Making Film Dosimetry Easy: Introducing the 'One-scan' Protocol

David F. Lewis Senior Science Fellow Advanced Materials Group Ashland Specialty Ingredients June 12, 2012



Radiochromic Film – The Advantages

- High spatial resolution
- Shoot from any angle
- Near water-equivalent
- Nearly energy independent
- Handle in light
- Cut to size, bend to shape
- Immerse in water
- Wide dynamic range

Highly valuable for new conformal therapies



Film is a hassle.

- Post-exposure waiting
- Film artifacts
- Scanner artifacts
- Dos and don'ts



So, what are we doing about it?

Simplifying calibration

- Fitting functions that "behave" like film
- Less films and all scanned together
- Combining plan verification with calibration
 - "One-scan" measurement protocol
 - Every patient film scanned with reference films
 - Eliminates inter-scan variability
- Reduce post-exposure waiting to minutes



Post-Exposure Change



Normalize the Responses

Post-exposure change and normalized response





Scaling

•Net response, X_{net}, - color C, dose D, time-after-exposure t:

$$\begin{aligned} X_{net}(C,D,t) &= X(C,D,t) - X(C,zero,t) \\ &= X(C,D,t) - 1 \end{aligned}$$

•For all doses:

 $X_{net}(C,t_1) = X_{net}(C,t_2) * K(C,t_1,t_2)$ where K is a constant



Responses after Normalization and Scaling

Relative responses after scaling





Similar Equivalences

- Different scanners (same type)
- Different models Epson 10000XL, V700, 1680
- Different scan temperatures
- Different photon energies
- Different orientations landscape and portrait



Response Equivalence

Landscape vs portrait orientations





Lot-to-lot: Curves Have Different Shape



Requires three-point re-scaling, i.e. re-calibration
GafChromic

Dosimetry Using Two-point Re-scaling

- Set up and expose treatment plan
- Expose reference film (same lot) ~80-100% D_{max}
- Scan patient film, reference and unexposed film all together
- Use reference films to re-scale calibration



Benefit of Re-Scaling

- Eliminates scan-to-scan variability
 - Repeatability
 - Response varies up to about 0.3%
 - Maps to about 1% in dose
 - Temperature
 - About 0.1% response change per °C
 - Maps to about 0.3% in dose per °C
- Allows scanning a few minutes after exposure



Post-exposure Change – Coping the Old Way

• Wait 24 hours for rate of change to diminish





Post-exposure Change – The New Way

 Expose application and reference films in a narrow time window

Wait before scanning, min.	Exposure window, min.	Dose error
10	5	<1%
20	5	<0.5%
40	5	<0.25%



'One-Scan' Dosimetry System

FilmQAPro 3.0 software

+

• GafChromic Film – EBT2, EBT3, MD-V3, HD-V2

'One-scan' Calibration





Fitting Calibration Data

Polynomial Functions



Not consistent with core properties of film **×** Function often oscillates between values **×** Cannot be inverted **×**

Rational Functions

X(D)= a + b/(D-c)D = dose; X(D) = response



"Behaves" like film \checkmark Easily inverted - D = c + b/(X(D)-a) \checkmark



'One-Scan' Measurement





"One-scan" Results

Time after exposure, minutes	Calculated dose, cGy (calibration at 2hr. post-exposure; scaling at 0 and 482.3 cGy)					
	Step 1	Step2	Step 3	Step4	Step 5	Step 6
60	0.4	30.9	61.4	118.6	233.7	482.3
120	0.4	30.9	61.3	118.5	233.7	482.3
255	0.5	31.1	61.7	118.7	233.8	482.3
490	0.4	31.0	61.5	118.3	233.6	482.3
1440	0.5	30.9	61.3	116.8	233.4	482.3
4800	0.5	30.9	61.3	116.8	233.2	482.3

- Scan calibration films at various times after exposure
- Calculate dose maps

- 2 hr. calibration, re-scale with 0 and 482.3 cGy films

Gaf<mark>Chro</mark>mic

IMRT Plan Examples vs. Time

Calibration films scanned 2 hours after exposure Patient/reference films scanned at various times



30 min. after

4 hours after

3 days after

Examples – IMRT Plan vs. Time

Time after exposure		Gamma % passing for 2%@2mm		
Calibration	Patient film and reference	Red	Green	Blue
2 hr	30 min.	97.9	97.0	97.6
2 hr	60 min.	97.6	96.2	97.3
2 hr	4 hr	97.7	96.3	97.3
2 hr	24 hr	97.9	97.0	97.8
2 hr	72 hr	97.9	97.6	97.9



Dose Maps at Different Times Compared

Calculate dose maps with "One-scan" protocol:

Calibration 120 min. post-exposure, reference films at zero and 300 cGy

Time after exposure, minutes		Dose Difference <1%	
Dose Map 1	Dose Map 2	% Pixels Passing	
30	60	93.4	
30	240	93.1	
30	1440	90.3	
30	4320	91.8	





"One-Scan" Protocol: Higher Achievement



'One-scan' Protocol - Summary

- Scan patient and reference films together
 - Avoid inter-scan variability
 - Adapt measurements to calibration
- Dose accuracy better than 1%
 - Sharper assessment of treatment plan
- Post-exposure timing rules relaxed
 - Measure in minutes not hours
 - No concern whether an old calibration is still valid
- Minimizes number of films, exposures and scans
 - Less complications, less errors



Film is a hassie. Swap





Film's Inherent Advantages

- Get the whole picture
 - Film provides millions of measurements
 - Arrays miss >99% of the area
- Shoot film from any angle
 - Shoot the whole plan on one film
 - Just like the patient gets it





With FilmQAPro 3.0

The future is film



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