|---|---|---|---|---|
| Before steering | In-plane | 101.0 | 100.88 | 0.12 |
| | Cross-plane | 101.4 | 101.21 | 0.19 |
| After steering | In-plane | 100.4 | 100.46 | −0.06 |
| | Cross-plane | 100.3 | 100.34 | −0.04 |
| Measured change | In-plane | 0.6 | 0.42 | 0.18 |
| | Cross-plane | 1.10 | 0.87 | 0.23 |

# EPID Panel pixel-to-pixel stability

- The third component that affects the MPC Uniformity test is EPID pixel-to-pixel stability.
- This is largely removed using the smoothing in MPC Uniformity, but smoothing is not ideal.
- PSM stability can be tested by comparing the stability of measured PSM when updated (initially suggest) six-monthly.
- PSM stability was demonstrated in the following paper:

Australas Phys Eng Sci Med (2011) 34:459–466
DOI 10.1007/s13246-011-0106-0

SCIENTIFIC NOTE

**Long-term two-dimensional pixel stability of EPIDs used for regular linear accelerator quality assurance**

**B. W. King · L. Clews · P. B. Greer**

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# Compare now again to SNC Daily QA3

- Sun Nuclear Daily QA3. MPC
  - Output constancy ✓ As demonstrated
  - Symmetry constancy (both planes) ✓ Absolute symmetry (both planes)
  - Flatness (both planes combined) ✓
  - Energy ✓
    Off-Axis-Factor/flatness (both planes) and can potentially be used as a check of energy
  - Field size (both planes) ✓
  - Field shift (both planes) ✓
    Jaw positions are tested and so is the beam center shift.

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# Proposal

1. The PSM is measured at install.

2. This PSM is stored in the MPC application

3. When MPC is run the PSM is removed from the current raw field used to measure Uniformity

4. On the corrected image symmetry is measured as well as flatness as an energy check

5. The PSM is updated semi-regularly (eg 6 monthly or annually) and at the time the PSM values are compared against previous values as a measure of EPID performance.

- What this would do is isolate out all of the Uniformity test influences for easy diagnosis.
  - Without adding any extra fields on a daily basis.
  - MPC provides tests similar to daily check devices

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# Thank you

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