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Present and Future of IMRT QA (3):

Log File-based Patient-specific QA

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DISCLOSURE

This work was partially supported by Varian Medical Systems (Palo Alto, CA, USA). I have no current or past relationships with commercial entities.

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Log

\lóg, läg\
noun / verb

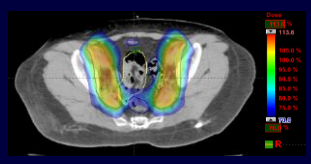
: A record of performance, events, or day-to-day activities

: to make a note or record of: enter details of or about in a log

(1) A final treatment plan

(2) Plan transferring to a R&V system

(3) Dry run



* Log file creation for individual patient treatment

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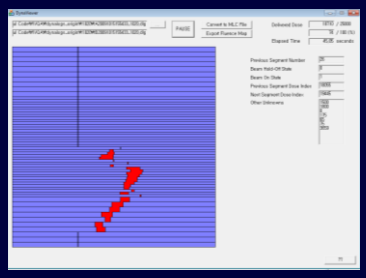
How can we get the treatment log files? (1) – *Varian*

- (automatic) Log file generation for all treatments/beams

(1) Dynalog (Clinac / Trilogy)



2 dynalogs for
bank A & bank B

a. MLC controller computer, 4DITC
C:\Program Files\Varian\Oncology\MLC\Controller\Exec

b. Type the command line
"diagAutoDynalogs 1" or "diagAutoDynalogs 2,1"

c. Dry run

d. Obtain a log file
C:\Program Files\Varian\Oncology\MLC\Controller\Exec\dynalogs

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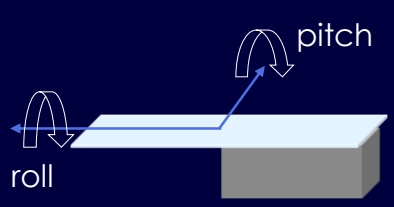
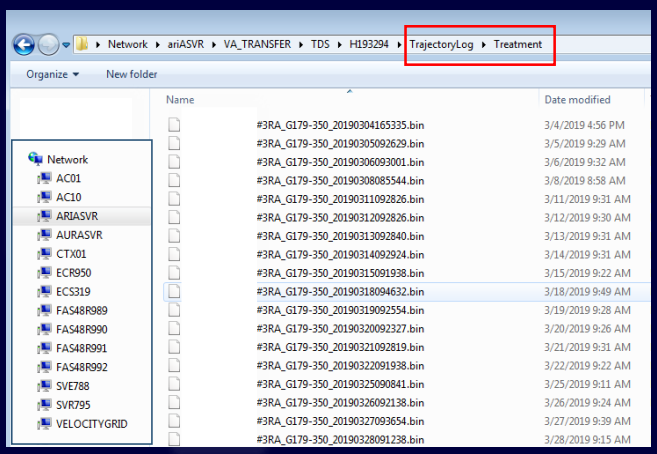
How can we get the treatment log files? (2) – *Varian*

(2) Trajectory Log (Truebeam , Truebeam Stx, Edge, Vital Beam)

<OutputFolder>\TrajectoryLog\Treatment

- Updated features
  - Sampling rate : 50 → **20 ms**
  - Added couch information
    - pitch and roll
  - (Tracking beam mode)





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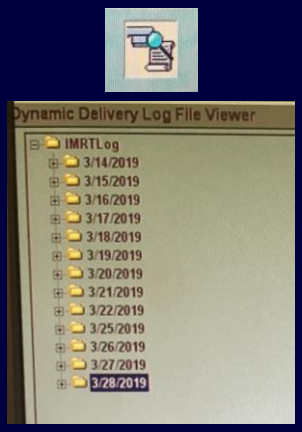
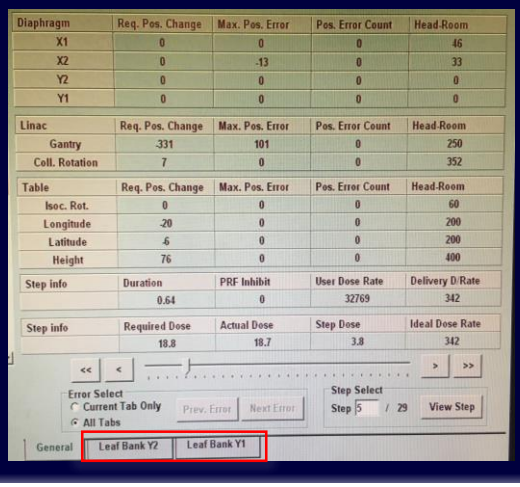
How can we **get** the treatment log files? (3) – *Elekta*

- Daily based-automatic log file creation for all treatments/beams
- Service mode > Dynamic Delivery Log File Viewer





MLC leaf – Leaf Bank Y1

Leaf	Required	Max.	Error	H/Rm
41	0	1	0	33
42	0	3	0	31
43	0	5	0	29
44	0	5	0	29
45	0	3	0	31
46	0	3	0	31
47	0	2	0	32
48	0	3	0	31
49	0	4	0	30
50	0	5	0	29
51	0	3	0	31
52	0	2	0	32
53	0	4	0	30
54	0	4	0	30
55	0	5	0	29
56	0	4	0	30
57	0	6	0	28
58	0	1	0	33
59	0	5	0	29
60	0	3	0	31

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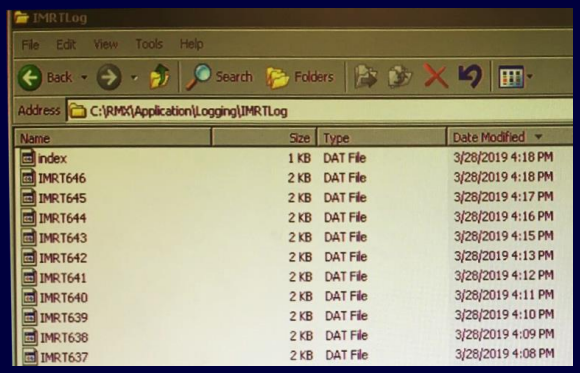
How can we **get** the treatment log files? (4) – *Elekta*

- NRT (Elekta controller) pc – window mode
  C:\RMX\Application\Logging\IMRT Log
- A networked computer which can access to the NRT pc

icom-Vx
(Linac verification interface)

R&V System

NRT



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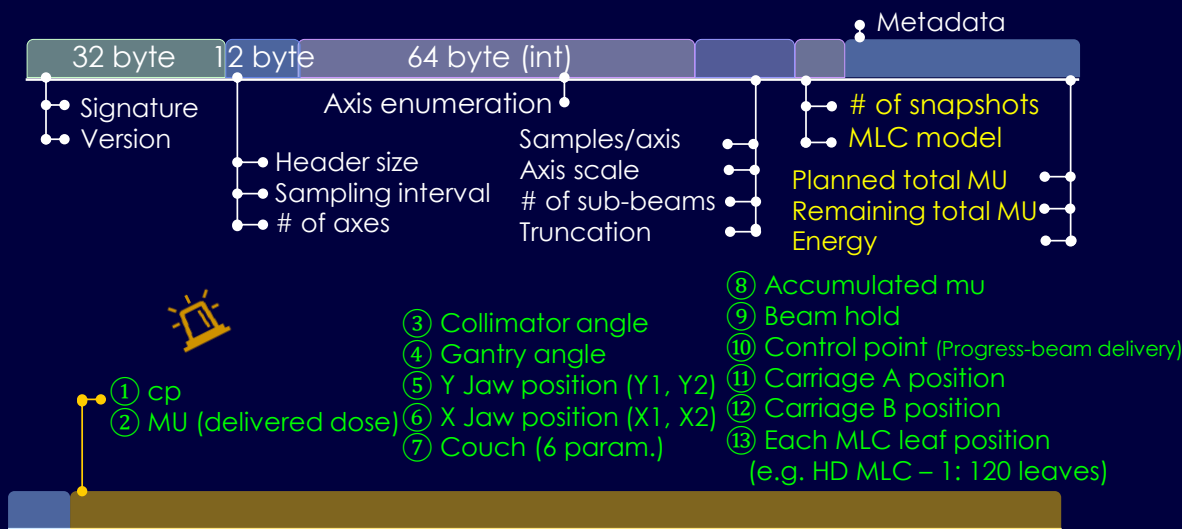
What data can we read from the treatment log files? (1)

- Decoding of Binary files (sequence of bytes) – Data type, structure



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What can we read from the treatment log files? (2)

- Generation of a text file (including subset data - # of snapshot)

Logfile_txt_ex.txt

```
VOSTL    4.0

Header Size: 1024
Sampling Interval [ms] :20
N_axes: 5018
MLC Model: 3

Patient_ID: 18-0350
Plan_Name: 183819#4HA
Planned_Total_MU: 663.1577
Remained_Total_MU: 663.1577
Beam_Energy: 6xFFF
Beam_Name: G181.1-179.9

-------- 1 st SNAPSHOT--------------------

Collimator Angle(Expected,Actual): [78.000000 77.999802]
Gantry Angle(Expected,Actual): [180.100006 180.139313]
JawY1(Expected,Actual): [-45.000000 -45.000005]
JawY2(Expected,Actual): [55.000000 54.999995]
JawX1(Expected,Actual): [-28.699999 -28.700013]
JawX2(Expected,Actual): [26.199999 26.200006]
mu(Expected,Actual): [0.000000 0.000000]
Beam_Hold(Expected,Actual): [2.000000 2.000000]
CP(Expected,Actual): [0.000000 0.000000]
Carriage_A(Expected,Actual): [5.743427 5.744028]
Carriage_B(Expected,Actual): [6.756573 6.756739]
```

```
-------- MI
#1 leaf(Exp
#2 leaf(Exp
#3 leaf(Exp
#4 leaf(Exp
#5 leaf(Exp
#6 leaf(Exp
#7 leaf(Exp
#8 leaf(Exp
#9 leaf(Exp
#10 leaf(Ex
#11 leaf(Ex
#12 leaf(Ex
#13 leaf(Ex
#14 leaf(Ex
#15 leaf(Ex
#16 leaf(Ex
#17 leaf(Ex
#18 leaf(Ex
#19 leaf(Ex
#20 leaf(Ex
#21 leaf(Ex
#22 leaf(Ex
#23 leaf(Ex
#24 leaf(Ex
#25 leaf(Ex
#26 leaf(Ex
#27 leaf(Ex
#28 leaf(Ex
#29 leaf(Ex
#30 leaf(Ex
```

```
-------- MLC_Leavse_Positions [X1] --------
#1 leaf(Expected,Actual): [-46.999998 -46.998782]
#2 leaf(Expected,Actual): [-46.999998 -46.998782]
#3 leaf(Expected,Actual): [-46.999998 -46.998782]
#4 leaf(Expected,Actual): [-46.999998 -46.998782]
#5 leaf(Expected,Actual): [-46.999998 -46.998782]
#6 leaf(Expected,Actual): [2.300000 2.299329]
#7 leaf(Expected,Actual): [-35.699999 -35.701394]
#8 leaf(Expected,Actual): [33.299999 33.301387]
#9 leaf(Expected,Actual): [33.299999 33.301387]
#10 leaf(Expected,Actual): [33.299999 33.301387]
#11 leaf(Expected,Actual): [33.299999 33.301387]
#12 leaf(Expected,Actual): [33.299999 33.301387]
#13 leaf(Expected,Actual): [33.299999 33.301387]
#14 leaf(Expected,Actual): [8.700000 8.701253]
#15 leaf(Expected,Actual): [3.800000 3.791449]
#16 leaf(Expected,Actual): [-0.200000 -0.206311]
#17 leaf(Expected,Actual): [-0.100000 -0.108429]
#18 leaf(Expected,Actual): [-0.200000 -0.206311]
#19 leaf(Expected,Actual): [3.600000 3.595057]
#20 leaf(Expected,Actual): [-0.200000 -0.209370]
#21 leaf(Expected,Actual): [0.100000 0.093753]
#22 leaf(Expected,Actual): [1.300000 1.293586]
#23 leaf(Expected,Actual): [1.400000 1.394851]
#24 leaf(Expected,Actual): [2.600000 2.594685]
#25 leaf(Expected,Actual): [6.300000 6.292381]
#26 leaf(Expected,Actual): [11.400000 11.393621]
#27 leaf(Expected,Actual): [18.900000 18.895012]
#28 leaf(Expected,Actual): [-34.300001 -34.304271]
#29 leaf(Expected,Actual): [-26.900001 -26.903608]
#30 leaf(Expected,Actual): [-18.099999 -18.112636]
```

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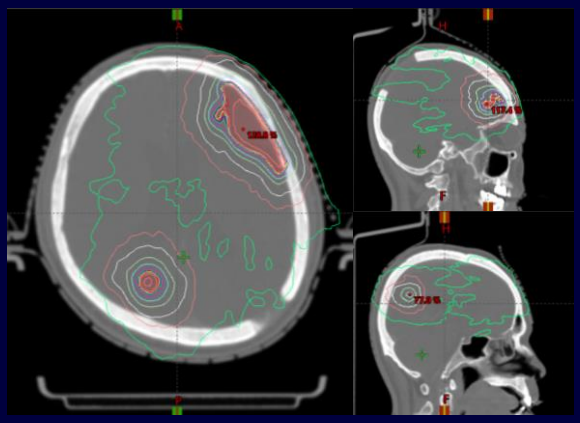
What can we analyze from the treatment log files? (1)

- Patient-specific QA for Linac-based SRS
  (e.g.) Truebeam™ STx - HyperARC, HD120 MLC



Plan Parameters

6X - FFF	Couch	Arcs			
		Start	End	Rotation	Collimator
1	0	181.1	179.9	CW	78
2	45	179.9	0	CCW	165
3	315	0	181.1	CCW	165
4	270	181.1	0	CW	159

TrajectoryLog files

Patient ID	#4HA_KVCBCT_Setup_20190107192501.bin
Patient ID	#4HA_G181.1-179.9_20190107192746.bin
Patient ID	#4HA_G179.9-0_C45_20190107193041.bin
Patient ID	#4HA_G0-180.1_C315_20190107193255.bin
Patient ID	#4HA_G180.1-0_C270_20190107193444.bin

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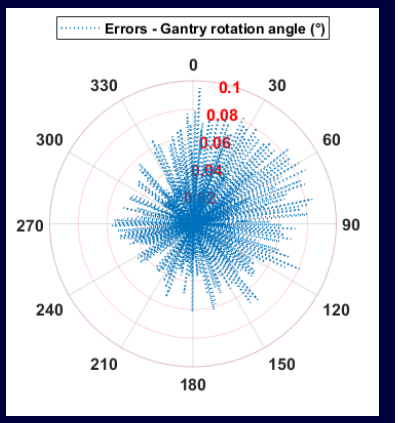
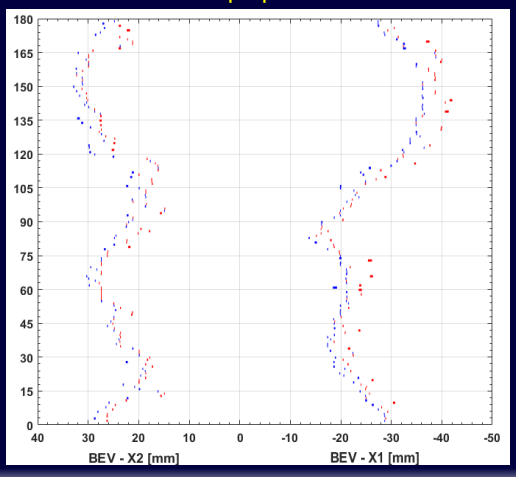
What can we analyze from the treatment log files? (2)

- Patient-specific QA
  - Beam delivery parameters

Gantry Angles, ε < 0.1°

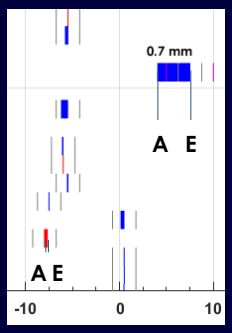


X Jaw, |ε| < 0.63 mm



|ε| ± 0.25 mm

CNP 60



Jaw	Error [mm]	
	Avg.	max.
X1	0.08	[-0.65 0.68]
X2	0.06	[-0.48 0.36]
Y1	0.18	[-0.74 0.77]
Y2	0.16	[-0.62 0.78]

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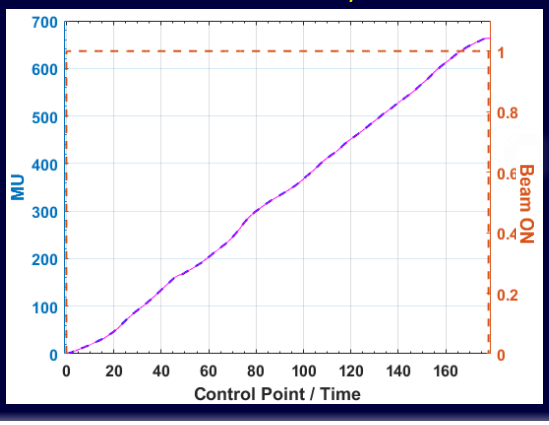
What can we analyze the treatment log files? (3)

- Patient-specific QA
  - Beam delivery parameters

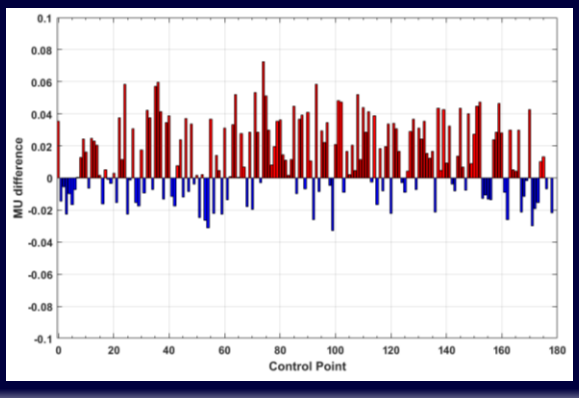
MU, ε < 0.07

Beam hold ON/OFF



Control point (Progress of beam delivery)

MU difference in detail



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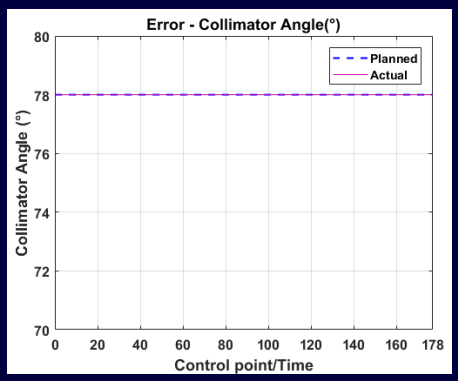
What can we analyze the treatment log files? (4)

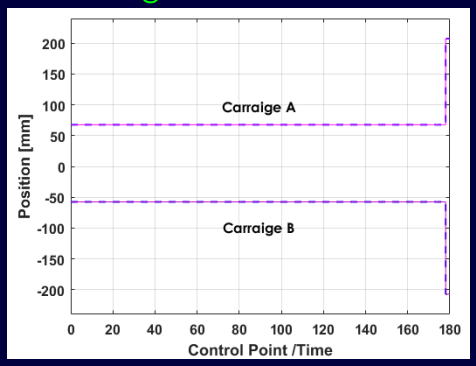
Carriage

- Patient-specific QA
  - Beam delivery parameters

Collimator, ε < 0.001°



Carriage A/B, ε< 0.01 mm MLC



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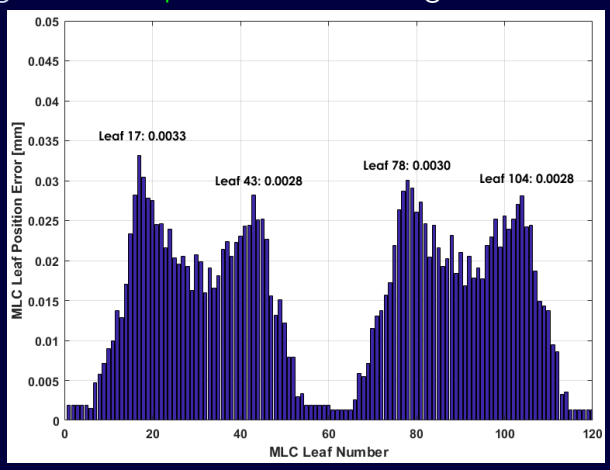
What can we analyze the treatment log files? (5)

- Patient-specific QA - HD120 MLC

Avg. MLC leaf position error during beam delivery



MLC leaf position :
(abs) max ε < 0.08 mm

MLC	Error [mm] (abs) max.
X1	0.0786
X2	0.0774

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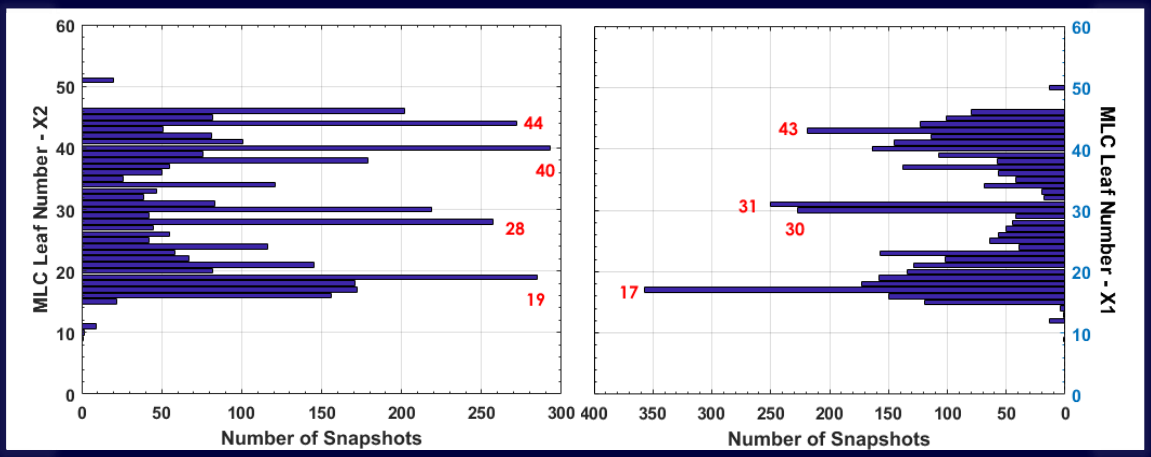
What can we analyze the treatment log files? (6)

- Patient-specific QA - HD120 MLC

X2 Frequency showing the max position error according to each MLC leaf **X1**



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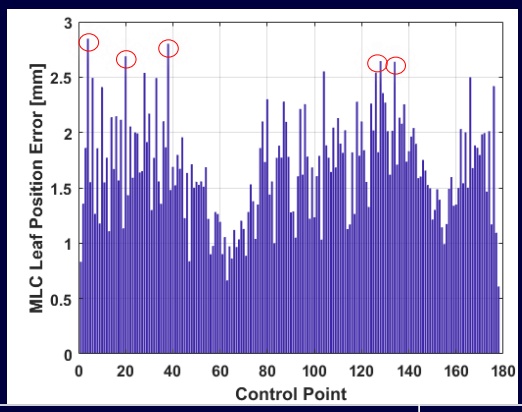
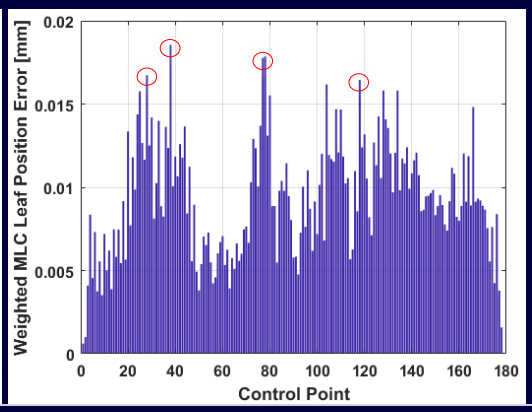
What can we analyze the treatment log files? (7)

- Patient-specific QA - HD120 MLC





Control Point (High MLC position error)	Non-weighted	Weighted
	4,38,20,128,134…	38,78,77,28,118..

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What can we analyze the treatment log files? (8)

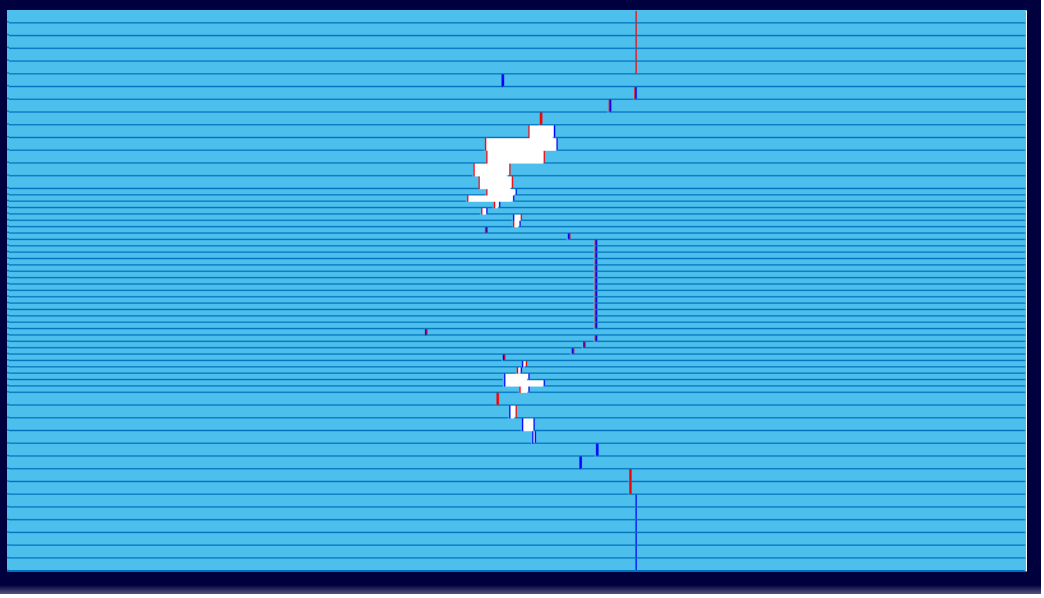
HD120 MLC

(1) Control Point 38

G-254.7°

(2) Control Point 78

G-336.5°



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What can we analyze the treatment log files? (9)

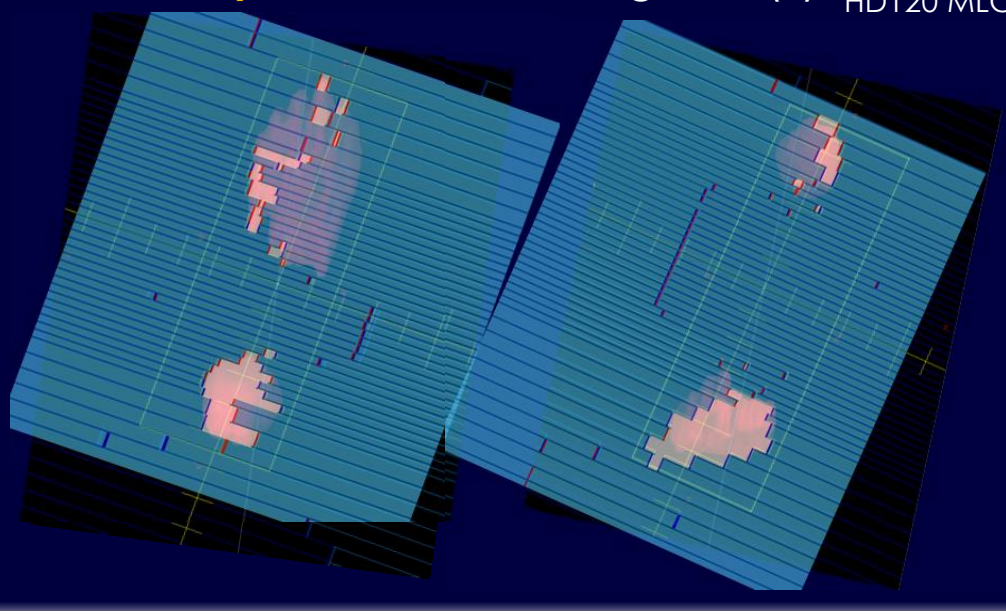
HD120 MLC

(1) Control Point 38

G-254.7°

(2) Control Point 78

G-338.5°



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Patient-specific QA summary using a log file (1) – Example

Patient	Patient Name:	ABC
	Patient ID:	123
Treatment	Technique:	HA – SRS (VMAT)
	Machine:	Truebeam

Plan Information	Plan Name:	HA#4 – Brain Mets
	Beam Energy:	6X – FFF
	MU:	663.16
	Gantry Angle:	Start (180.1) – End(179.9), CW
	Control Points:	178

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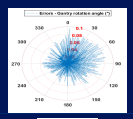
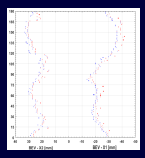
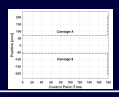
Patient-specific QA **summary** using a log file (1) – Example

	QA Components		Error	Analysis (in detail)	
Beam Delivery	(1) Gantry angles: 180.1° - 179.9°		max < 0.01°		Perfect !
	Angles required to check: 182.9° (CP: 2/3), 258.3° (CP: 39/40)		+ Gantry speed/ acceleration		
	(2) Jaw	(a) Collimator Angles: 78°	max < 0.001°		Perfect !
		(b) Jaw - X1	max < 0.7 mm		
		(d) Jaw –X2	max < 0.7 mm		
		(e) Jaw – Y1	max < 0.8 mm		
		(f) Jaw – Y2	max < 0.8 mm		
	(3) Carriage	(3) Carriage A: 57.44	max < 0.01 mm		Perfect !
		(4) Carriage B: 67.56	Max < 0.01 mm		Perfect !

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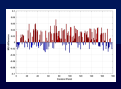
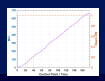
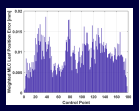
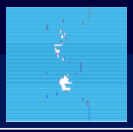
Patient-specific QA **summary** using a log file (1) – Example

	QA Components		Error	Analysis (in detail)	
Beam Delivery	(5) MU		< 0.007		Perfect !
	MU required to check: Control point: 74 (G - 328.3°), 93 (G - 7.16°), 36 (250.63°)				
	(6) Beam ON/OFF		No pause No issue		Perfect !
	(7) MLC	A) Averaged position errors for each leaf	Avg. < 0.03 mm		Perfect !
		B) Max position errors for each leaf	max < 0.08 mm		
		C) Position errors for each control point			
+ Leaf traveling speed/acceleration		CP required to check : Control point: 74 (G - 328.3°), 93 (G - 7.16°)			

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Q. How much dosimetric effect can be changed in dose distribution, when we reflect the actual beam parameters from the treatment log files?

Q. How do we usefully use the treatment log files for IMRT patient-specific QA?

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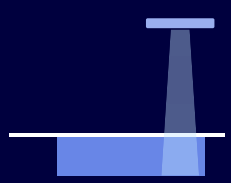
Estimated dosimetric effects in IMRT dose delivery (1)

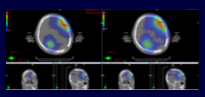


Treatment Log files

Extracting plan parameters for all control points

A new Rp file
A new beam file

Evaluation of dosimetric effect



Dicom Rp file
RTP file

TPS

R&V System

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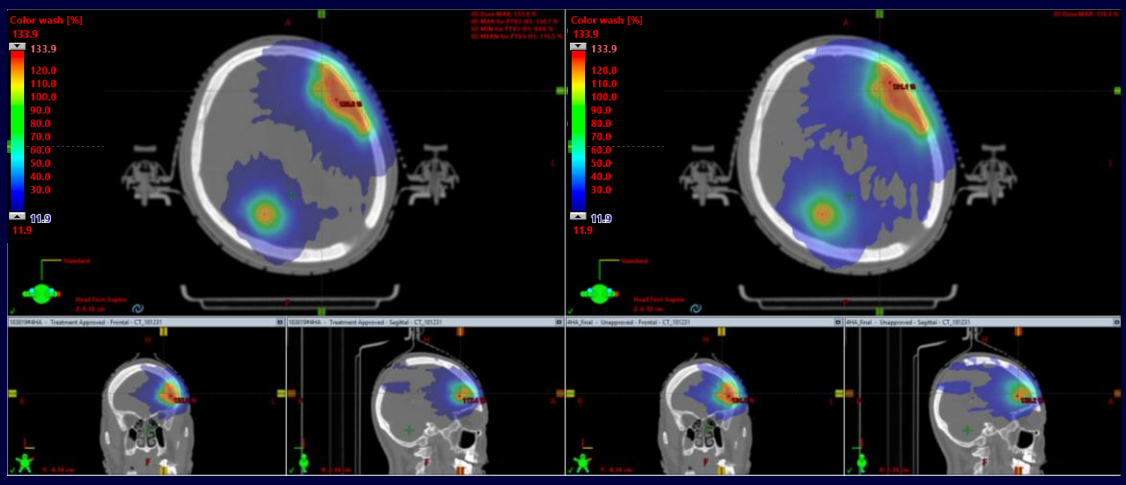
Estimated dosimetric effects in IMRT dose delivery (2)

Difference at the isodose level of 30-40%



Original plan

Recreated plan using the Log files

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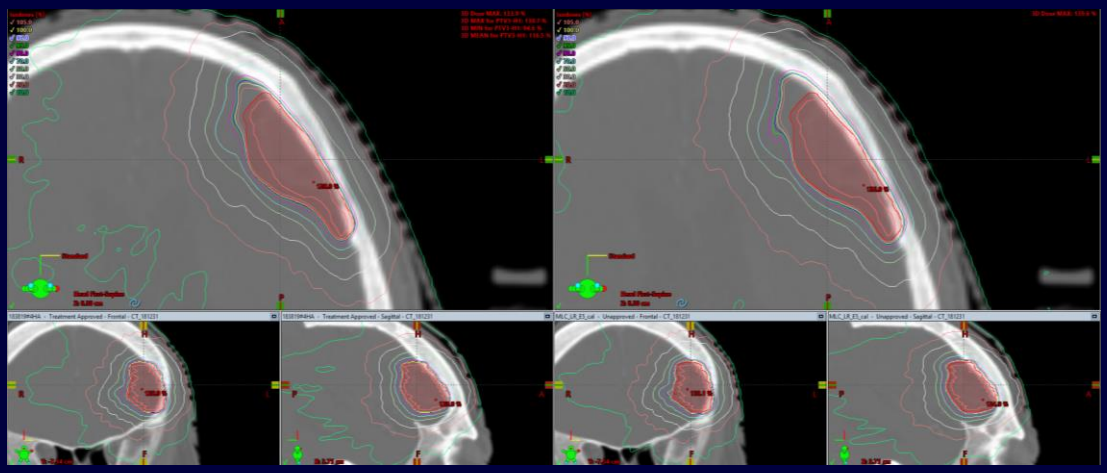
Estimated dosimetric effects in IMRT dose delivery (3)

- Error sensitivity and specificity by the beam delivery parameters



Original Plan

Recreated Plan – MLC
(L: -0.5 mm, R: +0.5 mm)

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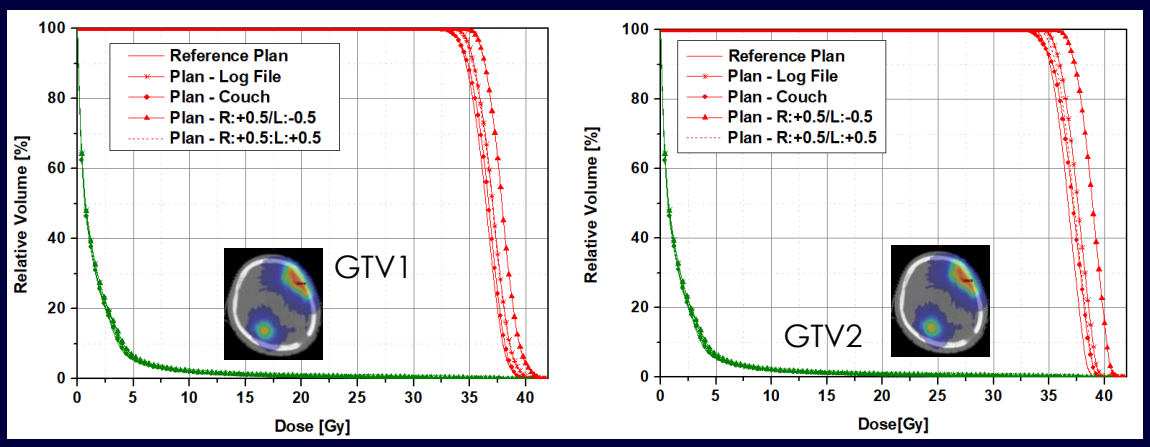
Estimated dosimetric effects in IMRT dose delivery (4)

- Error sensitivity and specificity by the beam delivery parameters

GTV-1 (9.8 cc) GTV-2 (4.1 cc)



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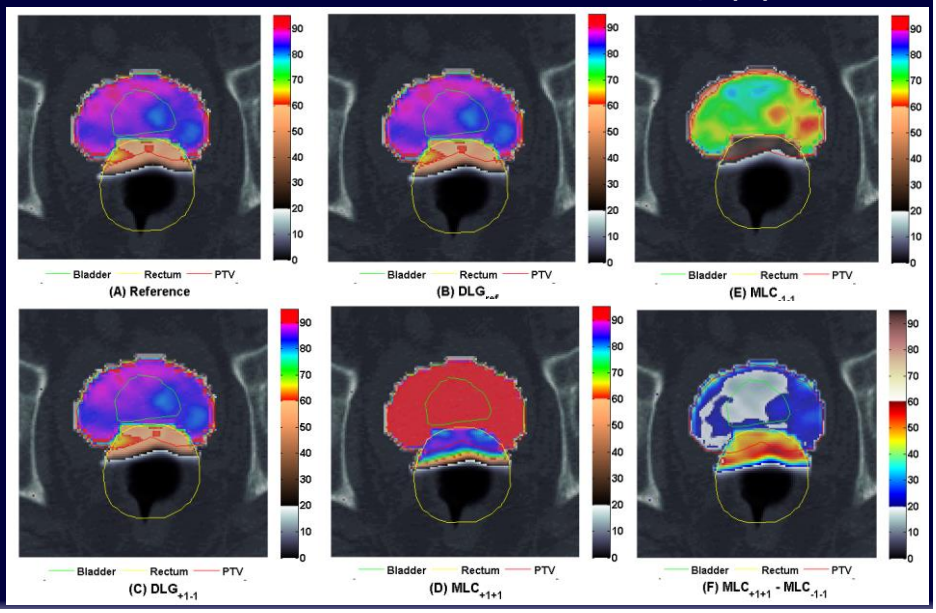
Estimated dosimetric effects of IMRT dose delivery (5)

- ✓ Patient-specific
- ✓ Machine – specific
- ✓ Organ-specific evaluation



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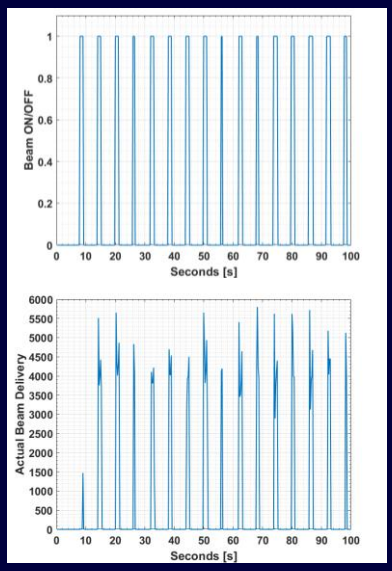
Estimated dosimetric effects in gated IMRT(1)

Beam ON/OFF input using patient motion information

Actual Beam Delivery



A new Rp/beam file
Gantry Angle'
MLC shape'
Delivered MU' …
at the moment of beam delivery
↓

- 4D dose simulation in gated IMRT using the patient (4D) CT images

Dose measurement using a phantom

- Real-time measurement
- Evaluation of individual partially delivered dose distributions

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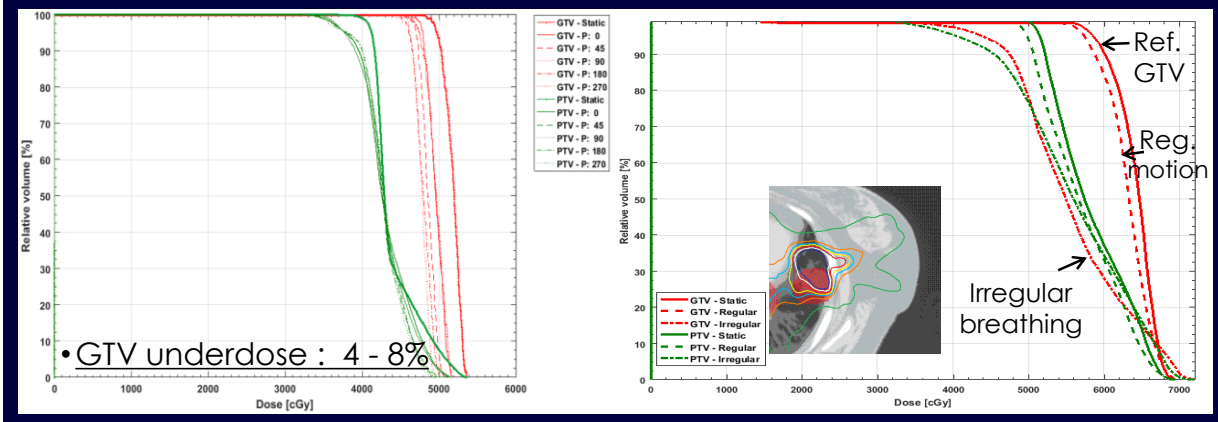
Estimated dosimetric effects in gated IMRT (2)

- Interplay effects in gated VMAT using 6FFF



Different starting phases

Irregular breathing motion in high intensity modulation

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Discussion & Conclusion

* Log file-based patient-specific QA

- Component by component evaluation beyond End-to-end test
- Error sensitivity evaluation by individual specific parameter
- Beam delivery process-oriented evaluation as well as composite measures/evaluation

- Patient-specific / Machine-specific
- Treatment type – specific
- Treatment procedure – specific
- Beam energy/type – specific

- Treatment site – / organ – specific dosimetric evaluation

- Consistent methodology & Criteria
- Optimal plan optimization parameters

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