Characteristics and Clinical Implementation of the Varian TrueBeam Accelerator

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Disclosure

- UAB has Varian research contracts
- Honorarium from Varian

Special Thanks

- John Fiveash
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- Brendan Prendergast
- James Bonner
- Varian

TrueBeam – distinquishing characteristics

- Completely digital control system
- Waveguide and filter design allows 5 flattened photon energies up to 20 MV.
- Electron scattering foils are of a new design.
- Implements 6 MV and 10 MV flattening filter free (FFF) beams that provide dose rates up to 2400 monitor units per minute.

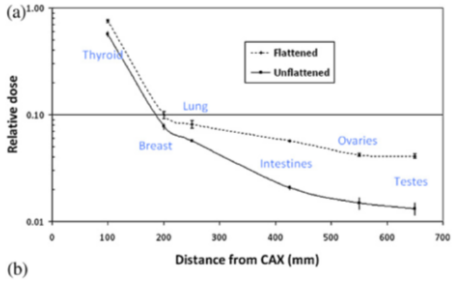
Possible Benefits of a FFF

- Efficiency
- More accurate beam modeling due to decreased head scatter
- Decreased leakage and dose outside field

The study showed that removing the filter increased the dose rate on the central axis by a factor of 2.31 (6 MV) and 5.45 (18 MV) at a given target current. Because the flattening filter is a major source of head scatter photons, its removal from the beam line could reduce the out-of-field dose.

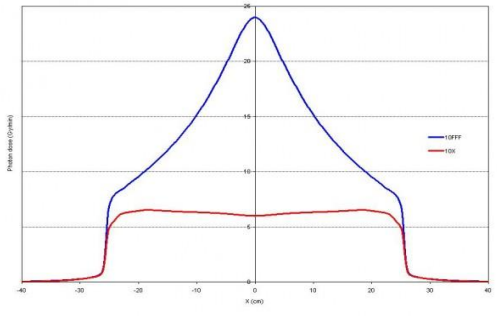
Vassiliev ON, Titt U, Kry SF, Pönisch F, Gillin MT, Mohan R Med Physics 2006 vol. 33 (4) pp. 820-7

Unflattened Beam Has a Lower Risk of Secondary Tumors



Cashmore et al, IJROBP 2011 in press

Beam Profile – Flattening Filter



Depth Dose with Flattened Beam

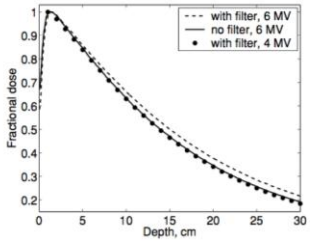


Figure 1. Depth dose dependence for a 10 × 10 cm^2 field. 6 MV with the flattening filter (dashed line), 6 MV without the filter (solid line), 4 MV with the filter (circles).

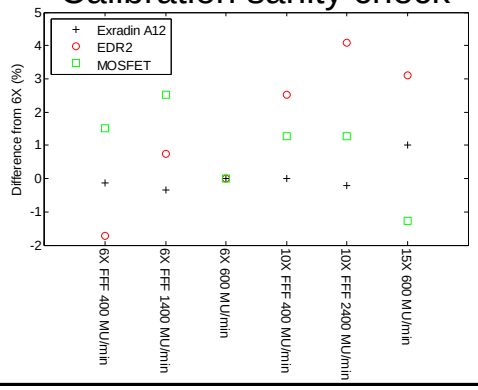
2004 Phys. Med. Biol. 49 1535

Calibration

- No difference for FFF
- Polarity and recombination corrections small

Energy	Dose rate	Ppol	Pion
6X	600	1.000	1.004
15X	600	1.000	1.005
6X FFF	1400	1.000	1.006
10X FFF	2400	1.000	1.013

Calibration sanity check



RPC Calibration check

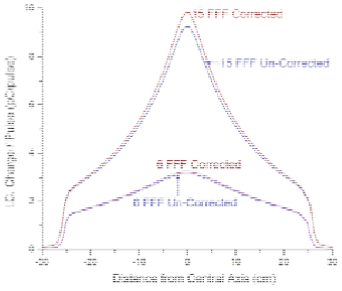
- RPC OSLD measurement / Institution
  - 6X FFF = 0.99
  - 10X FFF = 0.99

Photon commissioning

- AAA Data requirements are the same
- No additional data required for FFF

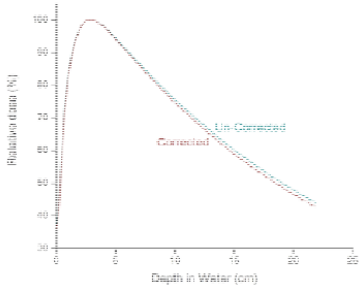
Profile and depth dose correction for recombination

Figure 4. Measured x-ray distributions for 6 FFF and 15 FFF beams, plotted as charge collected per beam pulse. Also plotted are the results from applying corrections for the ion chamber collection efficiency. The distributions were measured at 100 cm SSD with the 0.1 cm^3 chamber at D_{max} and biased with 300 V.

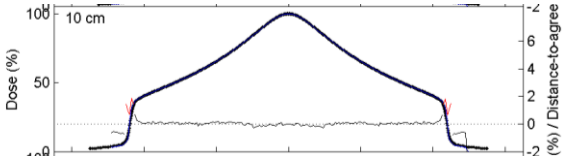


Profile and depth dose correction for recombination

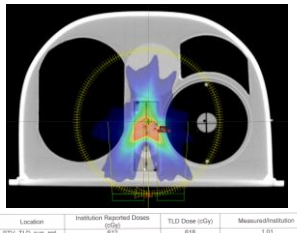
Figure 5. Measured 15 FFF x-ray depth-dose disribution and distribution resulting from applying corrections for ion chamber collection efficiency. Each curve is normalized to 100% at D_{max}. Data is for a 0.1 cm^3 chamber biased to 300 V; 10x10 cm^2 field at 100 cm SSD.



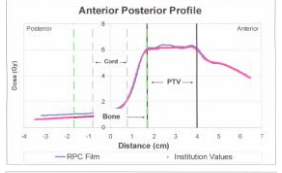
10X FFF profile

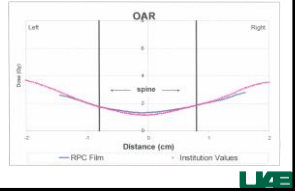


RPC VMAT Spine

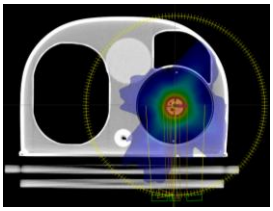


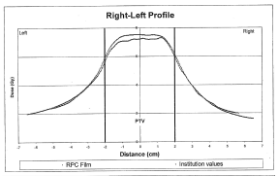
Location	Institution Reported Doses (cGy)	TLD Dose (cGy)	Measured/Institution
PTV_TLD_sup_ant	612	618	1.01
PTV_TLD_inf_ant	614	619	1.01
PTV_TLD_sup_post	616	619	1.00
PTV_TLD_inf_post	620	627	1.01
HEART_TLD	134	135	1.01

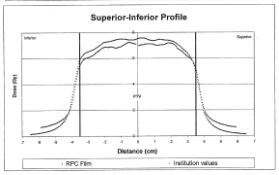




RPC Gated VMAT Lung







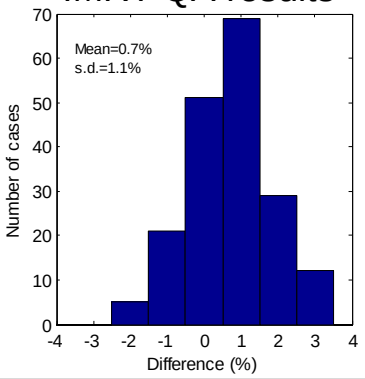
Summary of TLD and film results:

Location	RPC vs. Inst.	Criteria	Acceptable
PTV_TLD_sup	0.96	0.92 – 1.02	Yes
PTV_TLD_inf	0.96	0.92 – 1.02	Yes

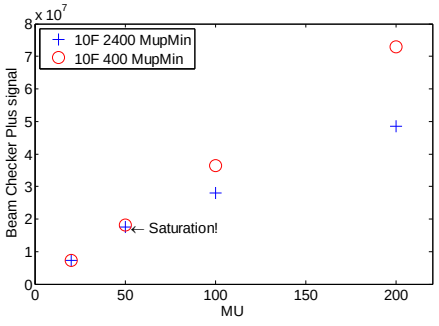
Film Plane	Gamma Index*	Criteria	Acceptable
Axial	100	≥ 80%	Yes
Coronal	99	≥ 80%	Yes
Sagittal	98	≥ 80%	Yes
Average over 3 planes	99	≥ 85%	Yes

*Percentage of points meeting gamma-index criteria of 5% and 5 mm

IMRT QA results



Daily QA Device



Which Cases Benefit from FFF?

- Treatment efficiency
- Plan quality

Treatment Efficiency for FFF Lung SBRT

Ten Lung SBRT clinical cases on a modified Clinac 21EX:
- Similar plan quality for FFF vs non-flat
- 6MV beam time reduced by 2.3 (1400 MU/600 MU)

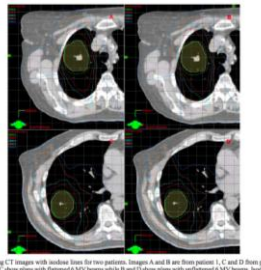


Fig. 2. Planning CT images with isodose lines for two patients. Images A and B are from patient 1, C and D from patient 2. Images A and C show plans with flattened 6 MV beams while B and D show plans with unflattened 6 MV beams. Isodose lines represent planned doses of 50 Gy (green), 40 Gy (red), 30 Gy (cyan), 20 Gy (orange), 10 Gy (blue). The maximum dose in these plans is less than 60 Gy. The PTV is shown in yellow.

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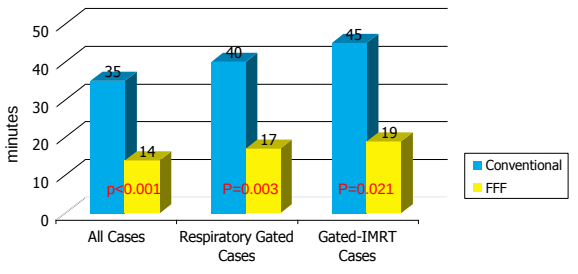
Treatment Time Comparison for Various FFF Modes vs. 6X Flat DMLC

Case Type	Dose Fraction (Gy)	Plan type	Dose Rate (MU/min)	Beam Arrangment	Beam-on Time (s)	Inter-beam time (s)	Total Time (s)	Treatment Time Reduction over Flat Beam
Lung	2	6X Flat DMLC	600	4 field axial	80.2	55.2	135.4	-
		6X FFF DMLC	1400	4 field axial	53.6	54.2	107.8	20.4%
		6X FFF VMAT	1400	1 arc	61.2	0.0	61.2	54.8%
		10X FFF DMLC	2400	4 field axial	46.2	53.9	100.1	26.1%
		10X FFF VMAT	2400	1 arc	61.0	0.0	61.0	54.9%
Prostate	2	6X Flat DMLC	600	5 field axial	56.3	43.6	99.9	-
		6X FFF DMLC	1400	5 field axial	32.3	44.0	76.3	23.6%
		6X FFF VMAT	1400	1 arc	61.0	0.0	61.0	38.9%
		10X FFF DMLC	2400	5 field axial	30.2	44.4	74.6	25.3%
		10X FFF VMAT	2400	1 arc	61.1	0.0	61.1	38.8%
Triple Cranial Metastasis	18	6X Flat DMLC	600	9 field axial	63.2	463.9	527.1	-
		6X FFF DMLC	1400	9 field axial	63.2	198.8	262.0	50.3%
		6X FFF VMAT	1400	2 axial arcs	3.8	115.4	119.2	77.4%
		10X FFF DMLC	2400	9 field axial	62.4	129.3	191.7	63.6%
		10X FFF VMAT	2400	2 axial arcs	3.4	55.3	58.7	88.9%

E. Thomas, JB Fiveash, RA Popple

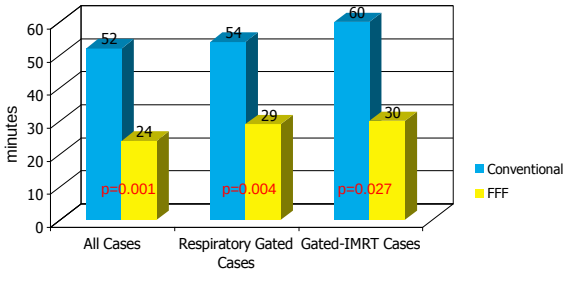
Beam On Time (n=83)



Beam On Time = Time from first beam on to last beam off, *inclusive of* intra-fraction imaging

Prendergast et al 2011

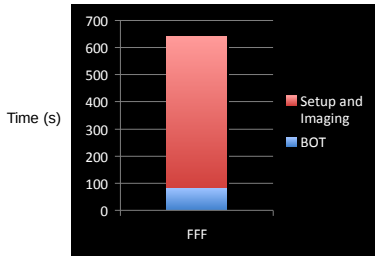
Time In Room (n=83)



Time in Room = Time from first alignment image (CBCT or KV) to last beam off

Prendergast et al 2011

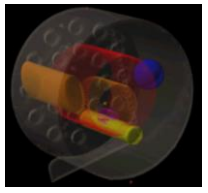
CNS Radiosurgery Efficiency (n=27)
12-30 Gy in 1-5 fractions

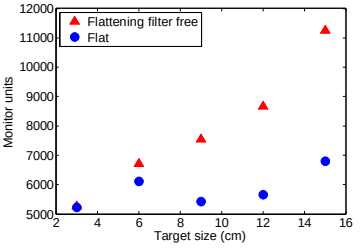


Beam on time = mean 81s
Clinical Dose Rate = 1840 MU/min

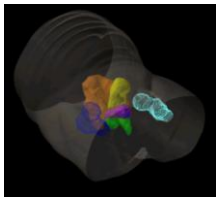
Prendergast et al 2011

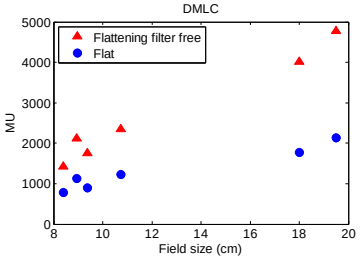
Impact of Field Size on Monitor Units in FFF



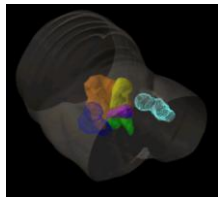


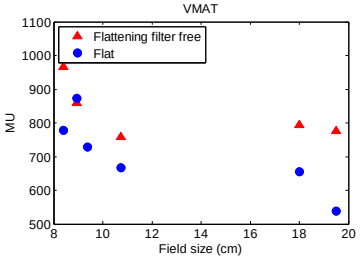
Impact of Field Size on Monitor Units in FFF





Impact of Field Size on Monitor Units in FFF

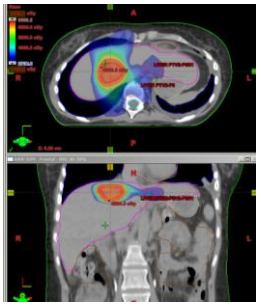




Delivery is gantry speed limited – no difference in delivery time!

Impact of Field Size on Monitor Units in FFF

Large field size (H/N) or multiple targets > 10 cm apart will increase total monitor units in FFF compare to flat beams.



Example case:

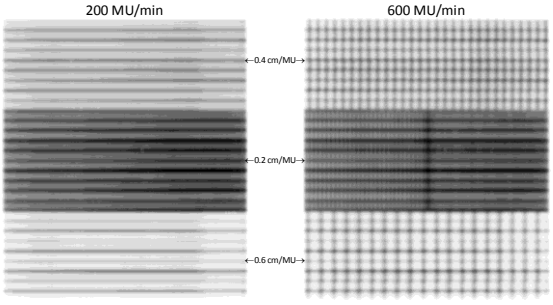
SBRT liver two targets (60 Gy and 30 Gy in 3 fractions).

Arc FFF = 6268 MU (2400 MU/min)
Arc 15X flat = 5255 MU (600 MU/min)

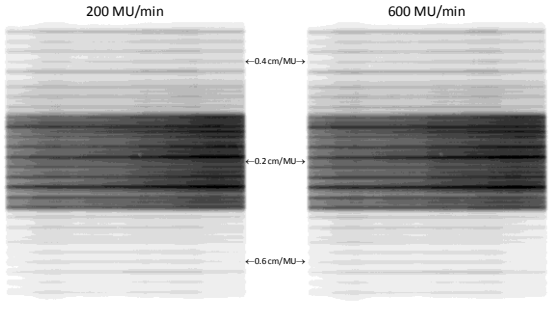
Advantages of a digital control system

Case study: MLC

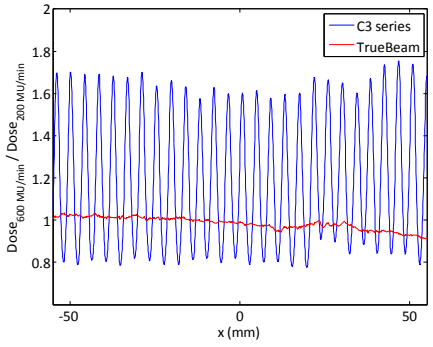
C3 Series



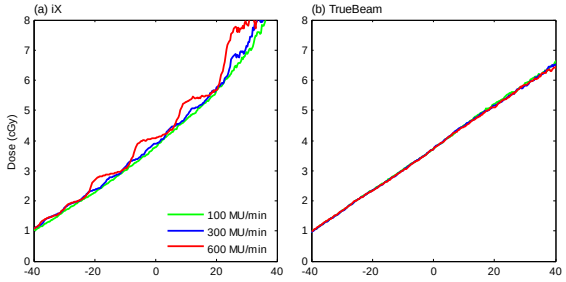
TrueBeam



Ratio for leaf velocity 0.6 cm/MU

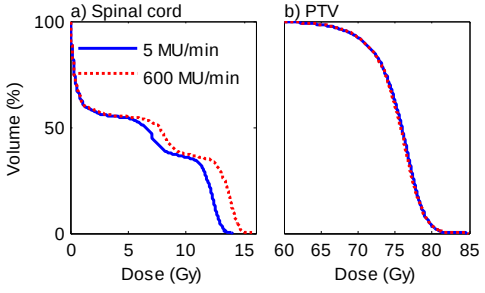


Closing MLC

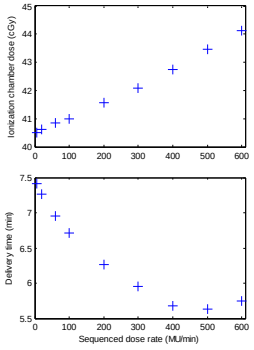


Clinical implications

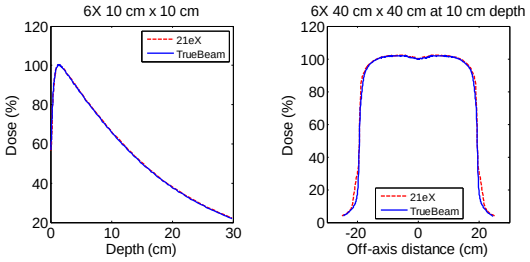
Clinical implications



Clinical implications



Beam data comparison



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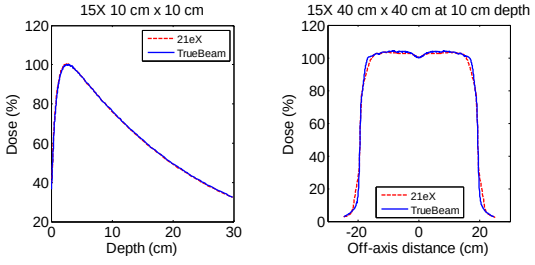
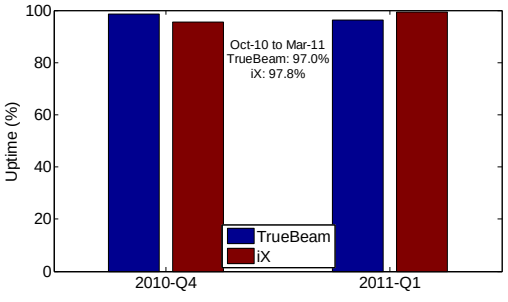


Reliability



Conclusions

- TrueBeam is a general purpose linear accelerator and can be used for all patient types.
- For conventional fractionation, treatment times are decreased due to reduction in the time required to prepare for delivery of each field.
- For hypofractionation, radiosurgery, and respiratory gating using the FFF beams, the treatment times are decreased significantly due to the higher dose rate.
- New architecture and control systems allow easier integration of future Varian and third party technologies