

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

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Varian and Elekta Linacs

iX/Triology: analog machine

MLC position check: 50mS



Truebeam: digital machine

MLC position check: 10mS

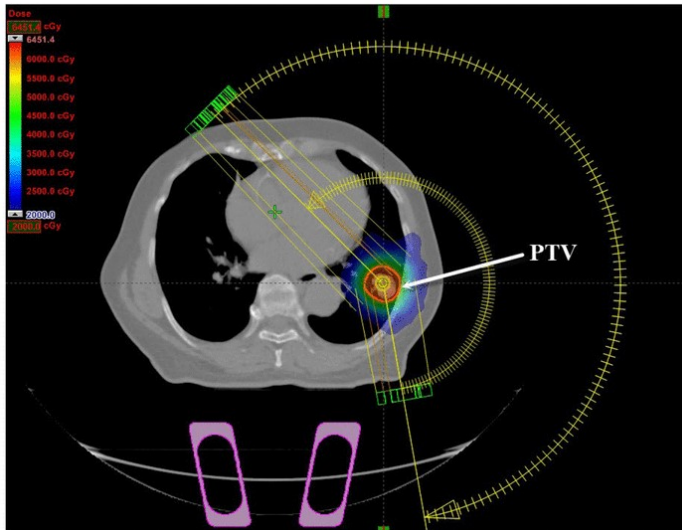


SynergyS: digital machine

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

□ IMRT QA for VMAT

Multi QA devices show

VMAT QA \approx IMRT QA

Gamma Index is 3%/3mm

VMAT QA is Better

IMRT QA passing rate is $93.7 \pm 3.7\%^*$

VMAT QA passing rate is $96.6 \pm 2.2\%^*$

J Appl Clin Med Phys. 2011 Apr 4;12(2):3367

*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 3⁰/3mm, 2⁰/2mm 1⁰/1mm



VMAT plans

- Ten patients were treated for whole brain with hippocampus avoidance (3000Gyx10)
- 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

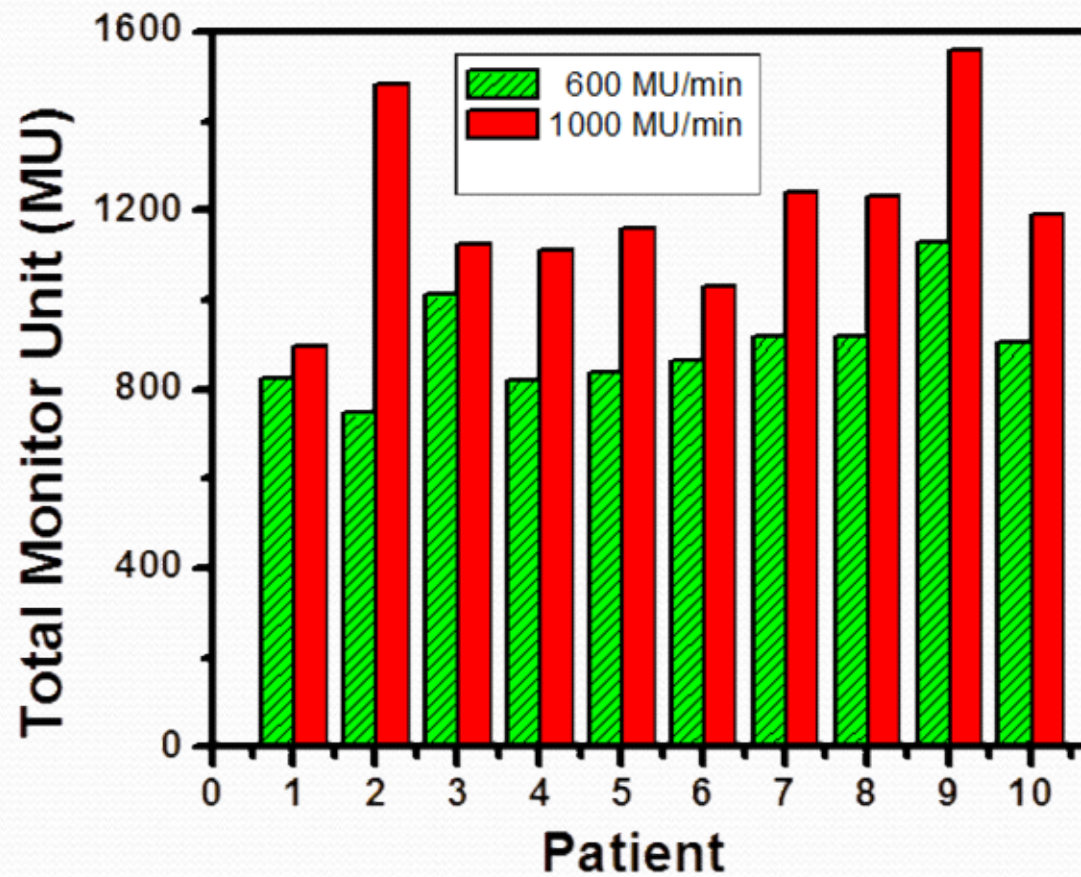
- Plan 1 vs Plan 3, Plan 2 vs Plan 3

Plan 1 delivered dose x 3 = Plan 3 dose

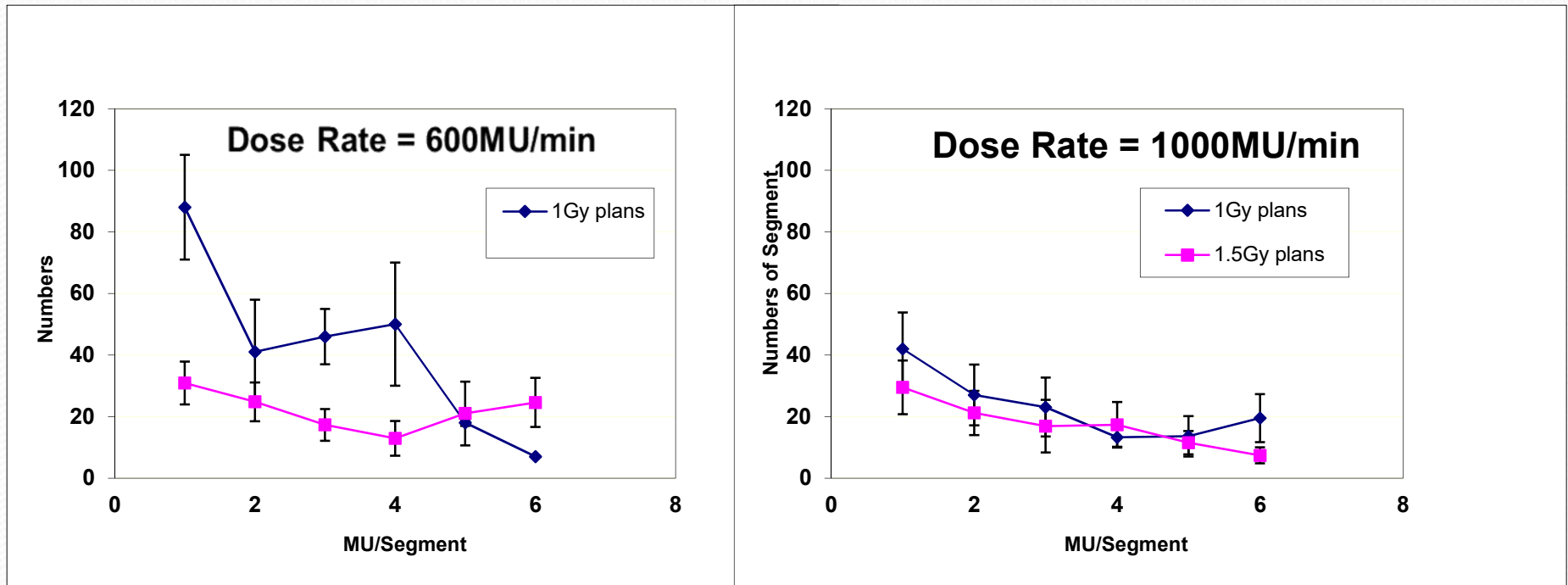
Plan 2 delivered dose x 2 = Plan 3 dose

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

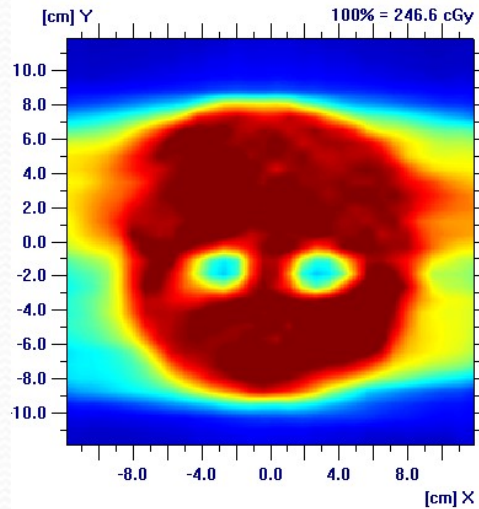
Total MU



MU per segment

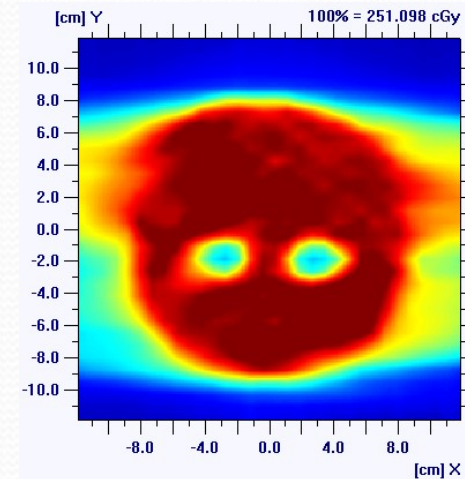


Gamma analysis

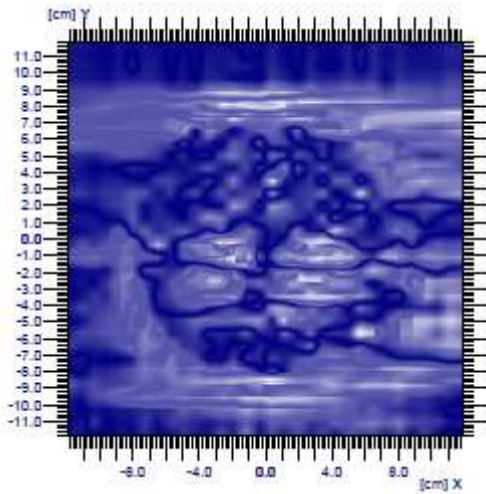


600 MU/min

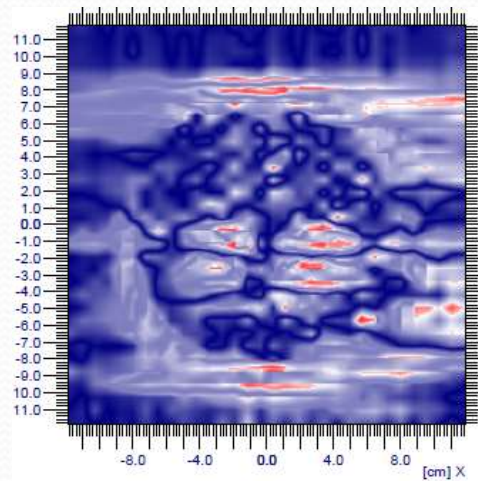
1/3 Dose plan



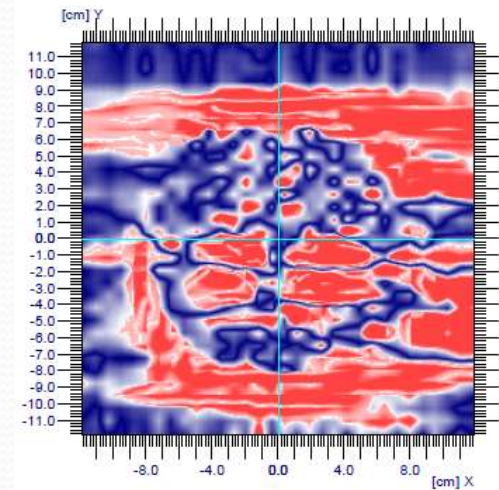
Original plan



Gamma 3% 3mm

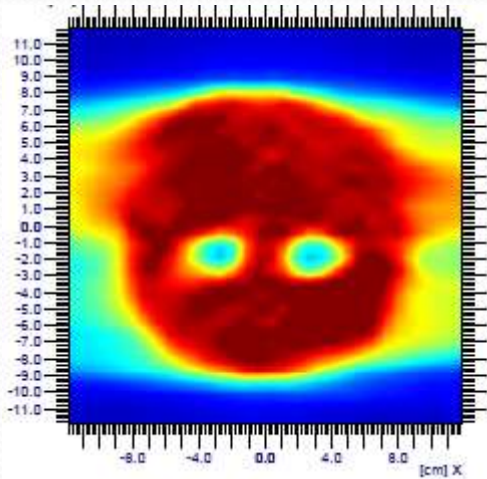


Gamma 2% 2mm



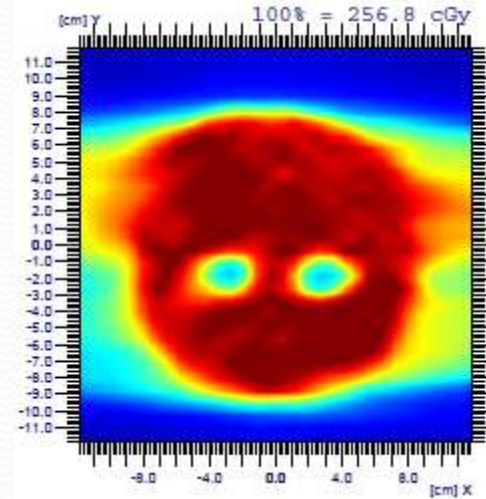
Gamma 1% 1mm

Gamma analysis

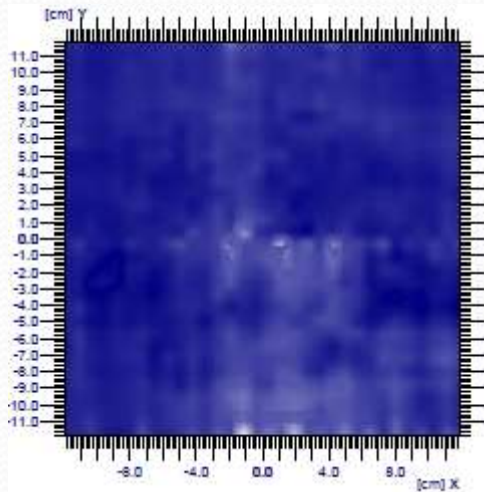


1/2 dose plan

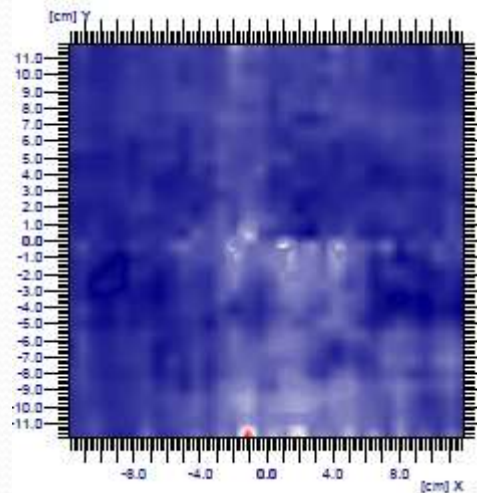
600 MU/min



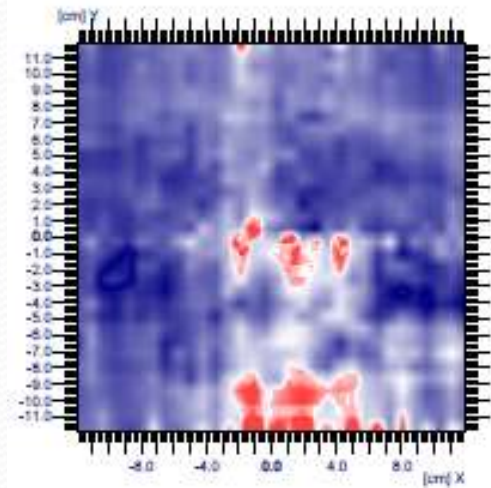
Original plan



Gamma 3% 3mm

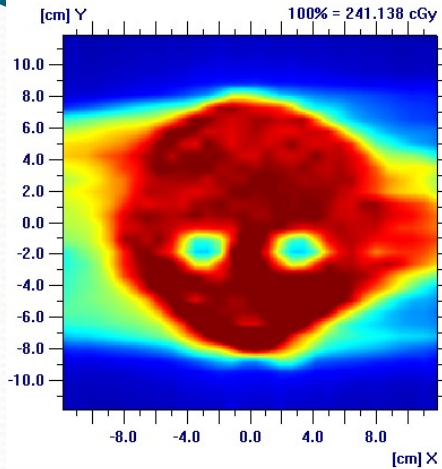


Gamma 2% 2mm

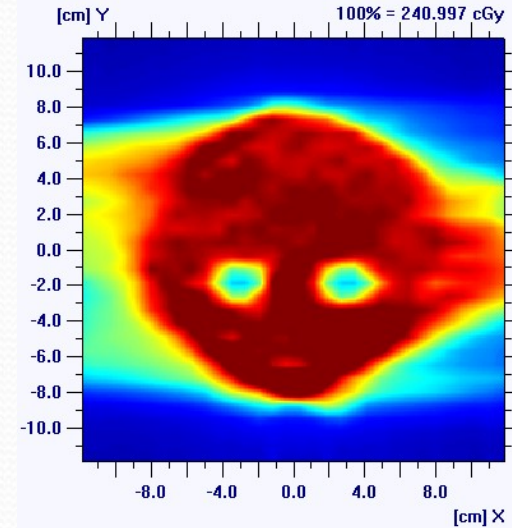


Gamma 1% 1mm

Gamma analysis

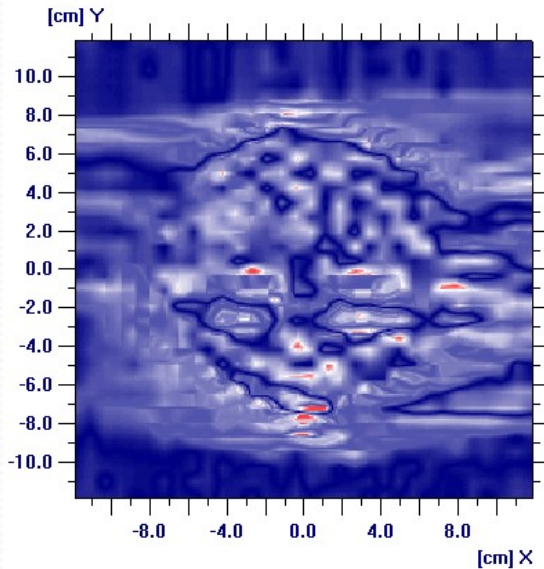


1000 MU/min

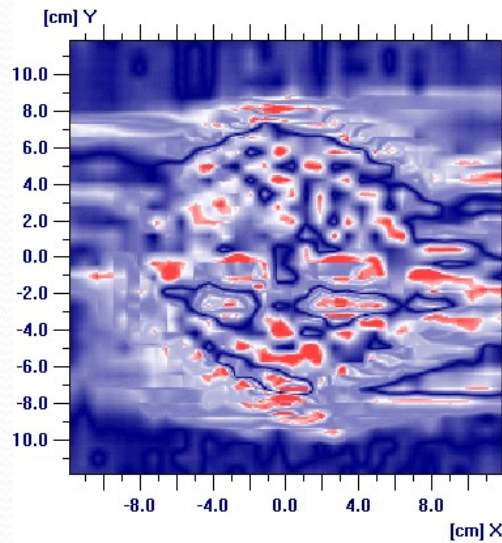


1/3 dose plan

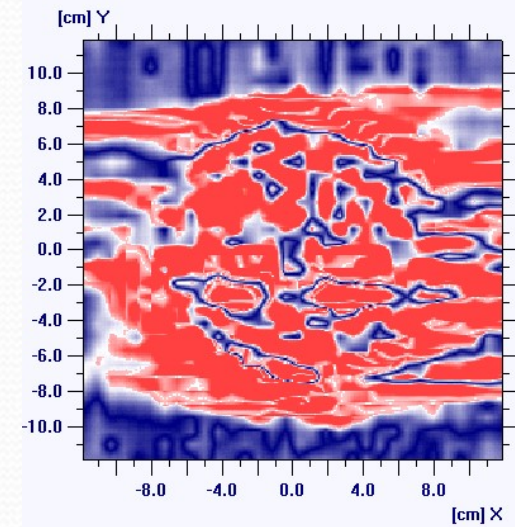
Original plan



Gamma 3% 3mm

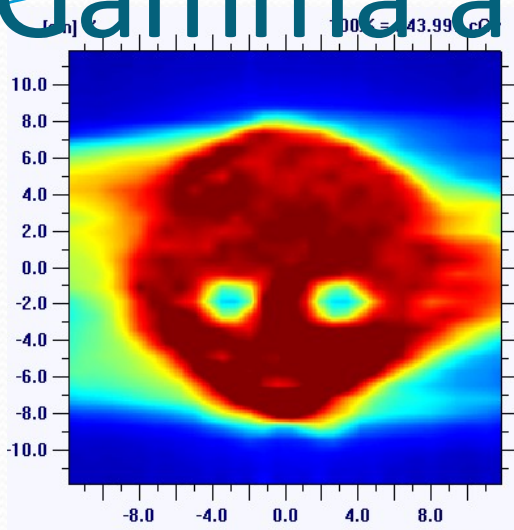


Gamma 2% 2mm



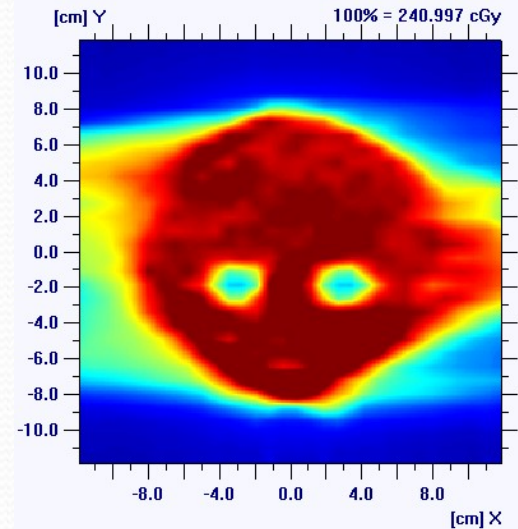
Gamma 1% 1mm

Gamma analysis

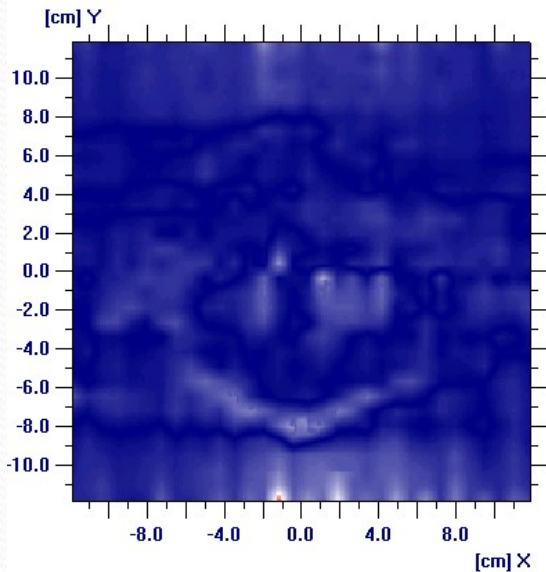


1/2 dose plan

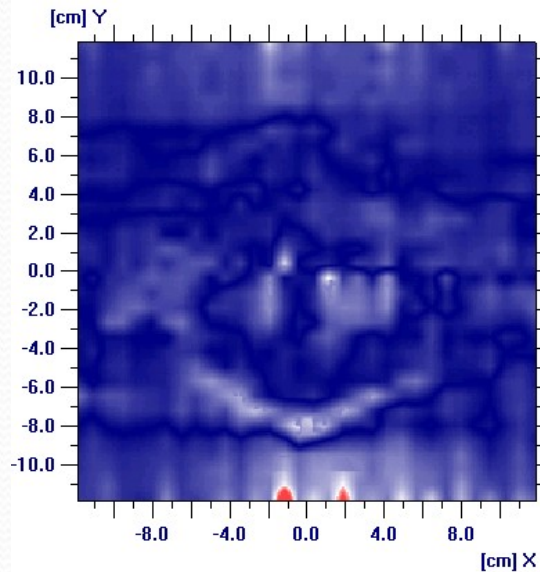
1000 MU/min



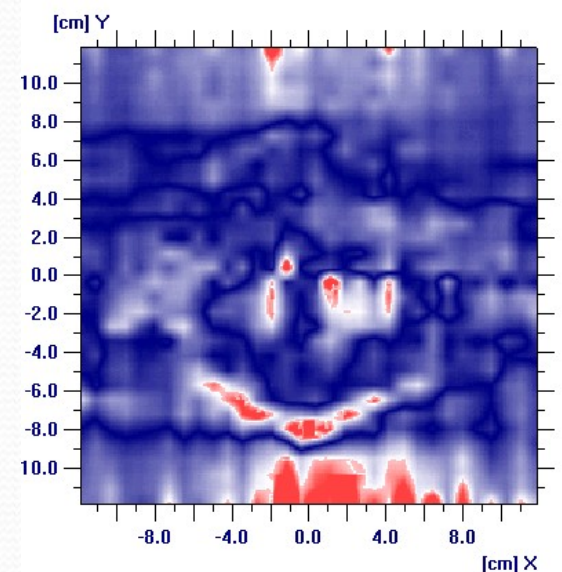
Original plan



Gamma 3% 3mm



Gamma 2% 2mm



Gamma 1% 1mm

Results cont.

	100 cGy vs 300 cGy			150 cGy vs 300 cGy		
Gamma	1%, 1mm	2%, 2mm	3%, 3mm	1%, 1mm	2%, 2mm	3%, 3mm
1	82.36	98.71	99.89	95.56	99.90	99.99
2	78.00	97.36	99.79	98.00	99.96	100.00
3	78.32	98.97	99.98	97.23	99.90	99.99
4	81.54	99.20	99.92	99.26	99.98	100.00
5	83.96	99.60	100.00	99.69	99.99	100.00
6	87.46	99.80	99.80	99.83	100.00	100.00
7	83.63	99.77	99.97	96.05	100.00	100.00
8	88.63	99.72	99.96	99.93	100.00	100.00
9	93.41	99.96	100.00	99.81	100.00	100.00
10	80.21	99.94	100.00	97.44	100.00	100.00
Mean	83.75	99.30	99.93	98.28	99.97	100.00
STD	4.86	0.80	0.08	1.66	0.04	0.00

Novalis TX 600 MU/min

Results cont.

	100 cGy vs 300 cGy			150 cGy vs 300 cGy		
Gamma	1%, 1mm	2%, 2mm	3%, 3mm	1%, 1mm	2%, 2mm	3%, 3mm
1	67.90	98.40	99.85	92.40	99.78	99.98
2	87.02	99.49	99.97	99.03	99.99	100
3	65.09	93.51	98.82	95.44	99.84	99.98
4	77.48	98.3	99.73	97.81	100	100
5	79.84	96.43	99.74	98.29	99.97	100
6	82.58	98.74	99.86	97.19	99.98	100
7	78.96	97.95	99.97	99.83	100	100
8	85.64	99.23	99.97	99.59	100	100
9	80.25	99.88	100	99.98	100	100
10	90.38	99.91	100	99.68	100	100
Mean	79.37	97.43	99.59	96.59	99.92	99.99
STD	9.96	2.67	0.52	2.70	0.10	0.01

Novalis TX1000 MU/min

Results cont.

	100 cGy vs 300 cGy			150 cGy vs 300 cGy		
Gamma	1%, 1mm	2%, 2mm	3%, 3mm	1%, 1mm	2%, 2mm	3%, 3mm
1	81.3	99.97	100	99.84	100	100
2	81.34	99.97	100	98.28	100	100
3	91.22	99.99	100	97.67	100	100
4	98.88	100	100	99.79	100	100
5	90.04	100	100	100	100	100
Mean	88.5	99.99	100	99.1	100	100
STD	7.4	0.01	0	1.0	0	0

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 \geq IMRT delivering quality
- Digital machine delivering quality \geq Analog machine (Elekta/Truebeam \geq 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)