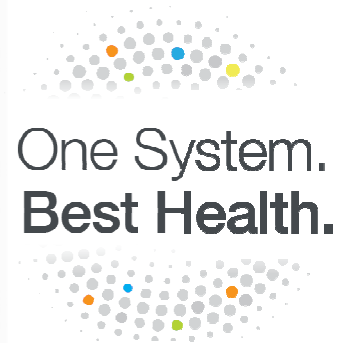




Lakeridge  
Health

# Frameless SRS using the Elekta Linac Platform

SAM Practical Medical Physics, AAPM,  
MO-K-304-3, July 15 2019



## Disclaimers and Credits



- No conflicts of interest to declare
- Acknowledgments
  - Daryl Scora
  - Lourdes Garcia
  - Catherine Neath

## Outline



- Review of clinical indications and criteria
- Equipment specification
- Technique development, commissioning and implementation
- Clinical workflow
- Quality assurance: daily linac QA and patient specific QA
- Advantages and limitations

## Clinical indications and criteria



- Brain metastases
  - Solid disease
  - Post operative cavity
- Up to 4 lesions
- Cones for lesions <2.5 cm
- MLC for lesions > 2 cm
- Doses range from 1500cGy x1 to 3250cGy/5 fractions



## Equipment Specification



### Delivery:

- Elekta linac
- Agility MLC (0.5 cm)
- Aktina cone system
- 6MV, 6MV FFF beams
- XVI kV cone beam system
- Hexapod 6 degree of freedom couch

### Immobilization:

- Aktina bite block system
- Fibreplast mask, 3.2 mm thick,
- On cantilevered portrait board
- Or on uniframe base plate

## Equipment Specification



### Treatment Planning:

- Monaco 5.11 TPS by Elekta
- Monte Carlo algorithm for dose calculation
- Fused planning MRI for target definition
- Non-coplanar arcs and cones (lesions <2.5 cm)
  - 5 arcs template
- VMAT (or DCAT) inverse planned (lesions >2 cm)
  - 1-2 arcs +/- 1 partial non-coplanar arc
  - Template based optimization
- In house DVH worksheet for constraints and coverage assessment

## Equipment Specification



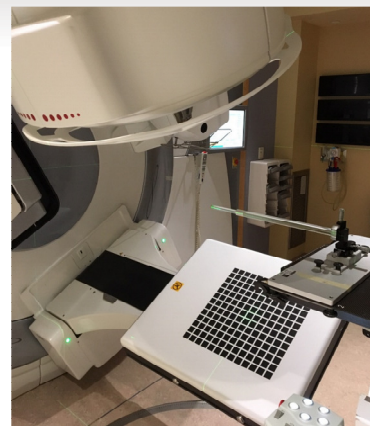
### Commissioning and QA:

- IBA water tank; PTW micro Diamond 60019 and Sun Nuclear Edge detectors
- STEEV phantom with CC04 ion chamber
- Sun Nuclear ArcCheck array detector
- Mobius 3D and FX
- Mobius Doselab Pro
- Sun Nuclear QA3
- QATrack+

## Commissioning



- Beam data acquisition and beam modeling
- Couch isocentre assessment
  - <1 mm diameter
- Couch/gantry coincidence
  - Within 0.5mm of each other
- Radiation and imaging isocentre coincidence (6MV, 6MV FFF; CW, CCW)
  - Tolerance 0.3mm / Action 0.5mm



## Technique development



- MRI target definition
- Aktina mouthbite system
- 2 mm PTV
- Non-coplanar arcs (cones)
- VMAT/DCAT inverse planning (MLC based)
- Up to 3 targets per isocentre



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## Clinical Protocol: single fraction



Inclusion:	1-4 Mets on MRI (not just CT imaging) ECOG 0-2 Maximum size 2.6 cm	
Exclusion:	Unable to have MRI (pacemaker/gadolinium allergy) Pregnancy Leptomeningeal Small cell, germ cell, lymphoma (may consider as salvage) ECOG 3-4 No tissue diagnosis otherwise possible Hydrocephalus/mass effect (obstruction risk > neurosurgery) History of severe allergic reaction to Peppermint oil (for Aktina) Loose teeth (for Aktina) Unable to lie flat	
Dose/fractionation:	Size dependent: 1500-2000 cGy / 1 fraction	
Technique:	Non-coplanar arcs with Cones	
Immobilization:	Supine Aktina Re-locatable stereotactic head frame with mouth bite (preferred) Rigid Thermoplastic Mask – neutral head position using portrait board	
Contouring:		By:
Normal Tissues	External contour, Non Aktina: include portrait board as couch structure, Eyes, internal surface of skull	Sim MRT
Organs at Risk	Brainstem, Optic Nerve, Optic Chiasm, Lens, Cochlea	RC
GTV	Enhancing lesion on T1 MRI	RC
PTV	GTV + 0.2 cm	Dosim

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## Clinical Protocol: fractionated



Dose/fractionation:	2500cGy/5 fractions; 3000cGy/5 fractions; 3250cGy/5 fractions Treatment Daily	
Technique:	DCAT, VMAT	
Immobilization:	Supine Aktina Relocatable frame with mouthpiece (for exclusion criteria refer to SRS Brain Met Site Specific Guideline) OR Rigid Thermoplastic Mask-neutral head position	
Contouring:		By:
Normal Tissues	Patient (Non-Aktina: baseplate), Eyes, Internal surface of skull	Sim MRT
Organs at Risk	Brainstem, Optic Nerve, Optic Chiasm, Lens, Cochlea	RO
GTV	Enhancing lesion on T1+C	RO
PTV (Dependant on Immobilization)	Aktina: GTV + 0.2 cm Thermoplastic mask: GTV + 0.3 cm PTV must be greater than 2cm diameter, otherwise consult with physics.	Dosim

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## Dosimetry worksheet



### DRCC SRS Single Target Single Fraction Dosimetry Worksheet

Patient: \_\_\_\_\_ U# \_\_\_\_\_

#### PTV Evaluation

PTV-cc (a)			
Prescription cGy			
Max dose cGy			140%
DVH % PTV covered by Rx	%		
V 100%	cc (d)	Minimum	Maximum
Conformity index (d/a)	1.00 ratio	1.0	2.0

#### Normal Tissue Constraints

Tissue	Volume	Volume Dose (cGy)		Max Dose (cGy)	
		Value	Accepted	Value	Accepted
Eye					900
Lens					100
Optic Nerve					900
Optic Chiasm					900
Cochlea					1200
Brainstem	1cc		1200		1250
Spinal Cord					1300
	Dose	Volume (cc)		Max Dose (cGy)	
		Value	Accepted	Value	Accepted
Non PTV Brain V12 Gy	1200 cGy		≤5 -10		4000

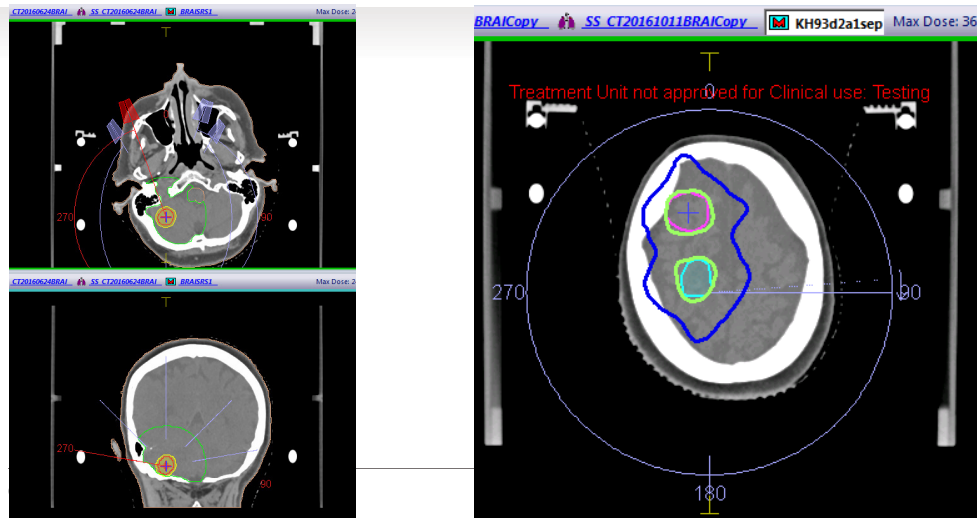
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Staff: \_\_\_\_\_

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Comment:

## Planning templates

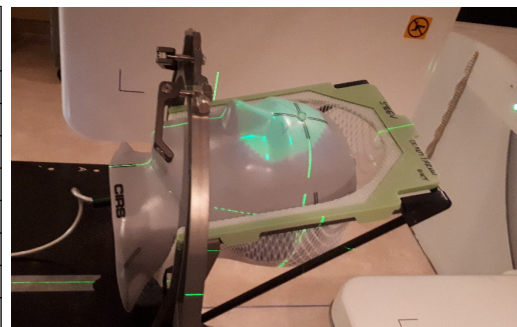


## End to End Testing



### STEEV phantom and CC04 Ion chamber

Delivery	Beam	Lesion position	Measured vs intended dose (% diff)
Cones	6MV	@isocentre	< 1.0%
	6MV FFF		< 1.0%
VMAT	6MV	@isocentre	< 1.0%
	6MV FFF		< 1.0%
	6MV	single lesion, offset from isocentre	< 1.1%
	6MV FFF		< 1.1%
	6MV	more than 1 lesion, offset from isocentre	< 1.1%
	6MV FFF		< 1.1%



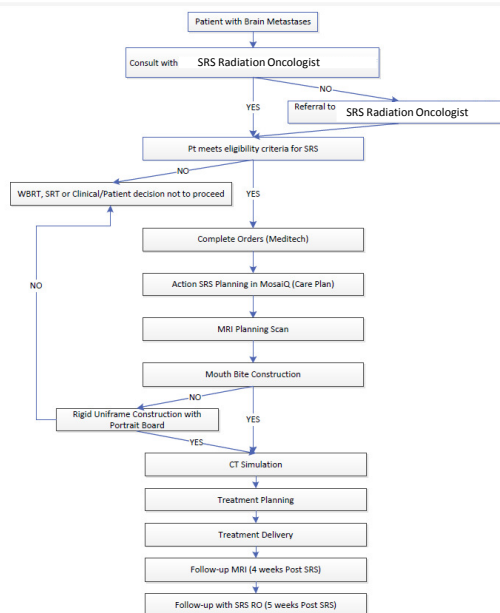
## Clinical workflow and tools



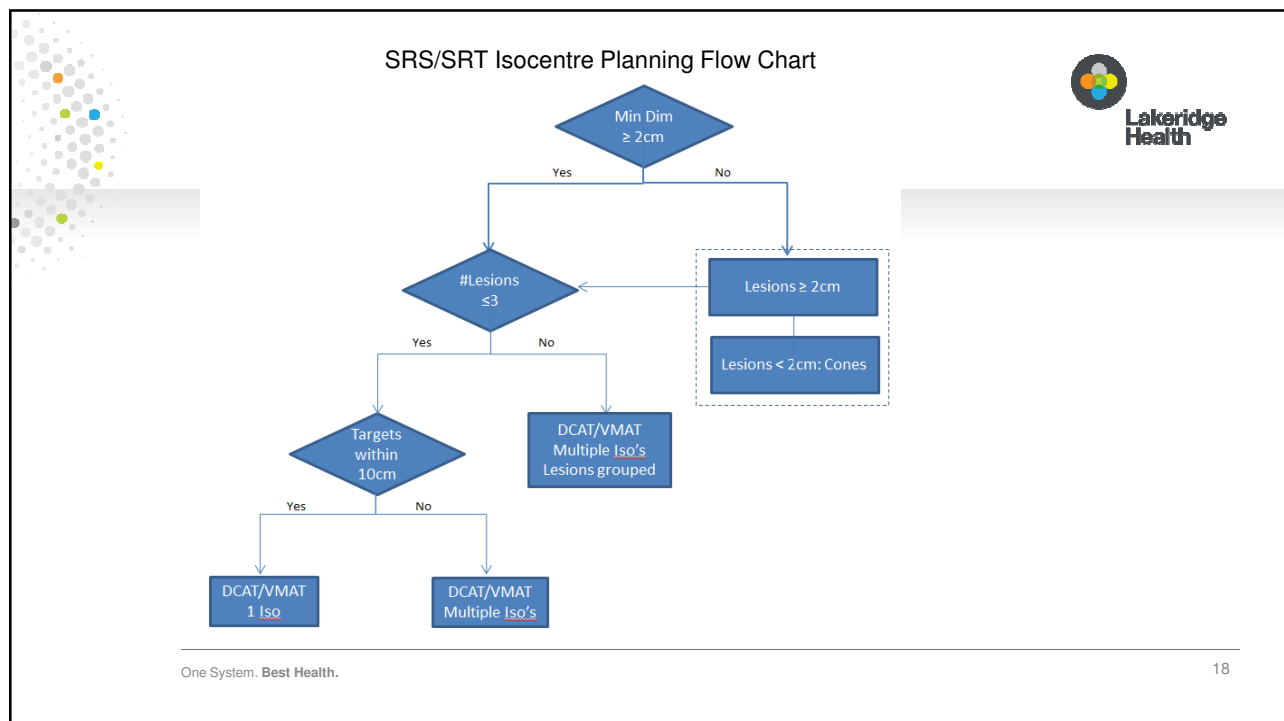
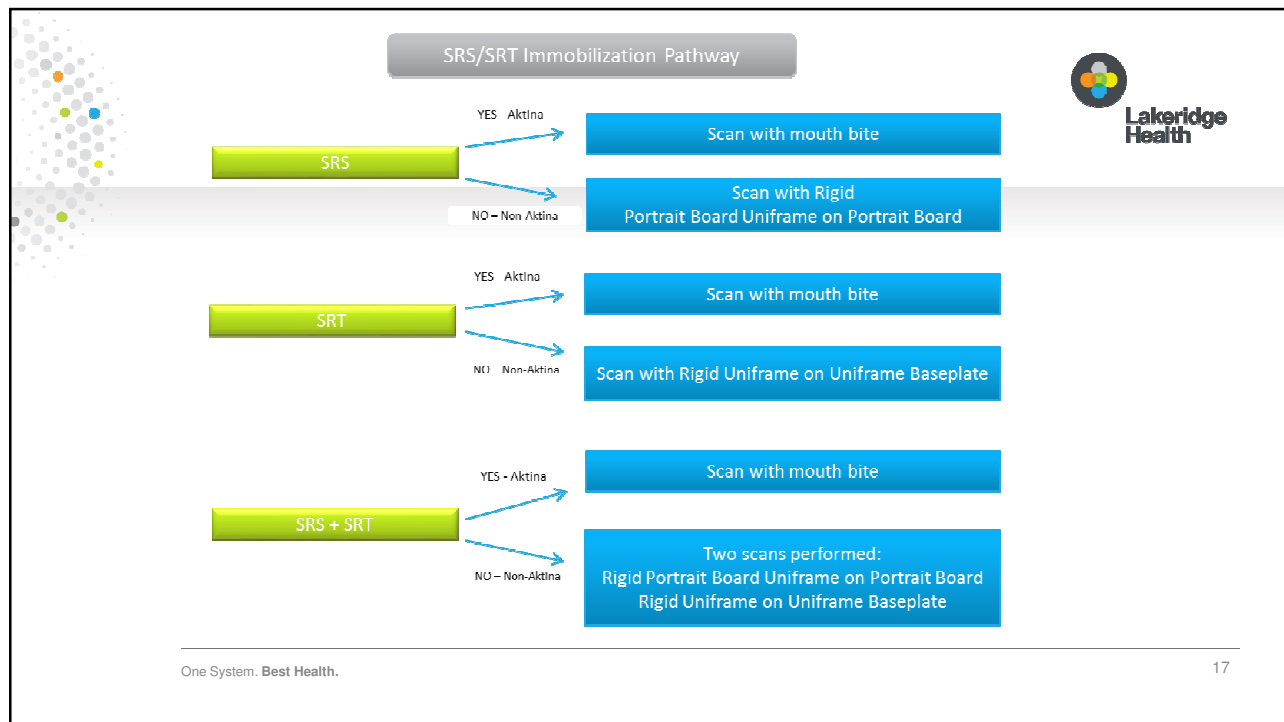
- Process diagrams and flowcharts to aid decision making

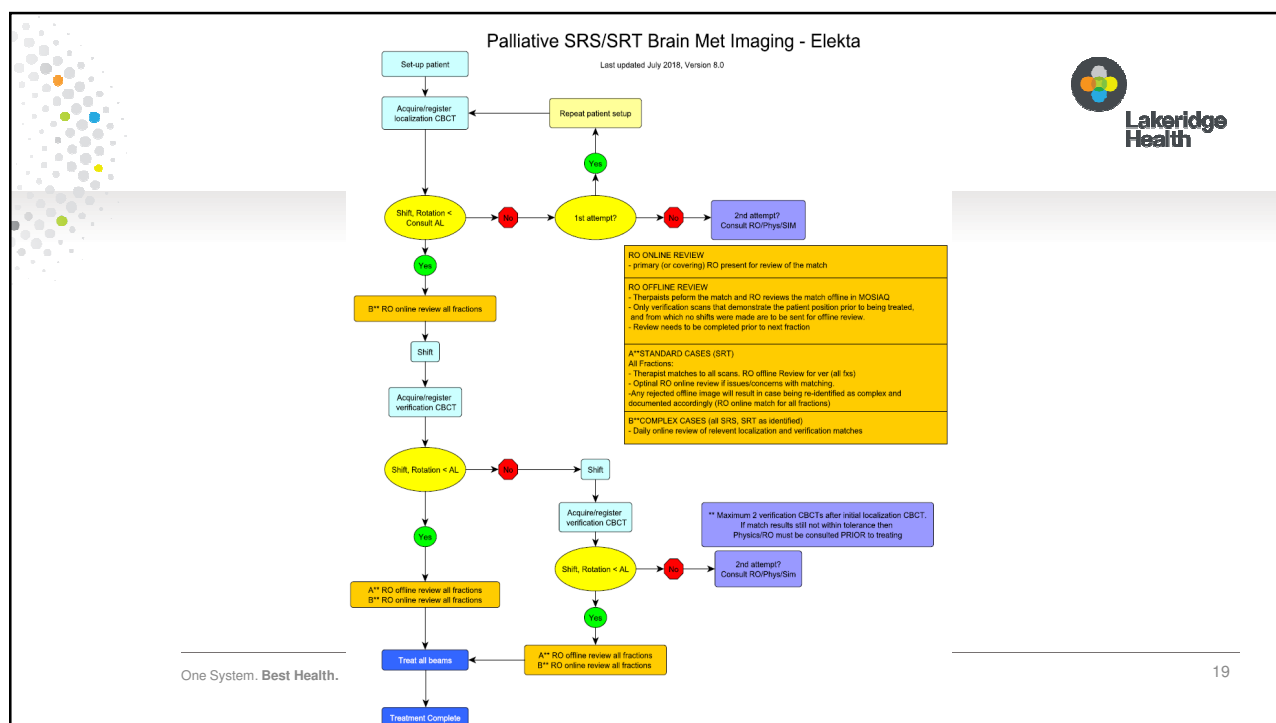
### Process Map: SRS PATHWAY

Durham Regional Cancer Centre









## Daily linac QA

Table accuracy

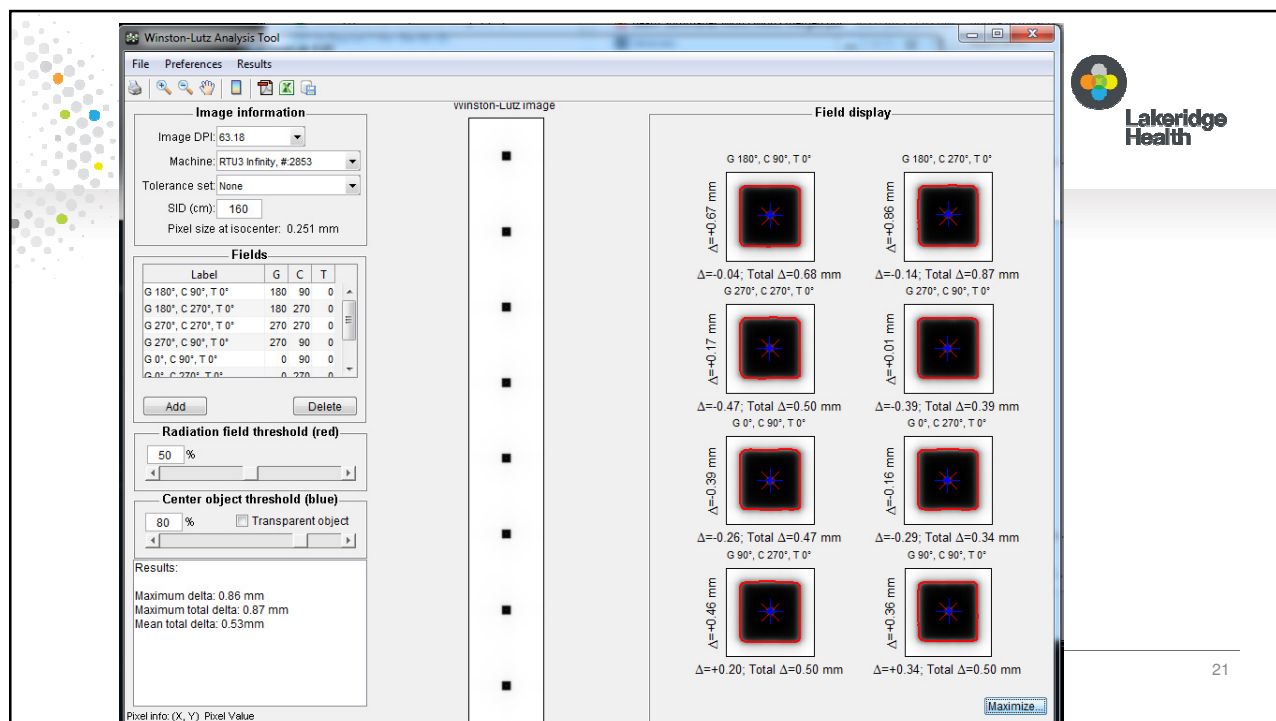
kV- 6MV isocentre coincidence

6MV and 6MV FFF beam coincidence

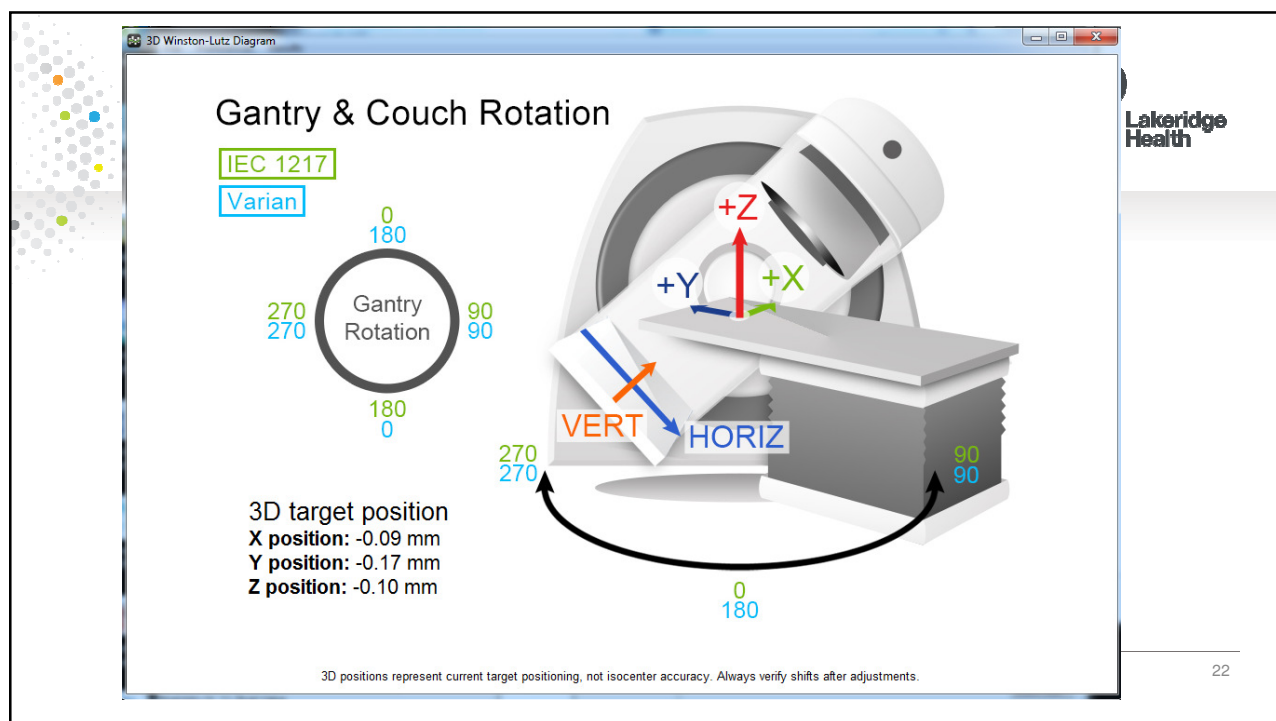
- DoselabPro Winston-Lutz phantom
- kVCB CT+ XVI software
- MV images
- DoselabPro analysis tools

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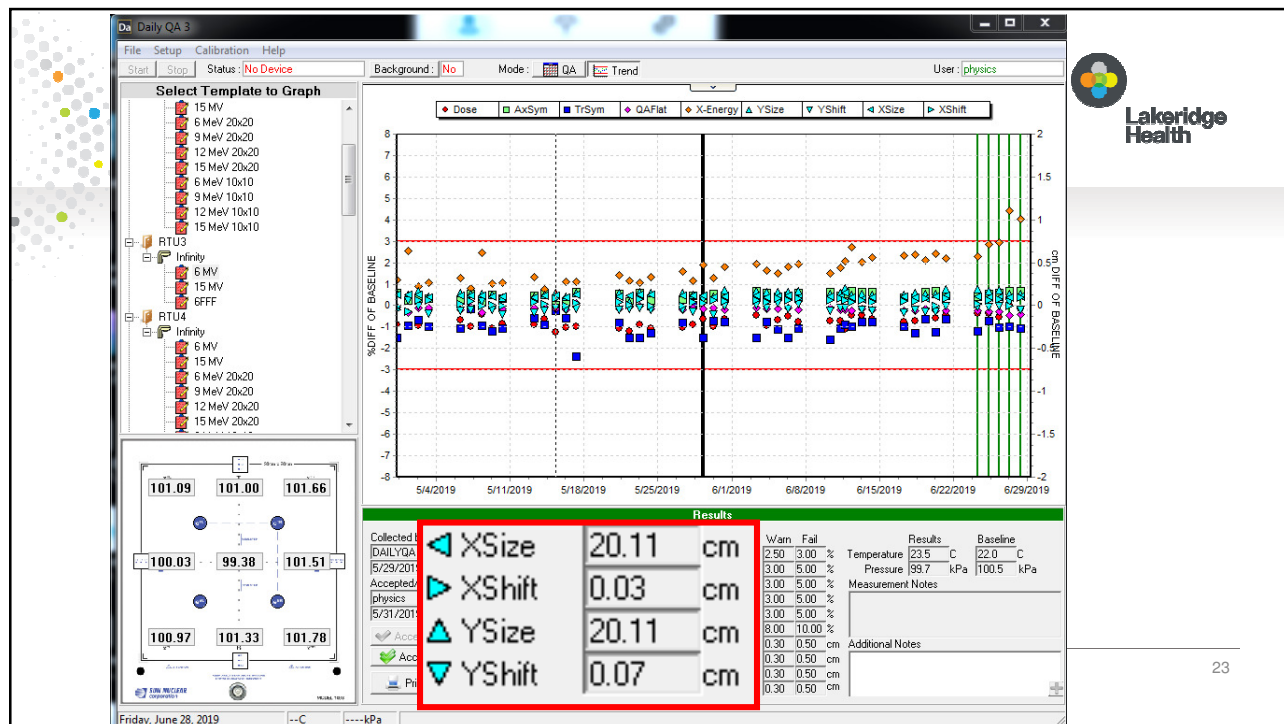
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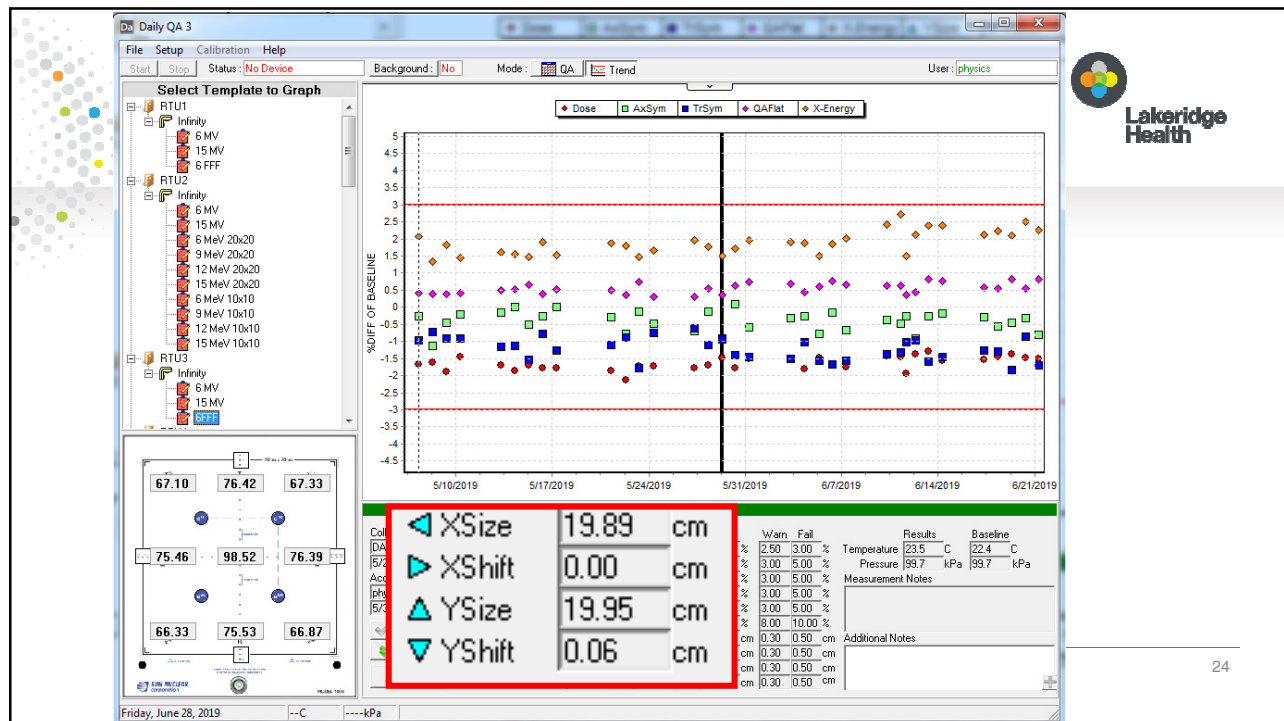
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# QATrack+



Test	Value	Reference
Winston Lutz Table Shift Lat (cm)	1.51	1.5
Winston Lutz Table Shift Long (cm)	2.09	2.1
Winston Lutz Table Shift Vert (cm)	1	1
Winston Lutz kV Residual SFOV CW Lat (cm)	0.02	0
Winston Lutz kV Residual SFOV CW Long (cm)	0.02	0
Winston Lutz kV Residual SFOV CW Vert (cm)	0	0
Winston Lutz kV Residual SFOV CCW Lat (cm)	0.02	0
Winston Lutz kV Residual SFOV CCW Long (cm)	0.03	0
Winston Lutz kV Residual SFOV CCW Vert (cm)	0	0
Winston Lutz MV Residual X (mm)	-0.09	0
Winston Lutz MV Residual Y (mm)	-0.17	0
Winston Lutz MV Residual Z (mm)	-0.1	0

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# QATrack+



QA3 6MV XShift (cm)	0.06	No Ref
QA3 6MV YShift (cm)	-0.06	No Ref
QA3 6FFF XShift (cm)	0.03	No Ref
QA3 6FFF YShift (cm)	-0.04	No Ref
FFF relative iso position X (cm)	-0.03	0
FFF relative iso position Y (cm)	0.02	0
WL 6MV kV-MV Coincidence SFOV CCW X (mm)	0.11	0
WL 6MV kV-MV Coincidence SFOV CCW Y (mm)	0.13	0
WL 6MV kV-MV Coincidence SFOV CCW Z (mm)	-0.1	0
WL 6MV kV-MV Coincidence SFOV CW X (mm)	0.11	0
WL 6MV kV-MV Coincidence SFOV CW Y (mm)	0.03	0
WL 6MV kV-MV Coincidence SFOV CW Z (mm)	-0.1	0
WL 6FFF kV-MV Coincidence SFOV CCW Y (mm)	-0.07	0
WL 6FFF kV-MV Coincidence SFOV CW Y (mm)	-0.17	0

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## Patient specific plan delivery QA



- All VMAT plans
- Measurement with ArcCheck
- Mobius 3D/FX calculation

**Patient specific dose verification summary**

Delivery	Beam	Array Measurement (ArcCheck $\gamma$ 3%/2mm)	Independent Calculation (Mobius 3D 3%/3mm)	Linac log file calculation (Mobius FX 3%/3mm)
VMAT	6MV	98.0%	98.0%	98.0%
	6MV FFF	98.4%	99.3%	99.2%

## Advantages and Limitations



- Effective use of technologies in the clinic
  - Full integration into standard processes and workflows
  - Part of comprehensive, standard care
  - Fast delivery, standard appointment times
- 2 mm PTV margin
  - Too generous? Based in reality?
- MLC is 5 mm (not micro)
  - Conversion to cones if lesions very small

## References



- PH Halvorsen, E Cirino, IJ Das, JA Garrett, J Yang, FF Yin and LA Fariobent, "AAPM-RSS Medical Physics Practice Guideline 9.a. for SRS-SBRT" J Appl Clin Med Phys **18**, 10-21 (2017).
- EE Klein, J Hanley, J Bayouth, FF Yin, W Simon, S Dresser, C Serago, F Aguirre, L Ma, B Arjomandy, and C Liu, "Task Group 142 report: Quality assurance of medical accelerators", Med Phys. **36**, 4197-4212 (2009).