

Best Practices with Radiochromic Film



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Outline

- Where we are in radiochromic film dosimetry
- Introduction to radiochromic film
 - Different types of radiochromic film
 - Best practices with radiochromic film
- New radiochromic film dosimetry
 - Multichannel film dosimetry
 - One-scan dosimetry protocol
 - Clinical samples of multichannel film dosimetry
 - IMRT/VMAT, SBRT/SRS commissioning/QA
 - Brachytherapy system commissioning/QA
 - In-vivo dosimetry

Equipment and Tools

- Varian Trilogy Linacs (3)
- GammaMedplus™ iX HDR
- Memorial Sloan-Kettering IMRT/VMAT TPS
- Eclipse™ and iPlan™ TPS
- GafChromic EBT3 film
- FilmQA™ Pro
- Epson 10000XL flatbed scanner
- GafChromic QuiCk™ phantom
- Two slabs of 5-cm thick Solid Water

The charges of AAPM TG-235, "Radiochromic Film Dosimetry: An Update to TG-55"

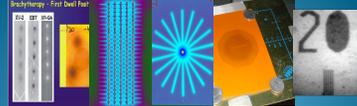
- To review the literature on RCF dosimetry in radiation therapy since TG-55
- To assess the densitometers/scanners used for digitizing RCF since TG-55
- To outline the procedures for accurate dosimetry and to evaluate measurement
- To provide guidelines on RCF dosimetry for clinical radiotherapy applications

Gafchromic Films

- Self developing film
- Eliminates processor
- Can handle in room light
- Can cut to size & bend to shape
- Can immerse in water
- Wide dynamic range
- High spatial resolution
- New software and protocol make film use much more accurate and user-friendly

Films for Beam Geometry

- Radiotherapy (MV photons, electrons, protons, HDR)
 - RTQA2 – 2 cGy to 8 Gy
- Radiology (kV photons)
 - XROA2 – 1 mGy to 20 cGy
 - XRCT2 – 1 mGy to 20 cGy
 - XRM2 – 1 mGy to 20 cGy



Films for Dose Measurement

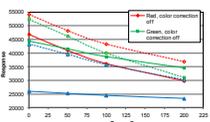
- Radiotherapy (MV photons/electrons/protons)
 - EBT2, EBT3, EBT-XD – 1 cGy to >40 Gy
 - MD-V3 – 2 Gy to 100 Gy
 - HD-V2 – 10 Gy to 400 Gy
- Radiology (kV photons)
 - XR-RV3 – 5 cGy to 15 Gy
 - XRQA2 – 1 mGy to 20 cGy



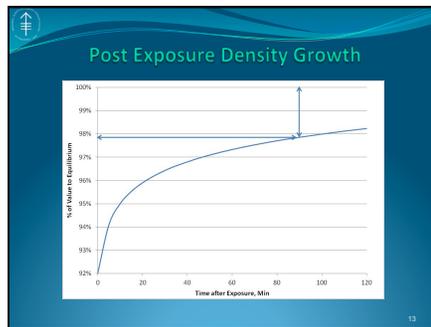
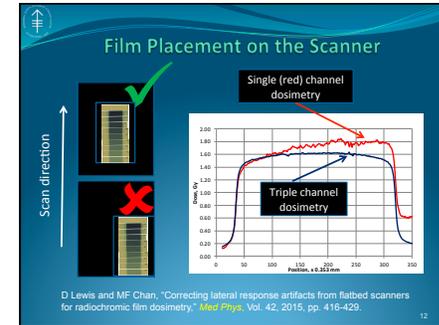
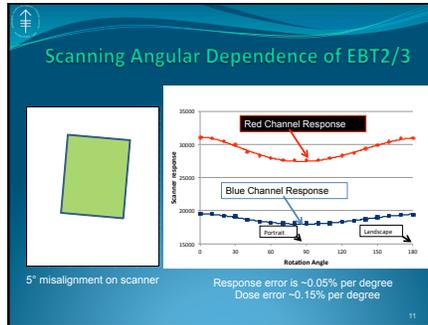
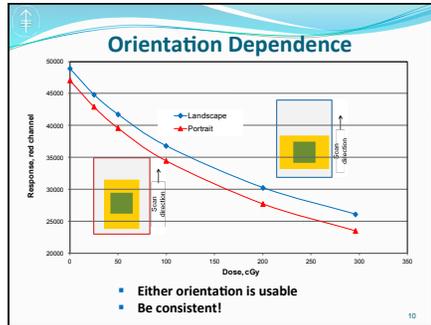
Best Handling of Radiochromic Film

- Film
 - Store in the dark, at temp. < 25°C, humidity < 50%
 - Avoid dust, fingerprints, or crimping
- Film Scan
 - Scanner type
 - Scanning procedure
 - A piece of glass to press the film flat
 - Inter-scan variation (orientation, location on scanner)
 - Ambient temperature/moisture change
 - Post-exposure film density change

Disable All the Image Adjustment Features

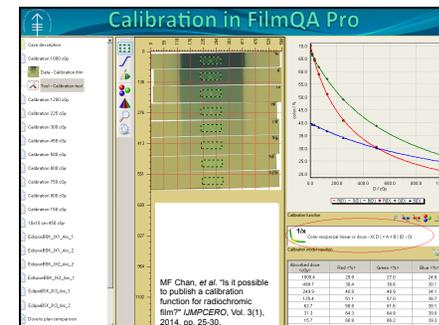
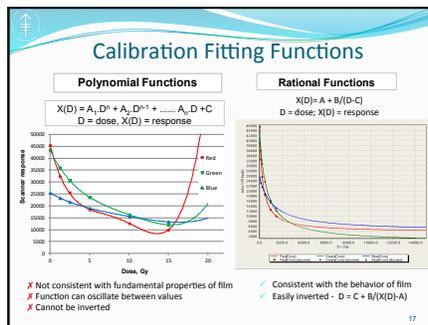
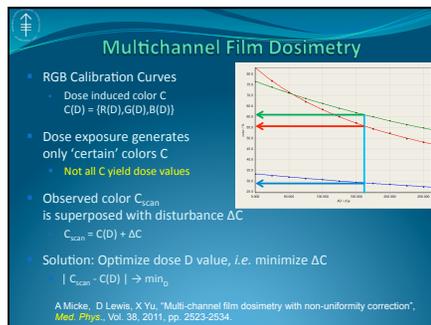



The graph plots Density (0 to 5000) against Dose (cGy) (0 to 225). It compares 'Raw, color corrected' (red line with circles), 'Green, color correction not' (green line with squares), and 'Blue, color correction not' (blue line with triangles). The 'Raw, color corrected' line shows the highest density for a given dose, while the other two lines are lower and relatively flat.



- ### New Gafchromic Film Dosimetry
- A systematic approach
 - Multichannel film dosimetry
 - Removes local disturbances
 - Achieves better calibration function
 - One-scan dosimetry protocol
 - Eliminates inter-scan variability
 - Avoids environmental effects (e.g., temp.)
 - Corrects for post-exposure density growth

Multichannel Film Dosimetry

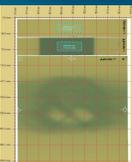


"One Scan" Film Dosimetry

19

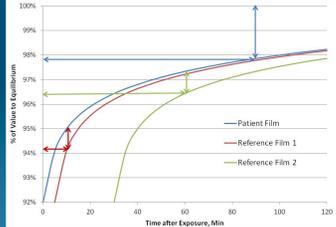
"One-scan" Protocol

- All dose response curves have similar shape
- Scan the patient and reference films together
- Two-point re-scaling - one exposed reference plus an unexposed film - applies to most situations
 - Post-exposure change
 - Inter-scan variation
 - Ambient temp/humidity change
 - Type of scanner used
 - Film-scanner orientation
- Ability to obtain accurate results in minutes



20

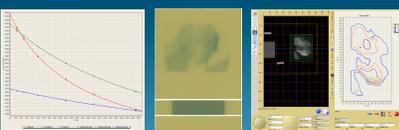
Deal with Post-exposure with One-scan



When $t > 4 \Delta t$ (min) the dose error < 0.5%

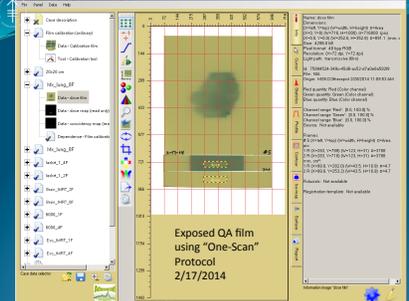
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One-scan Film Dosimetry Method

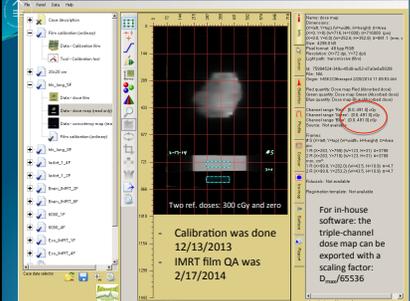


Step 1 Master Curve → Step 2 One-scan Digitization → Step 3 Overlay, add doses for each lot
Ref. D. (0.005-0.01) & 0.

D Lewis, X Yu, MF Chan, "An efficient protocol for radiochromic film dosimetry combining calibration and measurement in a single scan", *Med Phys*, Vol. 39, 2012, pp. 6339-6350.



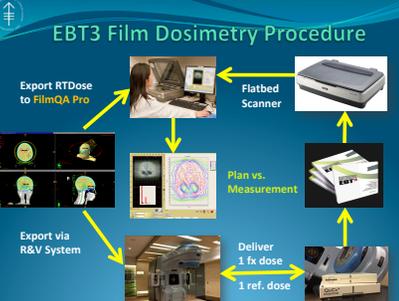
Exposed QA film using "One-Scan" Protocol 2/17/2014



Two ref. doses: 300 cGy and zero

For in-house software: the triple-channel dose map can be exported with a scaling factor: $D_{map}/65536$

EBT3 Film Dosimetry Procedure



Flatbed Scanner

Export RT Dose to FilmQA Pro

Plan vs. Measurement

Export via R&V System

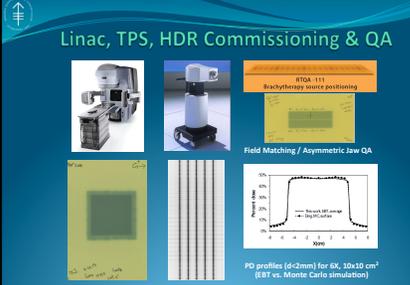
Deliver 1 fx dose

1 ref. dose

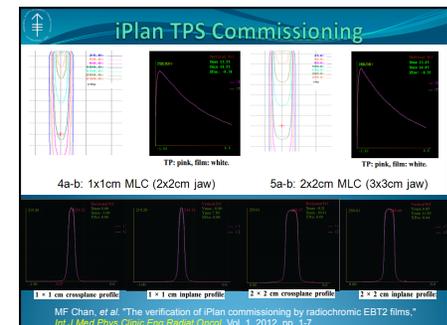
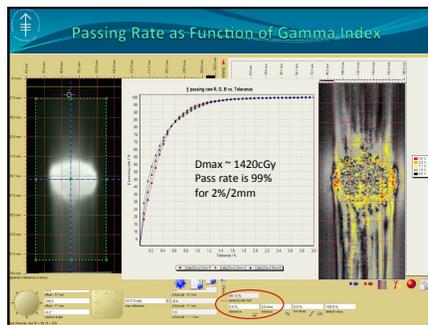
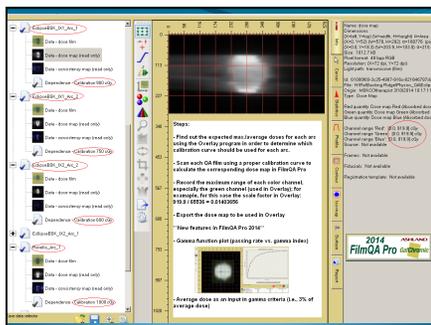
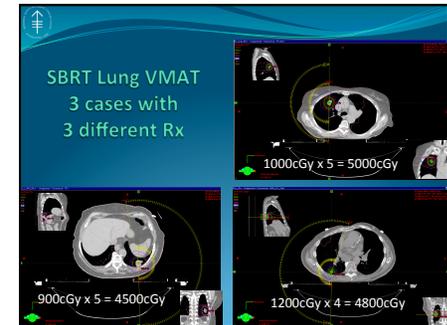
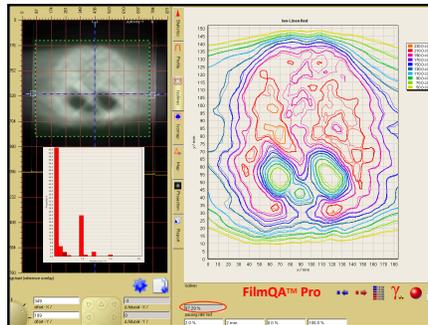
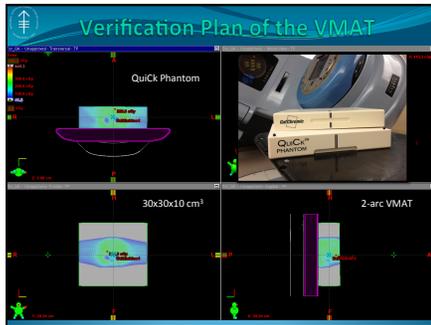
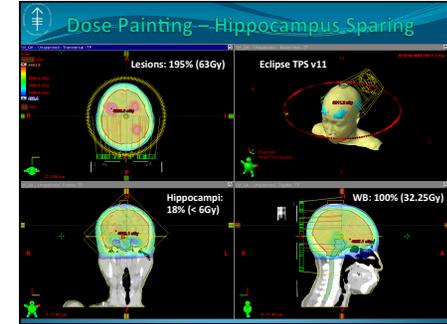
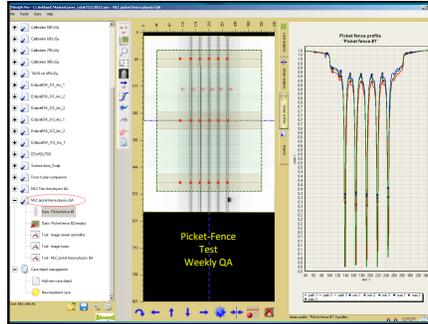
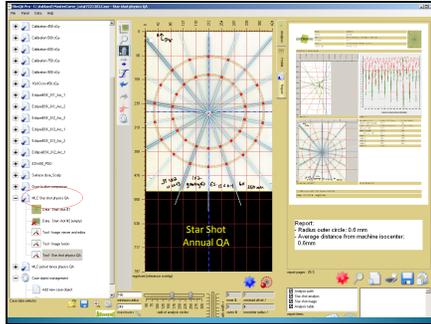
Linacs / Eclipse / iPlan Commissioning

22

Linac, TPS, HDR Commissioning & QA



Lutz - Parallel Opposed Fields Pickett-Fence Test 5 Chiu Tsao, MF Chan, *Med Phys*, Vol. 36, 2009, pp. 2074-83.



Brachytherapy Dosimetry

37

Sr-90/Y-90 Disk-shaped Source

Figure 3. (Left) Comparison of the radiochromic film measurement of the dose (solid line) to the Monte Carlo simulation (broken line) as a function of distance along the central axis from the surface of a disk source of 148 MBq of Y-90; (Right) Bland-Altman plot of the percentage difference between the radiochromic film (minimised) and the Monte Carlo simulation (subtrahend). The horizontal axis is the average of the two values and logarithmic, thereby emphasising the lower doses. The horizontal dotted lines represent plus and minus 5% differences.

RW Wendt. "Principal component analysis of EBT2 radiochromic film for multichannel film dosimetry." *Int. J. Med. Phys. Clin. Onc. Phys. Technol. Oncol.* Vol. 3, 2014, pp. 156-166.

One-scan Protocol in Brachytherapy

Test (Ir-192, Co-60 brachy sources) and reference dose (6 MV linac) films scanned together, aligned on central axis of scan direction

Palmer et al. Evaluation and implementation of triple-channel radiochromic film dosimetry in brachytherapy. *J. Appl. Clin. Med. Phys.* 2014;15 (in press)

Lateral Scanner Position – Multichannel

EBT3 film polarises light in scanner, signal changes with position on scanner plate, mitigated with triple-channel dosimetry

Single-channel dosimetry Triple-channel dosimetry

Courtesy of Tony Palmer, University of Surrey, UK

40

Trial Brachytherapy Dose Distribution

Isodose comparison. dashed lines = treatment planning system (TPS) calculation, thin lines = film-measured dose

Courtesy of Tony Palmer, University of Surrey, UK

41

In Vivo Dosimetry

42

EBT2/EBT3 for Superficial Region Dosimetry

Color window displaying an active CD film read under the layer with pre-set color shade. As a visual aid, the pre-set area of a color shade corresponds to the color of the active CD film exposed to a given dose.

Color of laminated layer

2.0mm
8.0mm
5.0mm

-S Chiu-Tsao and MF Chan, *Med. Phys.*, Vol. 37, 2010, pp. 3611-3620.
 -S Chiu-Tsao and MF Chan, *Med. Phys.*, Vol. 36, 2009, pp. 2074-2082.
 -S Chiu-Tsao and MF Chan, *Int. J. Med. Phys. Clin. Oncol. Phys. Technol. Oncol.*, Vol. 5, 2009, pp. e1501-1612.

Patient Skin Dose Measurement

Scenario A: Lung MRT (axial) Scenario B: Lung MRT (axial) Scenario C: Lung MRT (axial)

(A) (B) (C)

w/o AC & CFC w/ AC & CFC

MF Chan, S Chiu-Tsao, J Li et al. *Medical Physics*, Vol. 11, 2014, pp. 571-581.

Ref. D (90% Dm) & 4t

Median Skin Dose

Median Skin Dose (90% Dm) = 10.5 Gy