AAPM Practical Medical Physics Course
Radiochromic Film Dosimetry Update

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Session: TU-F-201
2:45 pm – 3:45 pm
Tuesday, July 14, 2015

Radiochromic Film Dosimetry Update
Outline

- General Aspects of RCF Dosimetry
- Applications of RCF in SRS, SBRT, IMRT, VMAT, and kV Imaging
- Applications of RCF in Brachytherapy
- Applications of RCF in Small Fields and Proton Beams

Members of AAPM Task Group 235
An Update to TG 55 (1998)

Charges of TG-235
(An Update to TG-55)

- To review the literature on recent radiochromic films and dosimetry of RCFs 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 uncertainties, and
- To provide guidelines on recent RCF dosimetry for clinical radiotherapy applications.


Radiochromic Film Dosimetry Update
General Aspects of Radiochromic Film Dosimetry

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Session: TU-F-201-1
AAPM Practical Medical Physics Course
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Film Dosimetry

- Permanent Record of 2D Dose Distribution
- Dynamic Dose Range
- Darker Color (Grey) with Higher Dose
- Fine Spatial Resolution (5 µm)
- Steep Dose Gradient Region
- Cut to Size, Bend to Shape
- Irradiate at any Angle of Incidence
- Two Categories of Films for Radiation Dosimetry
  - Radiographic Film (19th Century)
  - AAPM TG69 (2005)
  - Radiochromic Film (Mid-20th Century)
  - AAPM TG55 (1998), TG235 (In Progress)
Radiochromic Film

- Polymer-based (Z~7)
- Nearly Tissue Equivalent
- NOT Sensitive to Light
- Handle in Room Light - But Store in Dark
- Easy to Position Accurately
- Self Developing
- Instant Color Change
- Water Resistant
- Weak Energy Response (Model Dependent)

Radiographic Film

- AgBr-based (Z >>7)
- NOT Tissue Equivalent
- Very Sensitive to Light
- Require Dark Room - Always
- Not Easy to Position Accurately
- Require Processing
- Grey Shades Develop with Processing
- Strong Energy Response

Radiochromic Films for Dosimetry and QA for Radiotherapy and Radiology

- Radiotherapy (MV and kV photons, electrons, protons, HDR and LDR brachytherapy)
  - EBT2, EBT3, EBT-XD – 0.01 Gy to >40 Gy
  - MD-V3 – 2 Gy to 100 Gy
  - HD-V2 – 10 Gy to 400 Gy
  - RTQA2 – 0.02 Gy to 8 Gy
- Radiography (kV photons)
  - XR-RV3 – 5 cGy to 1500 cGy
  - XRQA2 – 0.1 cGy to 20 cGy
  - XRCT2 – 0.1 cGy to 20 cGy
  - XRM2 – 0.1 cGy to 20 cGy

Radiochromic Film Configuration

EBT2, EBT3 and EBT-XD

Information Analysis from Irradiated RCFs

- The signal information is obtained from a light transmission measurement when compared with the incident light intensity:
  \[ T = \frac{I_t}{I_o} \]
  Transmission and delivered dose is inversely proportional and non-linear.
- Absorbance / Optical Density (OD) is defined as inverse log of T
  \[ OD = \log_{10} \left( \frac{1}{T} \right) = \log_{10} \left( \frac{I_o}{I_t} \right) \]
  OD is expressed in Absorption Units (AU) such as:
  - OD = 1 => 10% transmission
  - OD = 2 => 1% transmission
- OD is a function of the wavelength at which T is measured.
  Measured OD and delivered dose can be considered unique for the film and delivered dose only if sampled by spectrometer of a known wavelength, or by an optical densitometer with monochromic light source.

Dose Response Curves, Non-Linear

Crucial to do Proper Conversion from OD or PV to Dose

Radiochromic Film Post Exposure Density Growth

- Waiting time, t
- 1 hr: <0.1%
- 24 hr: <0.1%
One Scan Protocol to be described later
Some Example of Exposed RCFs for Radiotherapy (hv, e, p, HDR), QA

- EBT film (IMRT, H&N, Coronal, Phantom) with fiducial marks at composite and hot-lab
- EBT film (2.6 mm from inner surface of a CCR eye plaque)
- HDR source positioning QA measurement

Radiochromic Film Dosimetry Update
Applications of RCF in SRS, SBRT, IMRT, VMAT, and kV Imaging

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Session: Tu F 201-2
AAPM Practical Medical Physics Course
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Outline

- Commissioning
- Beam Data Acquisition
- Machine QA
  - Picket Fence Test
  - Winston-Lutz Test
- Patient-Specific QA
- Skin Dose Evaluation
- kV Imaging Dose Measurement

Radiochromic Film Dosimetry
SRS/SRT/SBRT/IMRT/VMAT

Major Advantages

- High Spatial Resolution (Sub-millimeter)
- No Angular Dependence of Film Response
- Dynamic Dose Range
- Steep Dose Gradient

- SRS/SRT/SBRT
- Single or Hypo Fraction
- EBT2, EBT3, MD-V3, EBT-XD
- IMRT/VMAT
- Conventional Fraction
- EBT2, EBT3

No Angular Dependence of Radiochromic Film Response

Linac Commissioning Validation
6, 10 MV Photon FFF beam, EBT3 Film

- Varian TrueBeam STx, BrainLab Cone
- 6 and 10 MV Photon FFF Beams
- EBT3 Film, Lot 
  #A9231103
- EBT3 10000XL
- Scanner
- Red and Green Channel Data

EBT Film, Epsom 1680 Scanner

EBT Film, Epsom 1680 Scanner

EBT Film, Epsom 1680 Scanner

EBT Film, Epsom 1680 Scanner
Varian Trilogy Linac, SRS, EBT2 Film
6 MV Photon, 1 cm x 1 cm (MLC), 2 cm x 2 cm Jaw
PDD Profile

EBT2 Film, Lot #A09031001A, Epson 10000XL Scanner, Red Channel Data
Verification of the iPlan Beam Commissioning Data Provided by BrainLab.

Winston-Lutz Test
Target Position Alignment

Film


Planar Dose: Gamma Index

Solid: TPS
Dotted: EBT2 Film

Gamma Index:

\[ \Gamma(D, d) = \sqrt{\frac{\delta(D) - \delta(d)}{\delta(D)}} \]

Distance Difference: \( \delta(D) - \delta(d) \)
Dose Difference: \( \delta(D) \)
DTA Criterion: \( \Delta d \)
Dose Diff Criterion: AD


EBT2/3 Film in Phantom on Couch

EBT2/3 Film
in Coronal Plane
New GafChromatic QuiCk Phantom

29 cm x 32 cm
Two Slabs
5 cm each

Brain SRS QA, EBT2 Film

For R, G, B Channels
97% 2
2 cm
2 cm
2 cm

SBRT Lung Treatment

Composite of
99% 5
3 mm.
95% 3
3 mm.
80% 2
3 mm.

SBRT patient QA
with EBT2 Film
(Real channel data)

Lang CA:
2000 cGy x 3

Solid line: iPlan
Dotted line: EBT2

One Scan Protocol

Isodose Curves w/ One Scan Protocol

EBT3 Film

VMAT, Double Arc, EBT3 Film

Scanned Image, Portrait Orientation

Two Slabs
Red channel data)

Films Together After Exposure

Patient Film

Reference Film

Scanned Film

0 Gy 1.7 Gy

Scan Patient/Reference/Unexposed Films Together After Exposure

Thick Line: 0.5 hr
Thin Line: 32 hr

Scan Calibration Films

After Exposure

2 hr

Gamma Passing Rate

> 98%

For R, G, B Channels


VMAT, Double Arc, EBT3 Film Isodose Curve comparison

- Skin Reaction is a Major Concern in RT
- Single or Hypofractionated Treatment
- Beams Delivered Through the Support/Immobilization Devices
- Bolus Effect – Lack of Skin Sparing
- Treatment Plan Comparison
  - Correction of the Bolus Effect
    (with Approx. Effective Bolus Thickness)
  - Without Correction

Skin Dose Elevation

Grade-4 Skin Necrosis

Treatment Plan Comparison

6 MVX IMRT Field, Dose at d = 2 mm

Radiochromic Film dosimetry

Useful for Patient-Specific QA in SRS/SRT/SBRT/IMRT/VMAT
kV Imaging in IGRT, CT Scan Dosimetry

Radiation Profile

XR-QA Film, Lot #A12090904B

Thank You