Impact Of Small Mu/Segment And Dose Rate On Delivery Accuracy Of Volumetric Modulated Arc Therapy (Vmat)

Long Huang
Huntsman Cancer Hospital
University of Utah
Introduction

Varian and Elekta Linacs
iX/Triology: analog machine
MLC position check: 50mS

Truebeam: digital machine
MLC position check: 10mS

SynergyS: digital machine
MLC position check: 50mS
“Real time”
Volumetric Modulate Arc Therapy (VMAT)

- All of these machines can deliver VMAT
- However, what about the delivery quality?
Deliver Quality

- Delivery quality between machines
  - Varian v.s. Elekta
  - IX v.s. Truebeam

- Plan vs. Delivery
  - IMRTQA
Plan vs. Delivery

- IMRTQA for VMAT

Multi QA devices show

**VMAT QA ≈ IMRT QA**

Gamma Index is 3%/3mm

**VMAT QA is Better**

IMRT QA passing rate is 93.7±3.7%*

VMAT QA passing rate is 96.6±2.2%*


*J Radiat Res. 2013 May;54(3):546-52
Between machines comparison

- Why?
  Different manufactures
  Analog vs Digital (old vs new?)

- How?
Between machines comparison

- How to design a VMAT plan to evaluate the machine limit

  Such as

  VMAT QA is bad / worst in these plans

  Or statistical analysis for one type of machine vs the other type of machine

- Gamma Index

  3%/3mm is not enough, how about 2mm/2%?
Design the test

- A limit patient number and same plan parameter for two machines
- Manually adjust segment complex to reach limits for the machine
- Manually adjust the dose rate for the machine
- Using Gamma index 3%/3mm, 2%/2mm 1%/1mm
VMAT plans

- Ten patients were treated for whole brain with hippocampus avoidance (300cGy\times10)
- VMAT on Novalis TX / Elekta SynergyS are chosen for these patients
- Dose rate choice: 600 MU/min and 1000 MU/min on Novalis TX
- Dose rate choice: 600 MU/min
VMAT plans

- Need one or two arc, each arc is around 200-360. The standard setting for VMAT is 4 degree/segment (control points) in Pinnacle. So it is 50 to 90 control points per arc.
- However, Eclipse gives default 2 degree/segment choice for one arc. It means that 100 to 180 control points in some plan.
- The MU per Arc is around 200-400 per beam, so the average segment is around 2-3MU/segment or 1-2 MU/segment.
Delivery

- One patient has a three plans:
  - Plan 1: 100 cGy/fraction with same segment
  - Plan 2: 150 cGy/fraction with same segment
  - Plan 3: 300 cGy/fraction with same segment
- Delivery on the same phantom at the same setting at the same time (day)
- Phantom: IBA Matrixx
Delivery comparison

- Plan 1 vs Plan 3, Plan 2 vs Plan 3
  Plan 1 delivered dose $\times 3 = $ Plan 3 dose
  Plan 2 delivered dose $\times 2 = $ Plan 3 dose

- Using Gamma index 3%/3mm, 2%/2mm 1%/1mm
Total MU

![Bar chart showing Total Monitor Unit (MU) for different patients. The chart compares 600 MU/min and 1000 MU/min for each patient, with bars representing the total MU for each patient.]
MU per segment

Dose Rate = 600MU/min

Dose Rate = 1000MU/min
Gamma analysis

1/3 Dose plan

Original plan

Gamma 3% 3mm  Gamma 2% 2mm  Gamma 1% 1mm

600 MU/min
Gamma analysis

1/2 dose plan

Original plan

Gamma 3% 3mm

Gamma 2% 2mm

Gamma 1% 1mm

600 MU/min
Gamma analysis

1/3 dose plan

Gamma analysis

Original plan

1000 MU/min

Gamma 3% 3mm

Gamma 2% 2mm

Gamma 1% 1mm
Gamma analysis

1/2 dose plan

Original plan

Gamma 3% 3mm

Gamma 2% 2mm

Gamma 1% 1mm

1000 MU/min
Results cont.

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<thead>
<tr>
<th>Gamma</th>
<th>100 cGy vs 300 cGy</th>
<th>150 cGy vs 300 cGy</th>
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Novalis TX 600 MU/min
### Results cont.

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Novalis TX1000 MU/min
### Results cont.

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Elekta 600 MU/min
Results Summary

- **Dose rate 600 MU/min vs 1000 MU/min**
  At 1mm/1%, 1000 MU/min is a little worse
  The delivery error is around 1mm and 1% range for analog machine. 83% vs 79%

- **Elekta machine vs Novalis TX (digital vs analog)**
  A little better 88% vs 83%
Questions left

- Truebeam vs IX
  10mS vs 50mS

- Truebeam vs Elekta
  10mS vs 50mS
  Same level?
Take home message

- VMAT delivering quality ≥ IMRT delivering quality
- Digital machine delivering quality ≥ Analog machine (Elekta/Truebeam ≥ IX/Triology)
- The difference is shown in 1mm/1% which means 2mm/2% can be used on VMATQA/IMRTQA
- Truebeam may be better due to less latency (10mS)