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

J Bayouth*, Y Huang, R Flynn, R Siochi
University of Iowa, Iowa City, IA

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.

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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

Measured Dose Profiles without Flattening Filter


Beam Matching

- Comparison of %dd measured with 0.125 cc ion chamber in water with a field size of 10 × 10 cm² between WF, UF and eqUF photon beams

Beam Matching – Buildup Region

- Comparison of %dd measured with 0.125 cc ion chamber in water with a field size of 10 × 10 cm² between WF, UF and eqUF photon beams
Dose Profiles

Figure 3: Comparison of cross-axis profiles of field size 4, 10, 20, 30, 40 of qoPF and WT 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 WT and qoPF beams.

Change in Pinnacle⁴ beam model after removing flattening filter

Central axis fluence spectrum

Off-axis energy softening

Off-axis fluence

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 25 cm.

Implications for IMRT Delivery

Beam Stability Over 1.5 Years
Beam Stability Over 1.5 Years

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

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.

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.
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

\[ t_{tot} = \frac{M}{M} T_{\tau} + t_{MLC} + t_{G} + t_{abl} \]
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

Data from Yunfei Huang, UIowa
Duty cycle @ 300 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 Pinnacle³ 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.

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