A Clinical Review of the Dosimetric and Temporal Impact of Unflattened X-ray Beams

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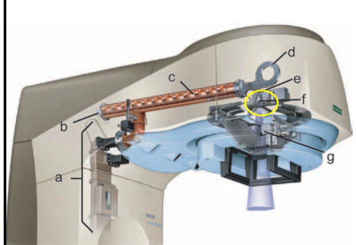
Learning Objectives

- Understand technique for matching beam quality of unflattened and flattened beams.
- Understand definition of field size and beam characteristics during initial 200 msecs.
- Review improved dosimetric accuracy and temporal advantages of unflattened beams in clinical use.

*Research sponsored by Siemens Medical Solutions Corporation

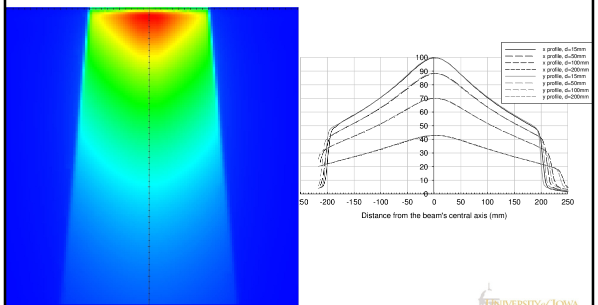
Removal of flattening filter increases dose rate from 300 to 2000 MU/min



- 2-3X ↑ in dose rate
- ↓ apparent focal spot size
- ↓ head scatter
- ↓ head leakage (>50%)
- ↓ electron contamination
- Superior beam symmetry

Bayouth JE, et al, Med Dosim; 32:134-141 (2007)

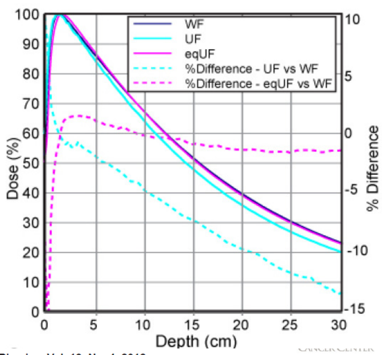
Measured Dose Profiles without Flattening Filter



Bayouth JE, et al, Med Dosim; 32:134-141 (2007)

Beam Matching

- Comparison of %dd measured with 0.125 cc ion chamber in water with a field size of 10 × 10 cm^2 between WF, UF and eqUF photon beams



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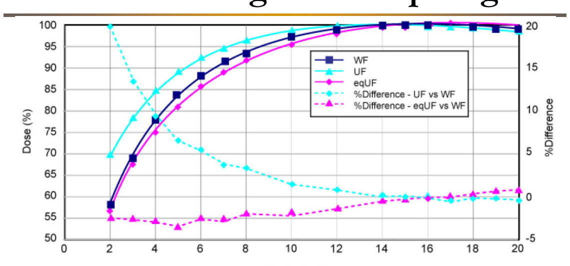
Beam Matching – Buildup Region



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Dose Profiles

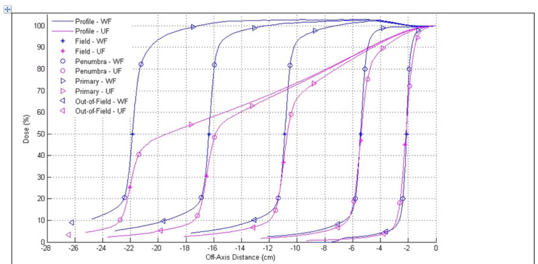


Figure 5. Comparison of cross-axis profiles of field size 4, 10, 20, 30, 40 of qeUF and WF photon beams at depth of 10 cm.

Variation of Dose Profile w/ Depth

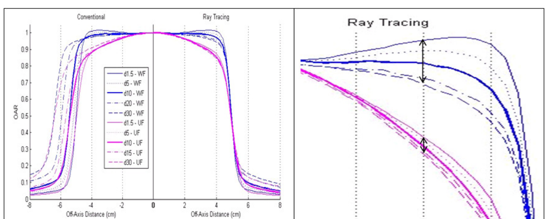
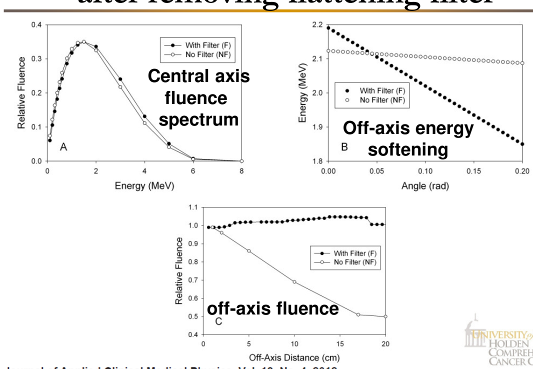
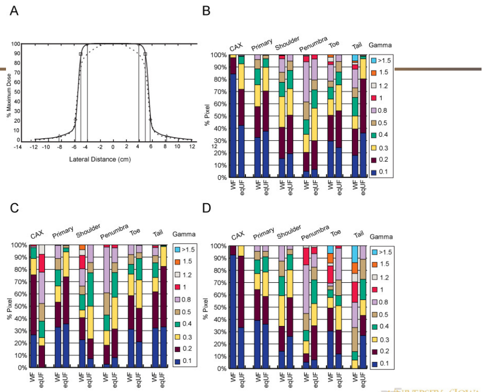


Figure 6. Comparison of OAR of at various depths at specific lateral distance with/without the beam divergence removed between the WF and qeUF beams.

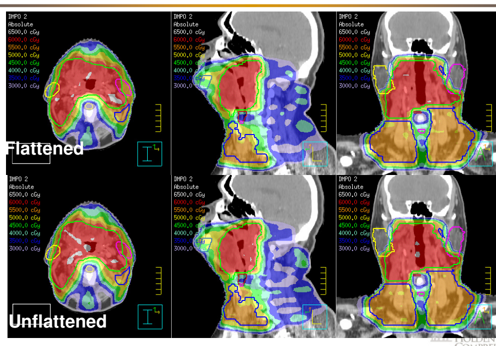
Change in Pinnacle³ beam model after removing flattening filter



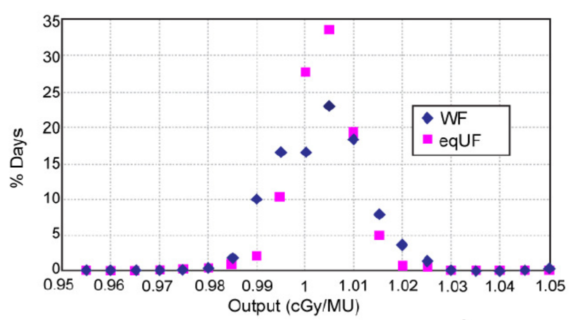


Comparison of 2mm/2% gamma-indices of the WF and eqUF beam model: (A) Definition of lateral regions. (B) Depth 1.5 to 25 cm (C) Buildup Region (D)Deep depth of greater than 25cm.

Implications for IMRT Delivery



Beam Stability Over 1.5 Years



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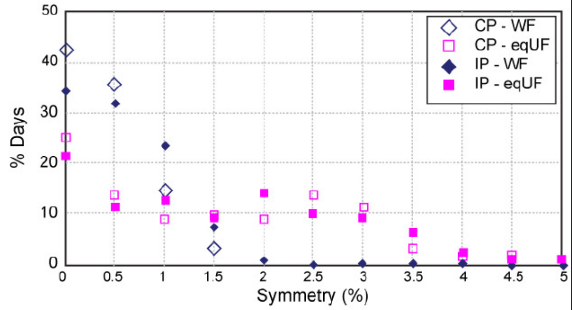
Beam Stability Over 1.5 Years



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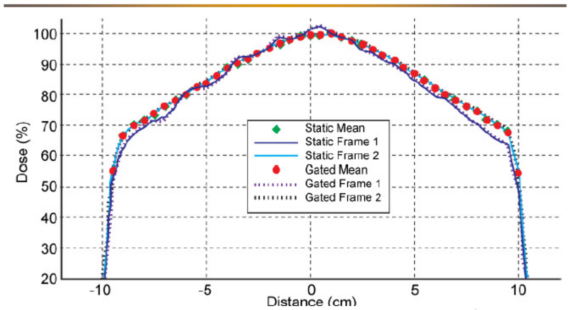
Beam Stability – Initial 200 msec



Profiles of eqUF beam with 0.5 cm spatial resolution during a delivery of 100 MU in the static or 500 ms gated mode.

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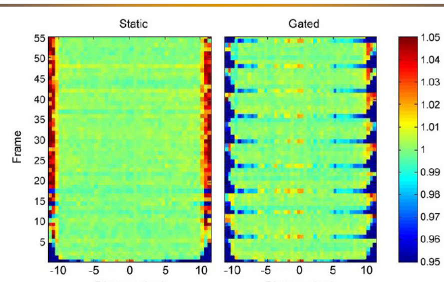
Beam Stability – Initial 200 msec



Percent differences in the profile of each frame in static or 500 ms gated mode compared to the average profile.

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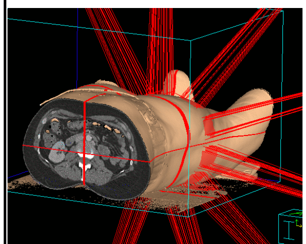
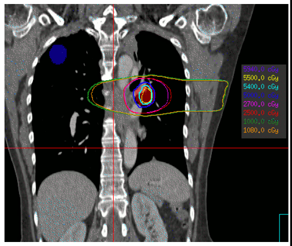
Lung SBRT Example Plan



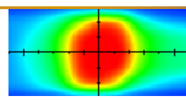
Beam angles



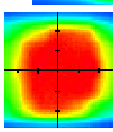
Dose distribution

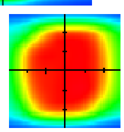
Lung SBRT in EST mode

Pinnacle calculation
Tick marks:
1 cm spacing



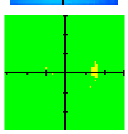
Film measurement

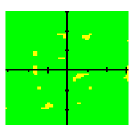




Secondary 2-D calc with RTPFilter

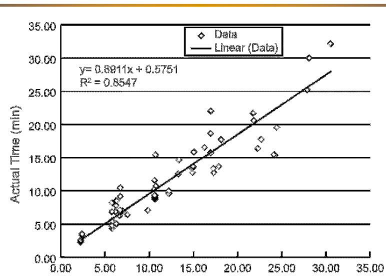
Pinnacle/Film Agreement:
3% and 3 mm: green
3% or 3 mm: yellow





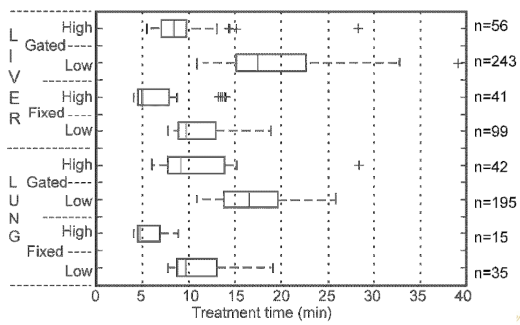
Pinnacle/ Secondary 2-D Calc Agreement

Gated RT Treatment Time



$$t_{tot} = \frac{M}{\dot{M}}\frac{T}{\tau} + t_{MLC} + t_G + t_{abn}$$

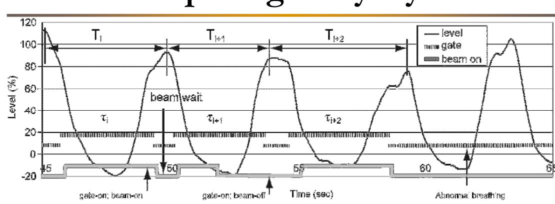
EST Mode summary



RT Planning Process Unique to 4D

- Quantify Amount & Direction of Motion
- Consider Duty Cycle
- Find Spatially Similar Phases
- Determine Uncertainty in Position
- Establish Gates & Margin
- Proceed to Planning

Computing Duty Cycle

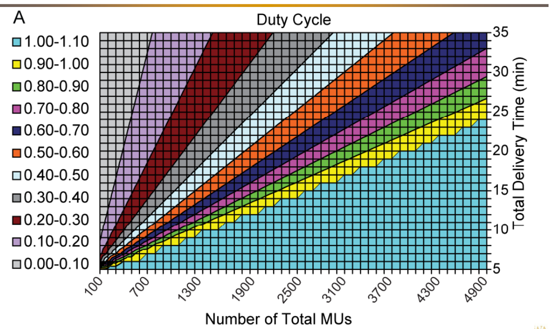


$$t_{tot} = \frac{M}{\dot{M}} + t_{MLC} + t_G + t_{abn}$$

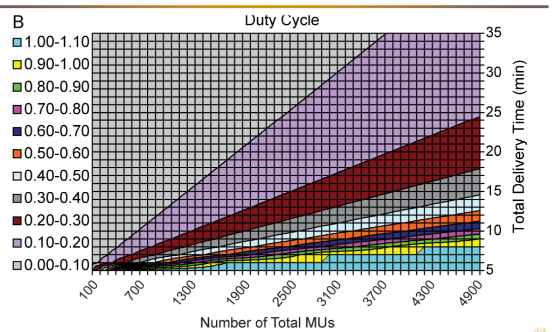
$$\frac{\tau}{T} = \frac{M/\dot{M}}{t_{tot} - (t_{MLC} + t_G + t_{abn})}$$

Data from Yunfei Huang, U Iowa

Duty cycle @ 300 MU / min



Duty cycle @ 1500 MU / min



Selecting the Phase Gating Window

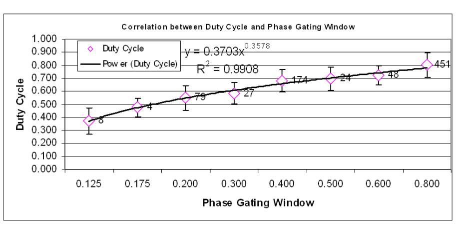
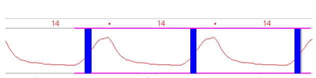


Figure 4. Gating duty cycle was not a linear function of the phase gating window. Number of cases are labeled on the top of each column.



Summary

- Increase in dose rate (x5) was implemented by removing flattening filter from 6 MV beam and increasing beam energy to around 7 MV.
- Unflattened beam can be modeled in the Pinnacle^3 treatment planning system.
- Main clinical use is for SRS / gated RT / SBRT where treatment times are reduced substantially.
- Unflattened beam should be characterized for behavior during first 200 msec.

Acknowledgements

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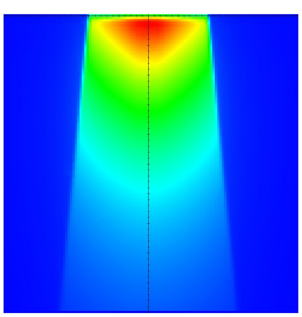
Vicki Betts
Brandie Gross
Kim McCune
Darrin Pelland
Judith Wacha

University of Iowa Holden Comprehensive Cancer Center

Thank you



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