Characteristics and Clinical Implementation of the Varian TrueBeam Accelerator

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Disclosure

- UAB has Varian research contracts
- Honorarium from Varian

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- Varian

TrueBeam – distinguishing 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.

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**Unflattened Beam Has a Lower Risk of Secondary Tumors**

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**Beam Profile – Flattening Filter**

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**Depth Dose with Flattened Beam**
Calibration

- No difference for FFF
- Polarity and recombination corrections small

<table>
<thead>
<tr>
<th>Energy</th>
<th>Dose rate</th>
<th>Ppol</th>
<th>Pion</th>
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<tbody>
<tr>
<td>6X</td>
<td>600</td>
<td>1.000</td>
<td>1.004</td>
</tr>
<tr>
<td>15X</td>
<td>600</td>
<td>1.000</td>
<td>1.005</td>
</tr>
<tr>
<td>6X FFF</td>
<td>1400</td>
<td>1.000</td>
<td>1.006</td>
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<tr>
<td>10X FFF</td>
<td>2400</td>
<td>1.000</td>
<td>1.013</td>
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</table>

Calibration sanity check

- Exradin A12
- EDR2
- MOSFET
- 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 cm² chamber at Dmax and biased with 300 V.

10X FFF profile

RPC VMAT Spine

Profile and depth dose correction for recombination

Figure 5. Measured 15 FFF x-ray depth-dose distribution and distribution resulting from applying corrections for ion chamber collection efficiency. Each curve is normalized to 100% at Dmax. Data is for a 0.1 cm² chamber biased to 300 V, 10x10 cm² field at 100 cm SSD.
RPC Gated VMAT Lung

IMRT QA results

Mean=0.7%
s.d.=1.1%

Number of cases

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)

Beam On Time (n=83)

<table>
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<tr>
<th>Case Type</th>
<th>Dose Fraction (Gy)</th>
<th>Plan Type</th>
<th>Beam Arrangement</th>
<th>Beam-On Time (s)</th>
<th>Inter-Fraction Time (s)</th>
<th>Total Time (s)</th>
<th>Treatment Time Reduction over Flat Beam</th>
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<td>6MV FFF DMLC</td>
<td>60x60 field area</td>
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<tr>
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<td>64.4</td>
<td>103.5</td>
<td>167.9</td>
<td>62.6%</td>
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</table>

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

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

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

E. Thomas, JB Fiveash, RA Popple
CNS Radiosurgery Efficiency (n=27)
12-30 Gy in 1-5 fractions

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

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 compared 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**

![Graph showing the ratio for leaf velocity](image)

**Closing MLC**

![Graphs showing closing MLC for different dose rates](image)

**Clinical implications**

![Clinical implications images](image)

**Clinical implications**

![Graphs showing clinical implications](image)
Clinical implications

Beam data comparison

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