SGRT - From SRS to Every Patient Every Fraction Beacon Hospital Experience

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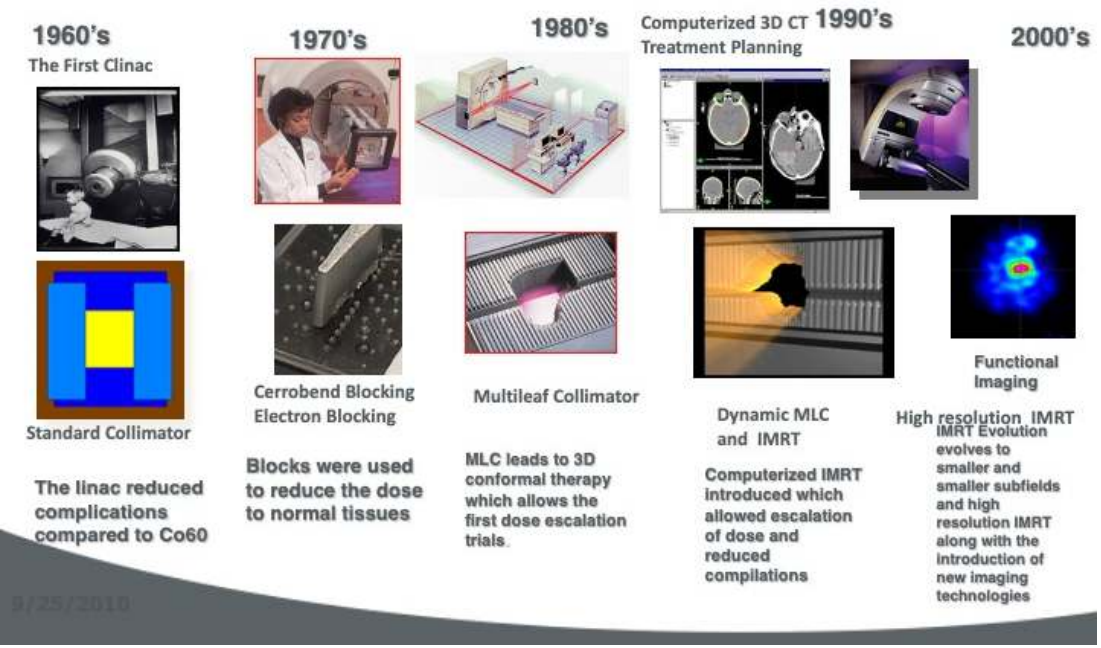
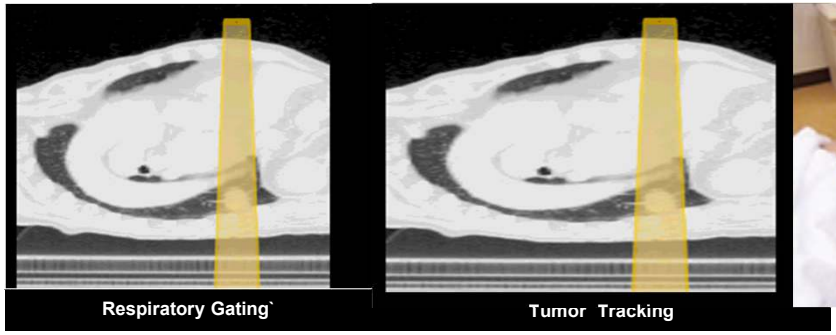
Disclosure

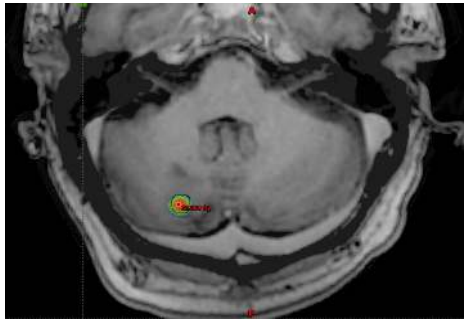
- Consultant for Vision RT –honorarium

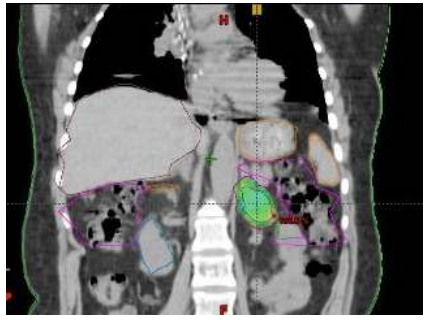
Advances in Radiotherapy

Currently: respiratory motion management/**SRS/SABR**



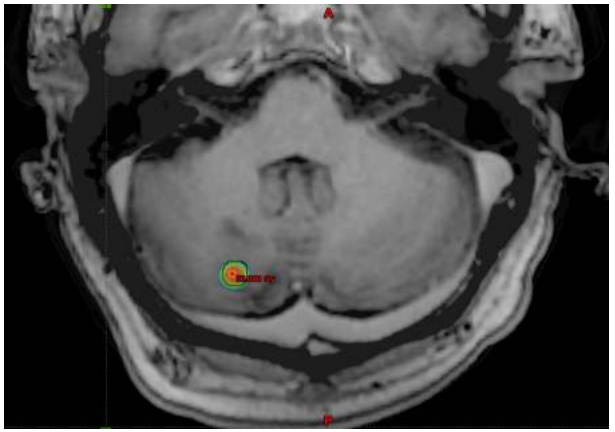






SRS/SABR – high precision, accuracy , reproducibility

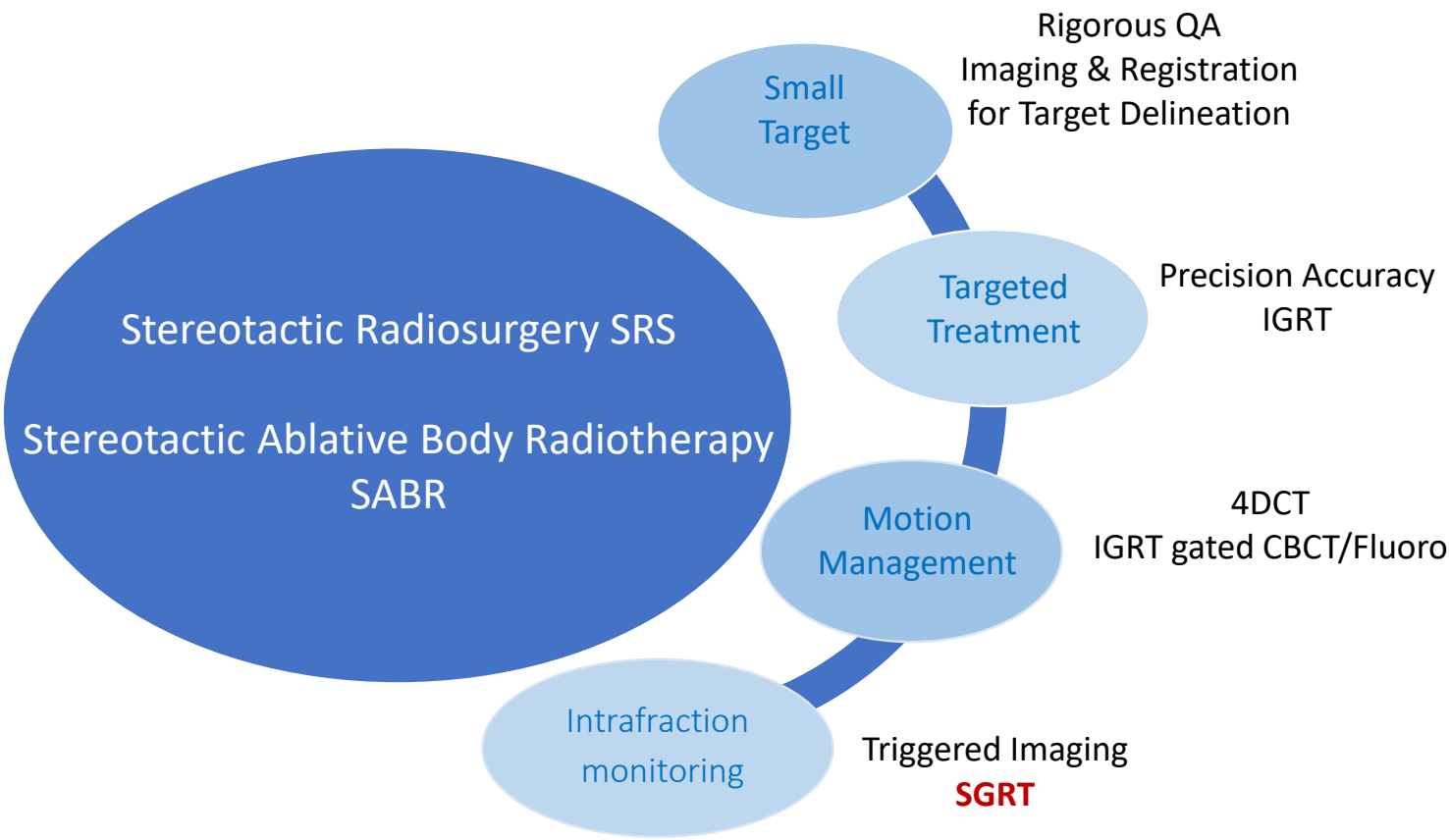
- **Benefits**
  - minimally invasive
  - usually no hospital stay
  - very low morbidity
  - suitable for patients who are poor candidates for surgery/other ablative techniques
- **Risks:**
  - large dose/fr - long trea time –patient compliance?
  - tight dose distribution – potential for geographic miss
  - tolerance of normal structures to high doses of radiation is not fully understood **- caution**



ACR/ASTRO Practice guidelines 2016

- Imaging, planning and treatment typically performed in close temporal proximity
- Treatment delivery should be **accurate within approx. 1mm**
- Little room from error in the overall process
- Strict protocols required

Requirements for SRS/SABR

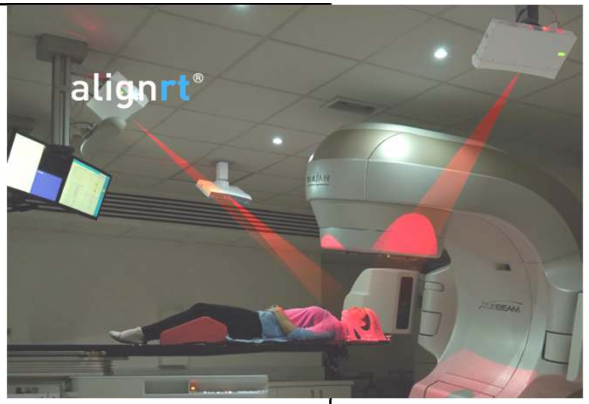


With long treatment times, patient compliance/positioning/movement –key issue

Why and when surface guidance?

- Patient set-up
  - **Non-invasive, non-ionizing 3D real time**
  - Accurate isocentric set-up **(<= 3mm/0.2 degrees)**
- Intra-fraction monitoring
  - 6DOF motion monitoring in real time
  - Automatically switch off beam if motion> preset threshold
- Increased patient safety and comfort
- Improved clinical outcomes – better targeting and better sparing of OARs

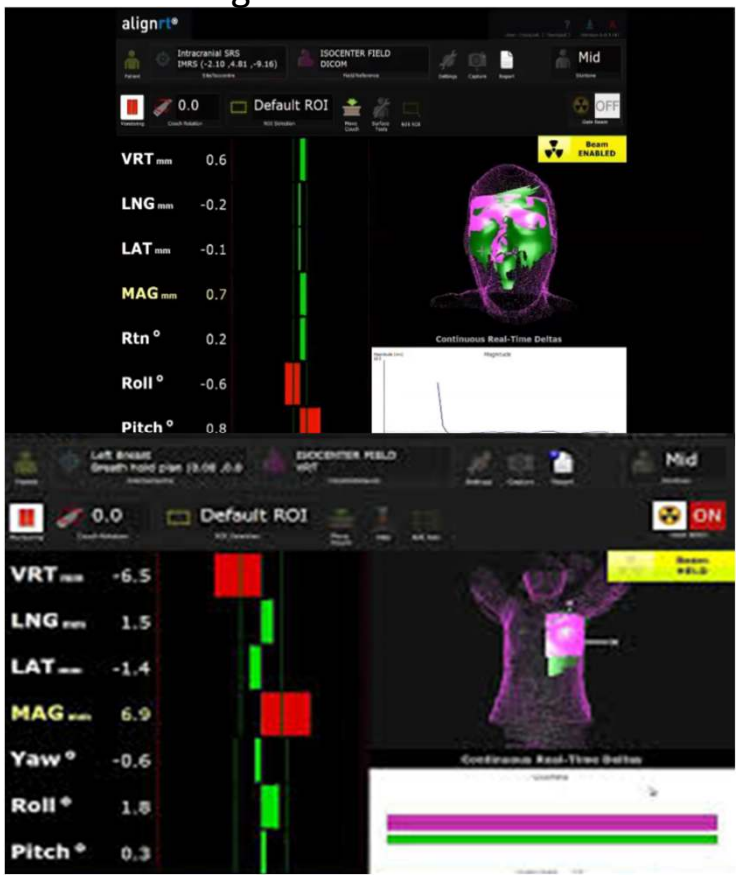
SGRT –wider acceptance and indications



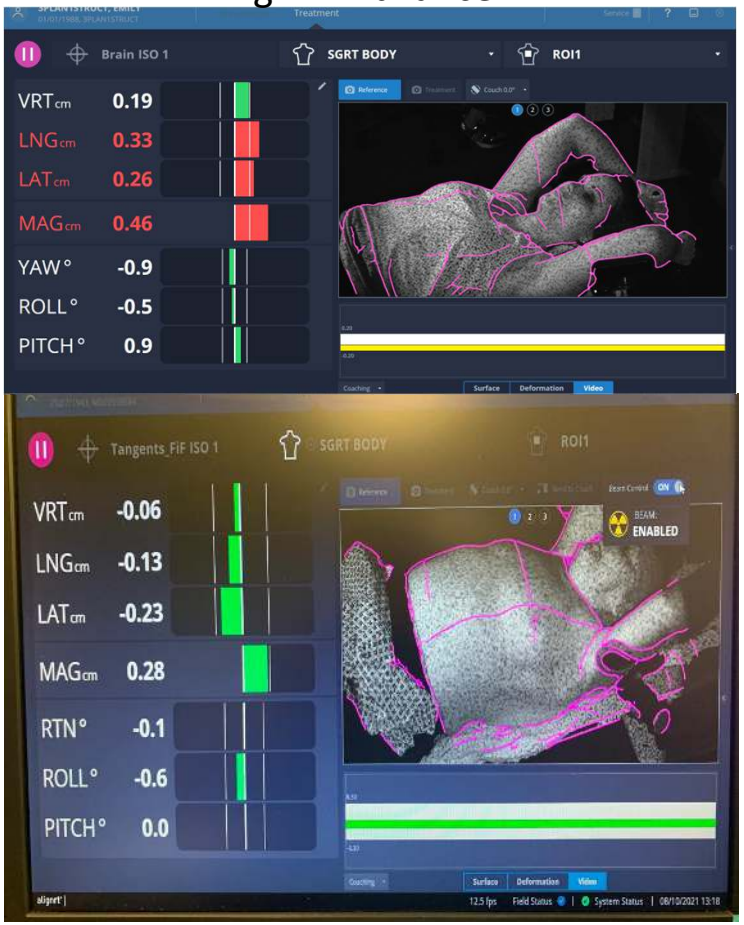
- **Intracranial (SRS, WBRT)**
- **Breast/chest wall irradiation**
- **DIBH radiotherapy**
- **Hypo fractionated treatments and respiratory management**
- Pediatrics
- Adaptive RT

AlignRT- set up and monitoring SURFACES, NOT TUMOURS

Align RT

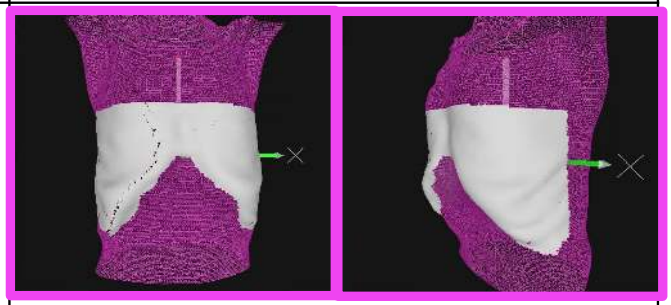
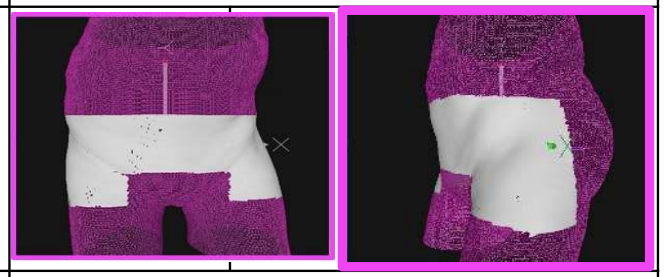
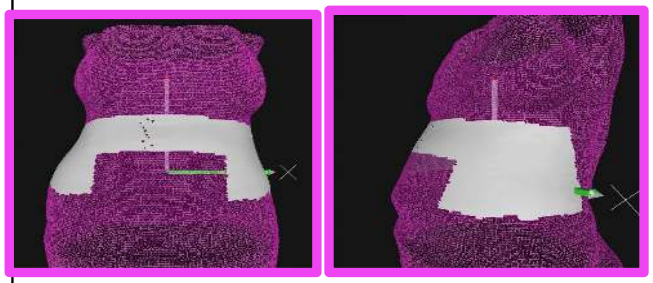


AlignRT Advance



REIMAGE NECESSARY- CBCT after applying the shifts

ROI selection -CRITICAL

Site	Include	Do not include	
Thorax	**Stable portion** of the skin surface Patient topography	Large unstable areas Anything not part of the patient such as gown or immobilization device Non-reproducible area due to breathing motion	
Pelvis	Anterior portion of hips Lateral portion of hips to the mid-coronal plane	Excessive adipose tissue Non-reproducible areas Anything not part of the patient	
Abdomen	Stable portion of the skin surface (ex. Ribs)	Large unstable areas Anything not part of the patient Non-reproducible area due to breathing motion	

Beacon SGRT Experience

Varian EDGE

Varian Trilogy

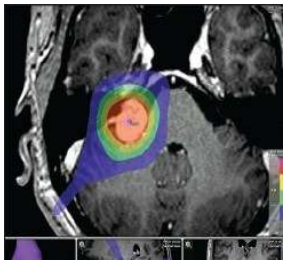
Year	Site	Setup	Intrafraction Monitoring	No fractions treated since 2014
2014	**Intracranial SRS**	✓	✓	**>1000**
2017	Extremities/Thorax/Abdomen/Pelvis intrafraction monitoring		✓	
2018/ 2019	Breast tattooless (DIBH)	✓	✓	**356**
2019	Most sites tattooless	✓	✓	
2019	**SABR Abdomen & Thorax**		✓	**3356 (fx)**

August 2021 Align RT Advance

SRS/fSRS

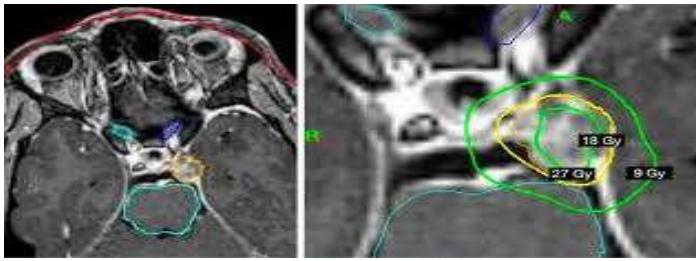
Results of the SRS /fSRS- high local control/ low toxicity…..

Vestibular schwannoma



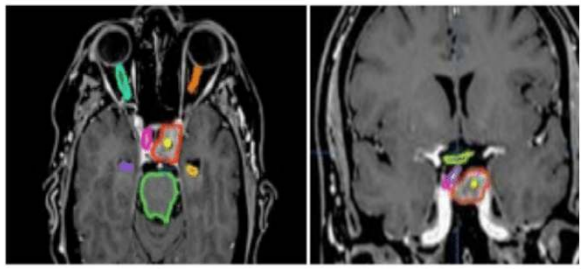
Actuarial LCR-96%-97%, improvement in symptoms, hearing preservation (>70%)

Meningioma



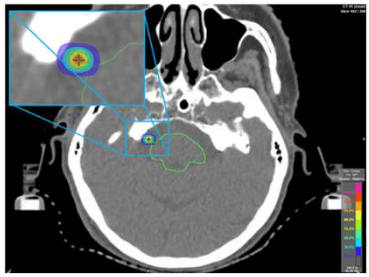
LRR/PD = 2-16% @ 10 ys
LC >90%

Pituitary adenoma



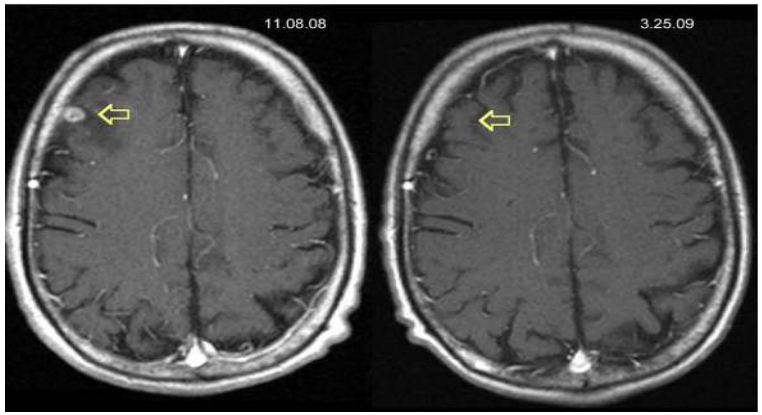
LC – 82-100%,
biochemical remission 17-90%,
late toxicity <10%

Trigeminal neuralgia



Success rates – 67-100%

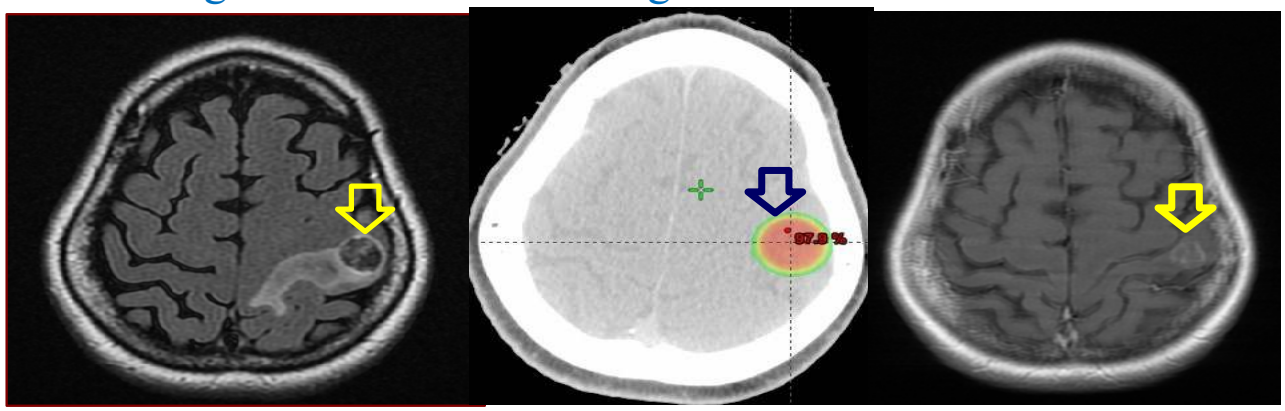
NSCLC single brain metastasis



Pre SRS

4 mts post-SRS

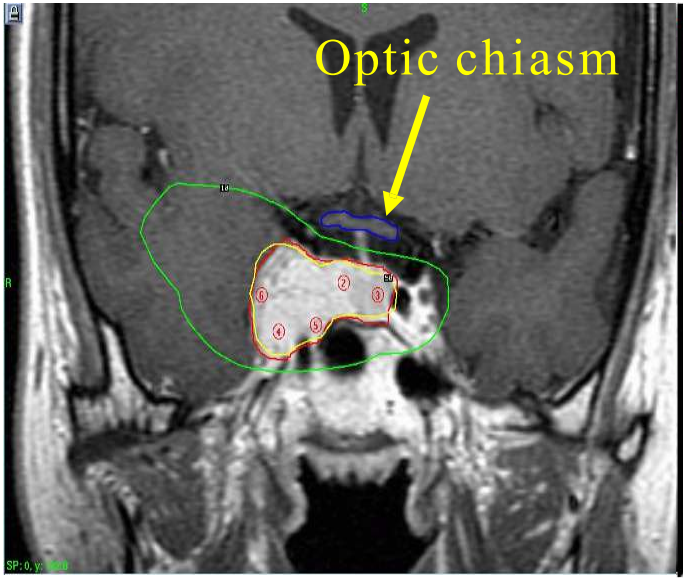
Oligometastatic CRC - single brain



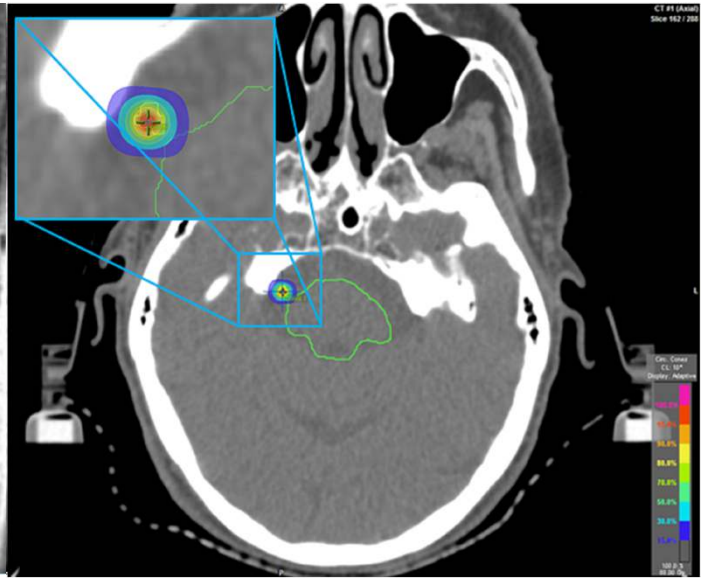
Pre-SRS

6 weeks post-SRS

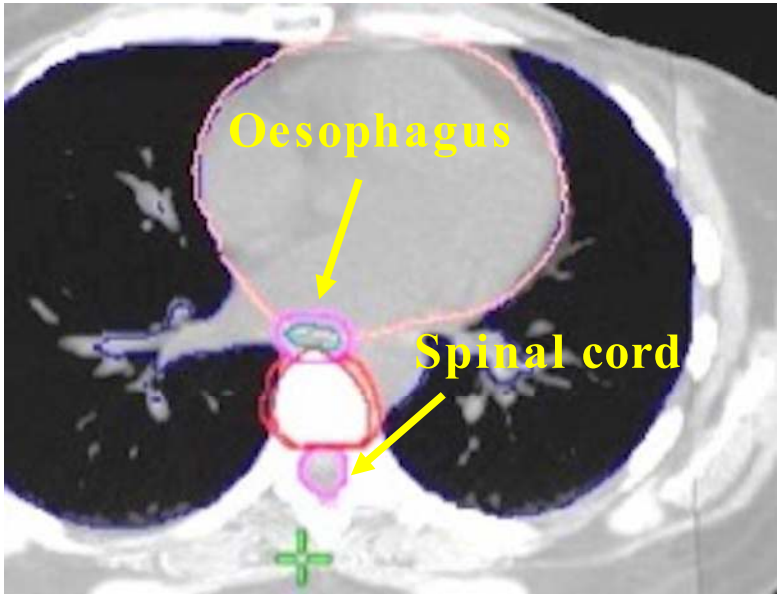
Significant side effects can be observed



Meningioma 14Gy/1fx
Optic chiasm < 10Gy



Trigeminal neuralgia
80-90Gy/1fx , 40 min



Spine SRS
18-24Gy/1-3fx

Beacon Hospital SRS Programme

- Treated 2500+ intracranial SRS since Dec 2007
- **Largest cranial series outside USA using AlignRT**
- **reference centre for VisionRT**
- Majority are brain metastases
- Also benign lesions
    - trigeminal neuralgia
    - meningioma
    - vestibular schwannomas

Beacon Experience SRS

Approx 1100+ treatments since 2007

SRS Programme	2007 – 2014	2014 – 2019	2019 - Present
Linac	Trilogy	Trilogy	Edge
Technique	Cones & arcs	Cones & arcs	Cones VMAT & HD-MLC
Verification	kV	CBCT	CBCT
Setup & Intrafraction Monitoring	Optical Guidance Platform (OGP)	Align RT	Align RT

Choosing a new solution

	Align RT	BrainLab Exactrac
Cost	Lower cost (factor of 3)	Higher Cost
Installation	little construction work	construction work required to install x-ray units
Downtime	½ day	2 weeks
Method of alignment	External contour of patient	Internal anatomy of patient
Non coplanar angles	Dependent on external anatomy	Non-coplanar verification of internal anatomy
6 Degrees of freedom	Achieved with head adjuster	6 degree couch included with package
Patient comfort	Open face mask	Closed face mask

Align RT Installation

- Vision RT room survey a month prior to install
- Beacon install mounting plates for cameras
- Cameras installed by Vision RT engineer over weekend
- Acceptance testing done on Monday
- **First patient treated that week**
- Integrated with Varian: MMI - Auto patient recall, couch control & beam hold

Patient positioning and immobilization

Frame based

Frameless (Z med)

Surface guided

Which method is better? Accuracy

- Phantom studies demonstrate AlignRT isocentre localization > 1mm

  [Paxton et al JACMP 2017; Wen at al Med Phys 2016]

- AlignRT comparable to existing x-ray imaging techniques

  [Wiant et al JACMP 2017; Oliver et al Adv Radiat Oncol 2017; Bry et al JACMP 2022]

Technical Note: Evaluation of the systematic accuracy of a frameless, multiple image modality guided, linear accelerator based stereotactic radiosurgery system

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Received: 8 June 2016 | Revised: 7 December 2016 | Accepted: 21 December 2016
DOI: 10.1002/acm2.12054

RADIATION ONCOLOGY PHYSICS

WILEY

Evaluation of a surface imaging system's isocenter calibration methods

Adam B. Paxton[1] | Ryan P. Manger[2] | Todd Pawlicki[2] | Gwe-Ya Kim[2]

Beacon Hospital experience –MD Anderson audit SRS treatments

Film Plane	Gamma Index
Coronal	99%
Sagittal	99%
	Ratio
Dose to the center of the target	0.98

The dosimetric precision of the TLD is ±3%, and the spatial precision of the film and densitometer system is ±1 mm. Used for end to end evaluation

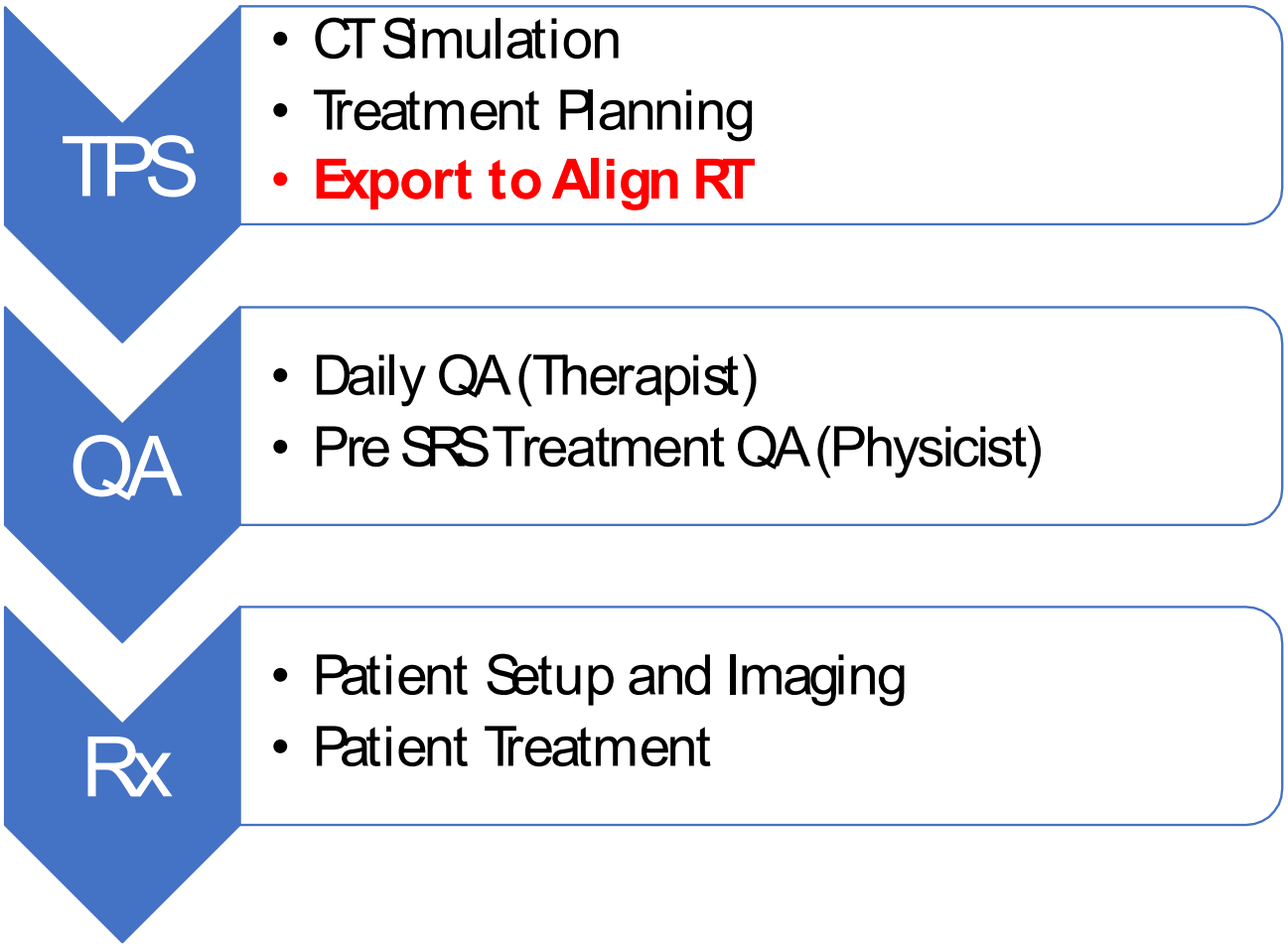
Which method is better? Univ California San Diego experience Clinical outcomes

	Frameless Zmed (Nath et al, 2010)	Framless Align RT (Pan et al, 2012)
No patients	65	44
Crude local control rate	88%	85%
Actuarial LC @ 1year	76%	76%
Actuarial OS @ 1year	40%	38%

Table 2 Comparison of local control and survival rates in retrospective studies of brain metastases treated with radiosurgery reporting kaplan-meier data[a]

Study	Treatment system	Patients, n	Crude LC, %	Actuarial 1-yr LC, %	Actuarial 1-yr OS, %
Schomas *et al.* (19) [2005]	Frame-based LINAC	80	91	89	33
Bhatnagar *et al.* (18) [2006]	Frame-based Gamma Knife	205	***	71	37[b]
Brenenman *et al.* (6) [2009]	Frameless LINAC	53	***	80	44
Nath *et al.* (7) [2010]	Frameless LINAC	65	88	76	40
Pan *et al.* (17) [2012]	Frameless, surface-imaging guided LINAC	44	85	76	38
Pham et al (2014)	Frameless, surface-imaging guided LINAC	163	85	79	56

SRS Workflow

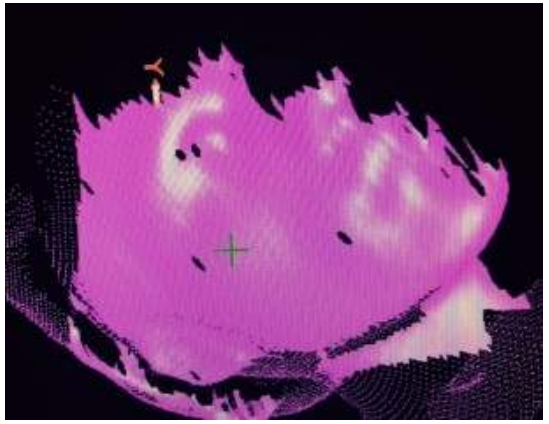


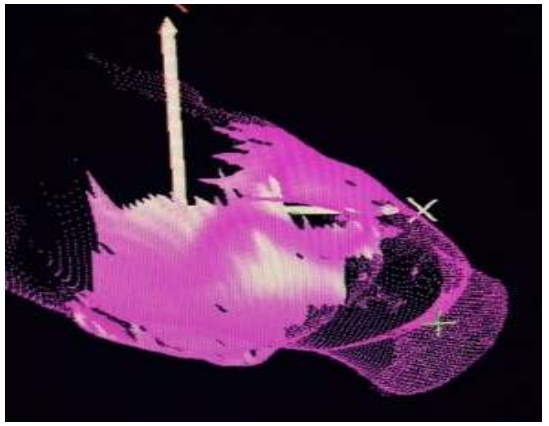
Simulation and Immobilization

- Macromedics DSPS open face mask
- Ensure enough of face is outside mask for ROI
- Chin down

2 fingers between the mask and the plate

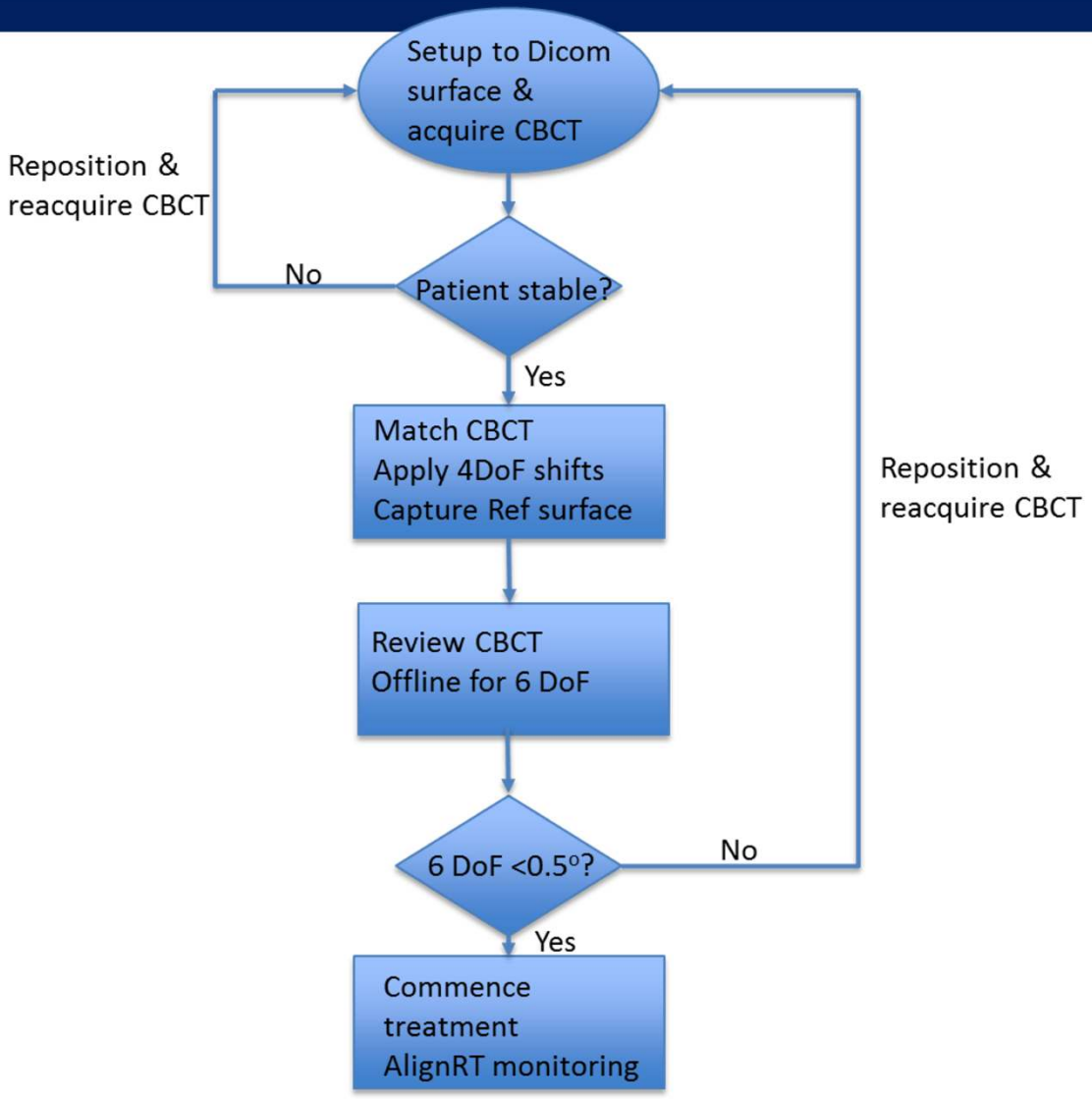
Why is chin down important?

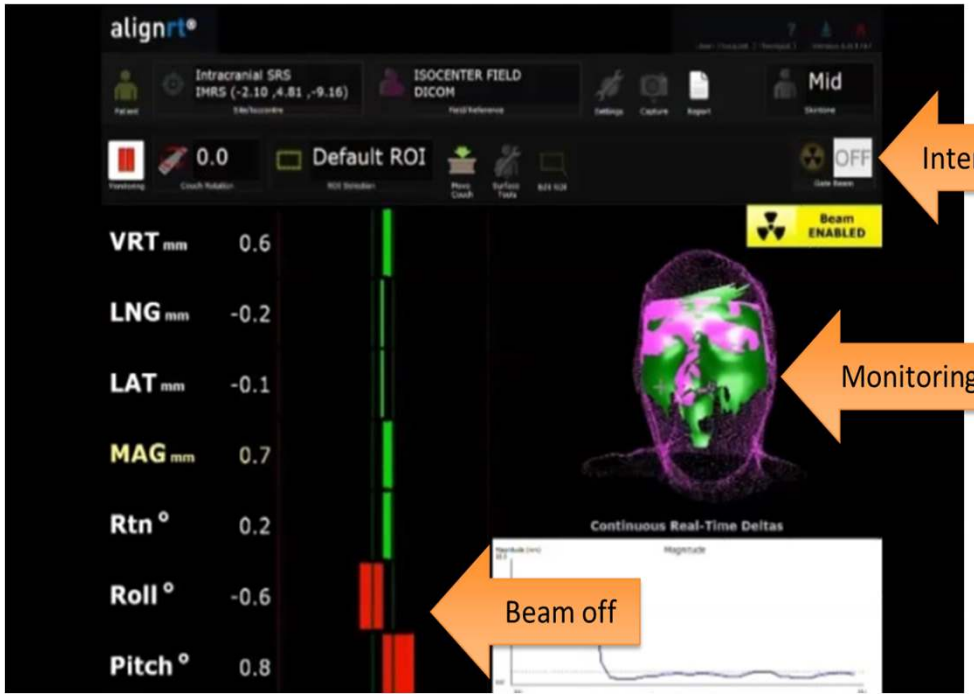




- 1 Pod blocked by gantry
- ROI view restricted due to chin
- Very little information for monitoring- noise

SRS Patient Setup Workflow

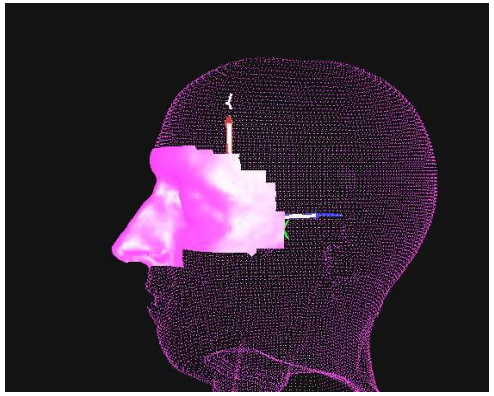


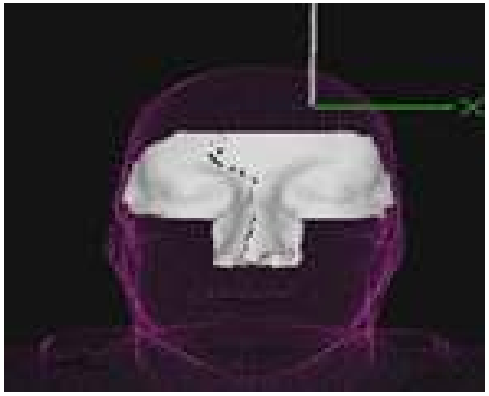


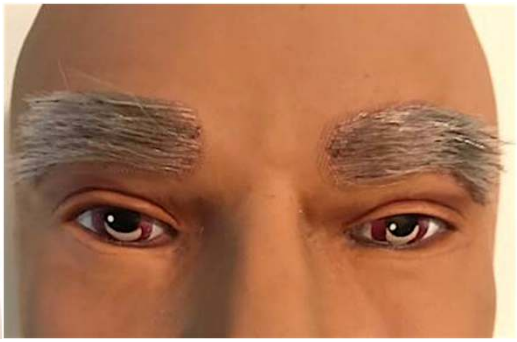
	TOLERANCES
Translations	1mm
Rotations	0.3°

Beacon Experience: ROI selection

- Primary cause of error
- Exclude mask
- ROI should only include rigid structures
  - Exclude Cheeks
  - Use Frontal bones
- No make-up or false eyelashes, bushy eyebrows

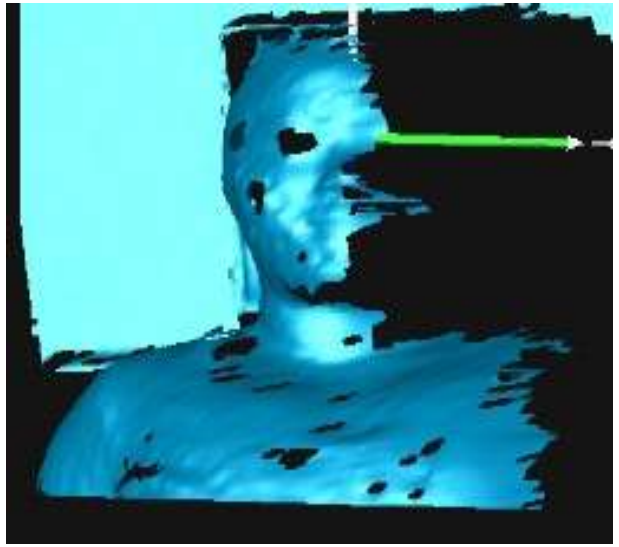




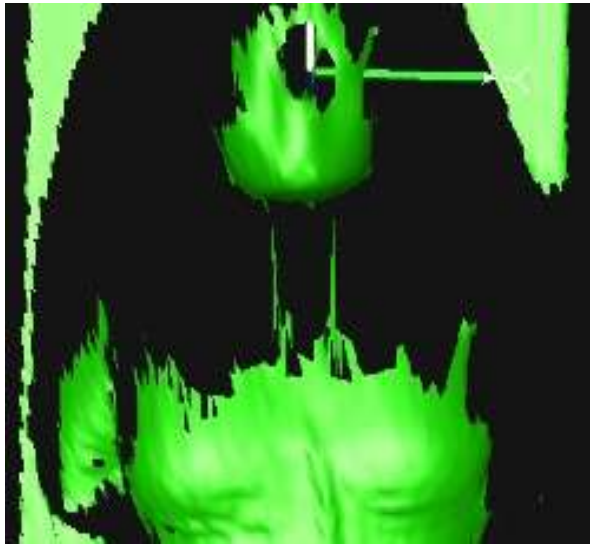


Beacon Hospital

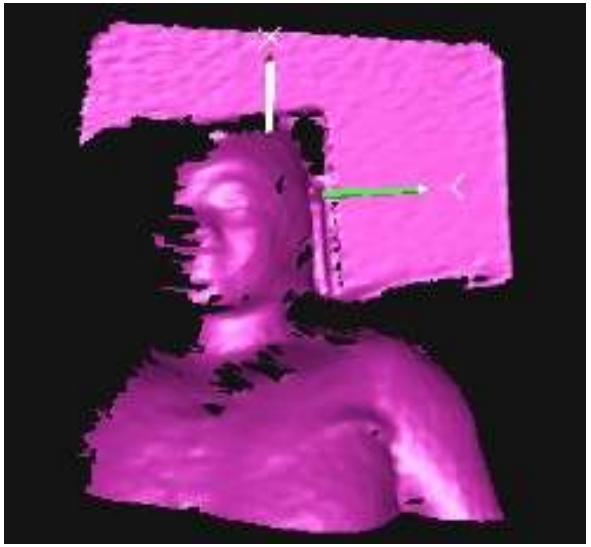
AlignRT Limitation: Camera blocked during gantry rotation



Left pod



Central pod



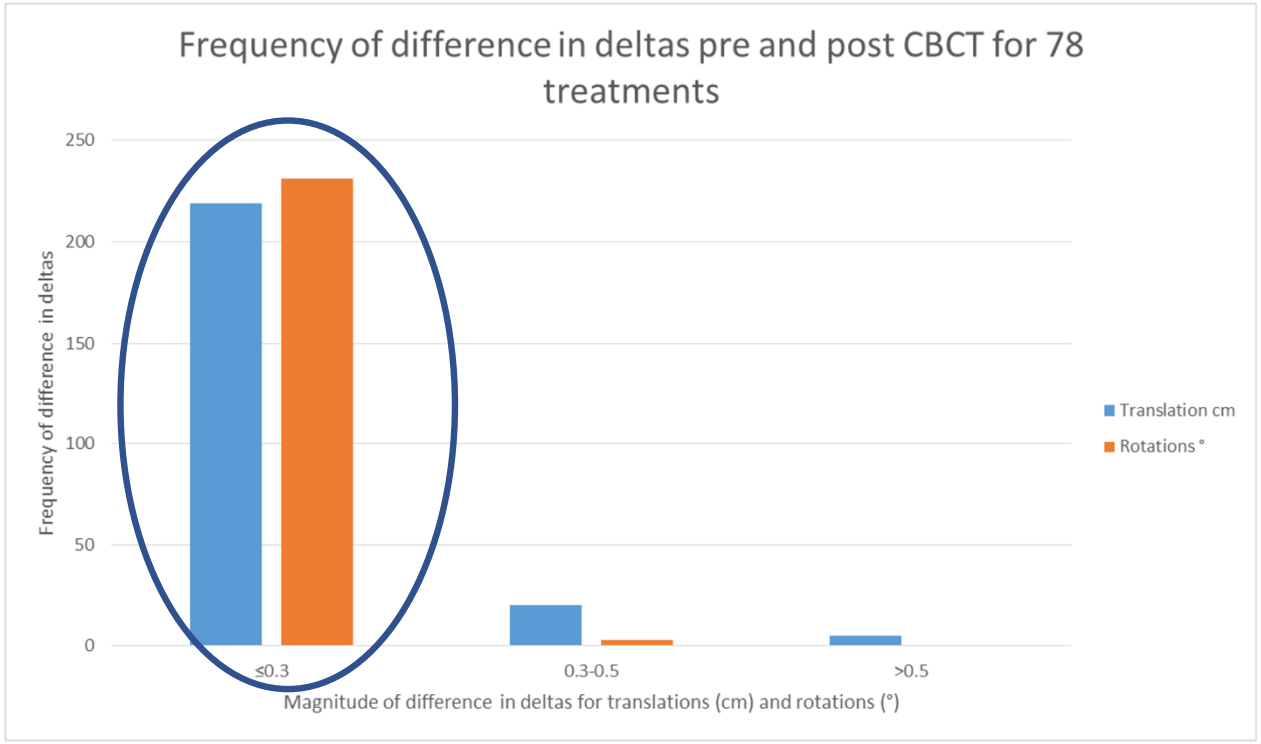
Right pod

- Two lateral cameras blocked for very short time during CBCT acquisition -will not capture any patient movement

- **Record patient position at the beginning and end of CBCT**

Beacon Experience: Open face mask stability

- 78 fractions
- Deltas before and after CBCT recorded
- Re-CBCT 5 patients due to motion during CBCT or matching
- Patients stable in mask
- Comfort is important



Open face mask stability

EDGE machine 2019 data

58 fractions – 2nd CBCT taken to check shifts applied correctly

Fig 1

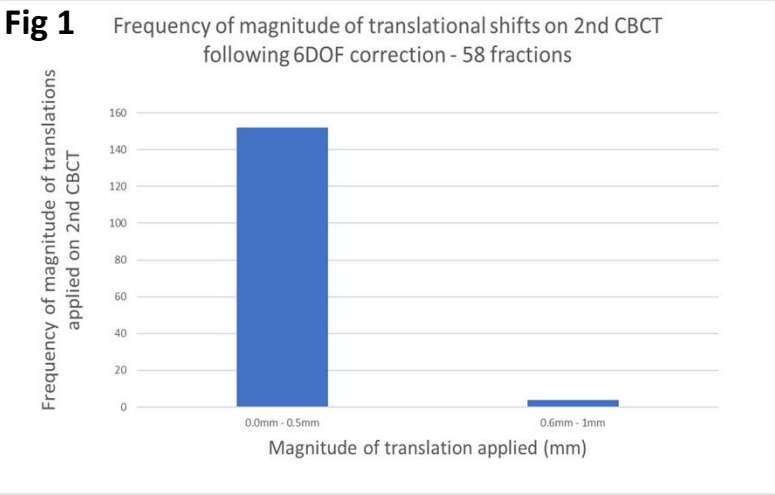


Fig 2

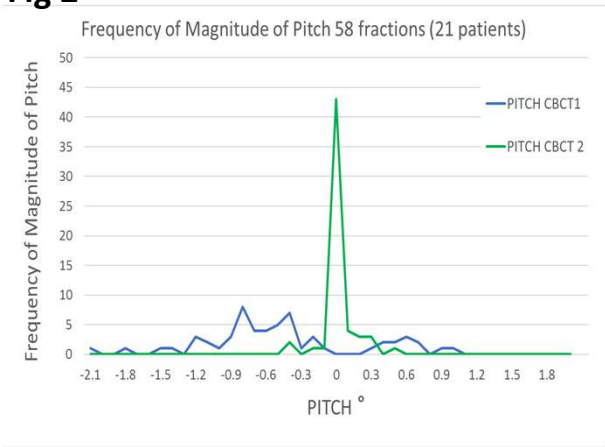
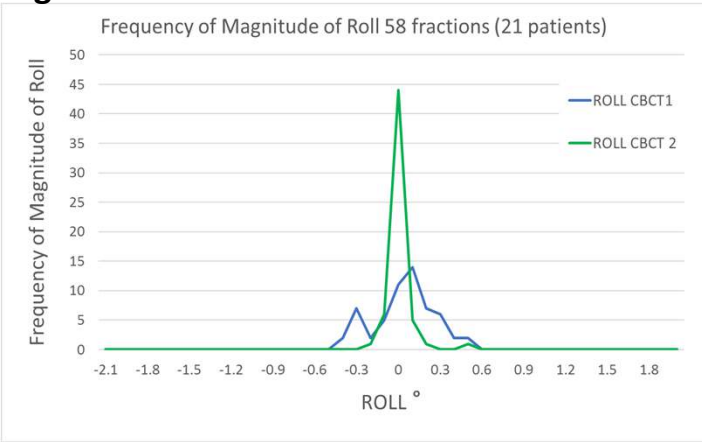
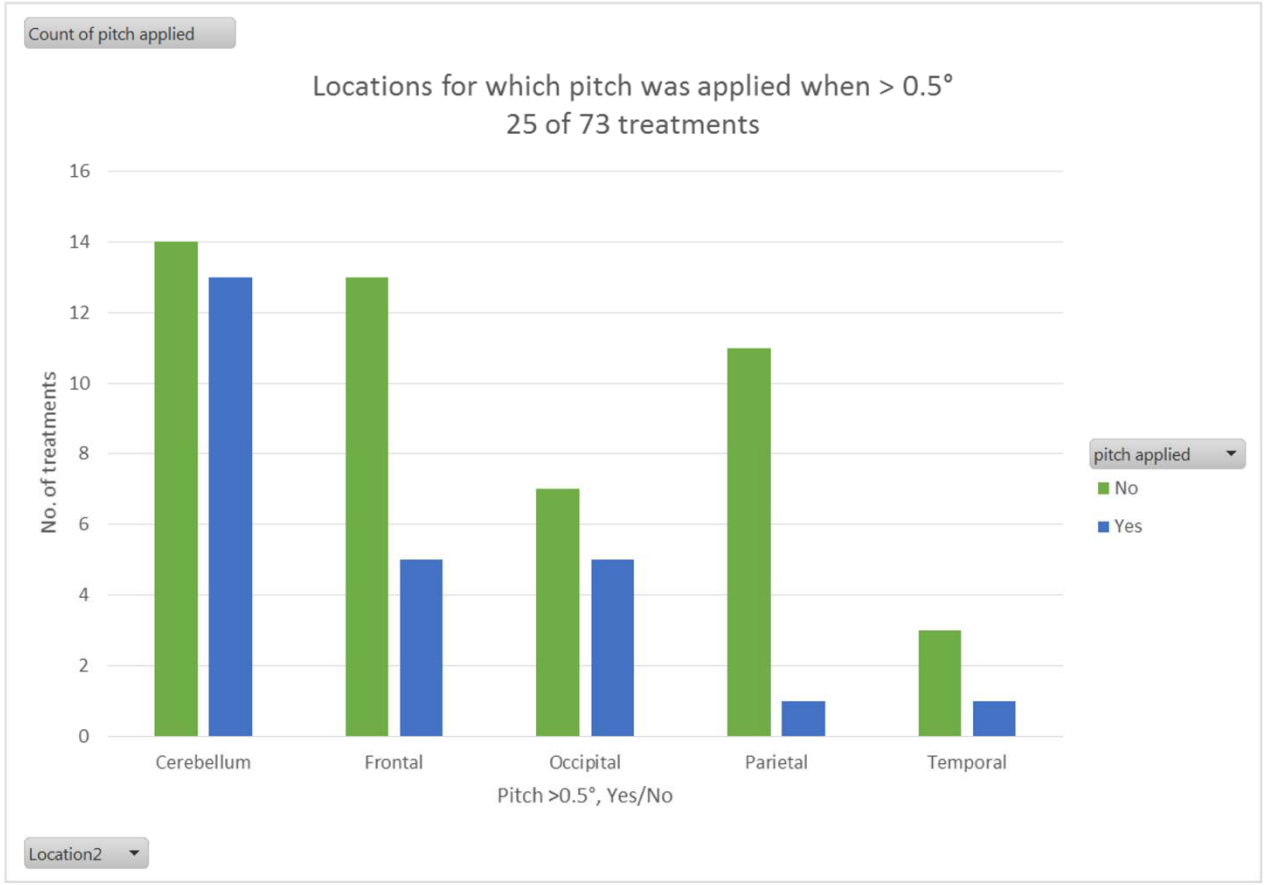
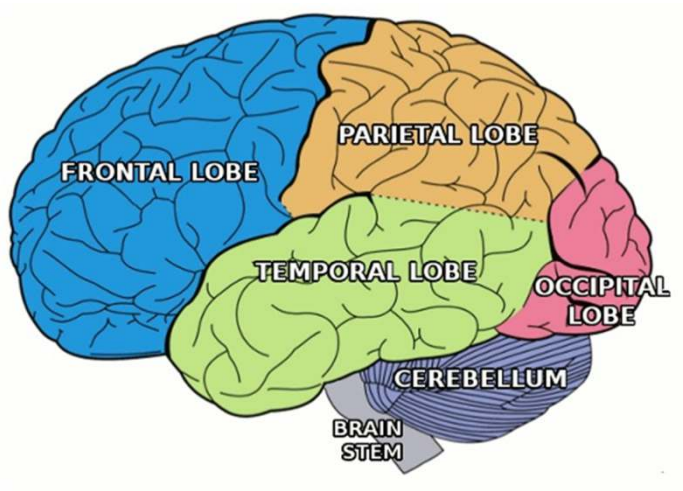


Fig 3



Beacon Experience: Stability : Isocentre Location vs Pitch

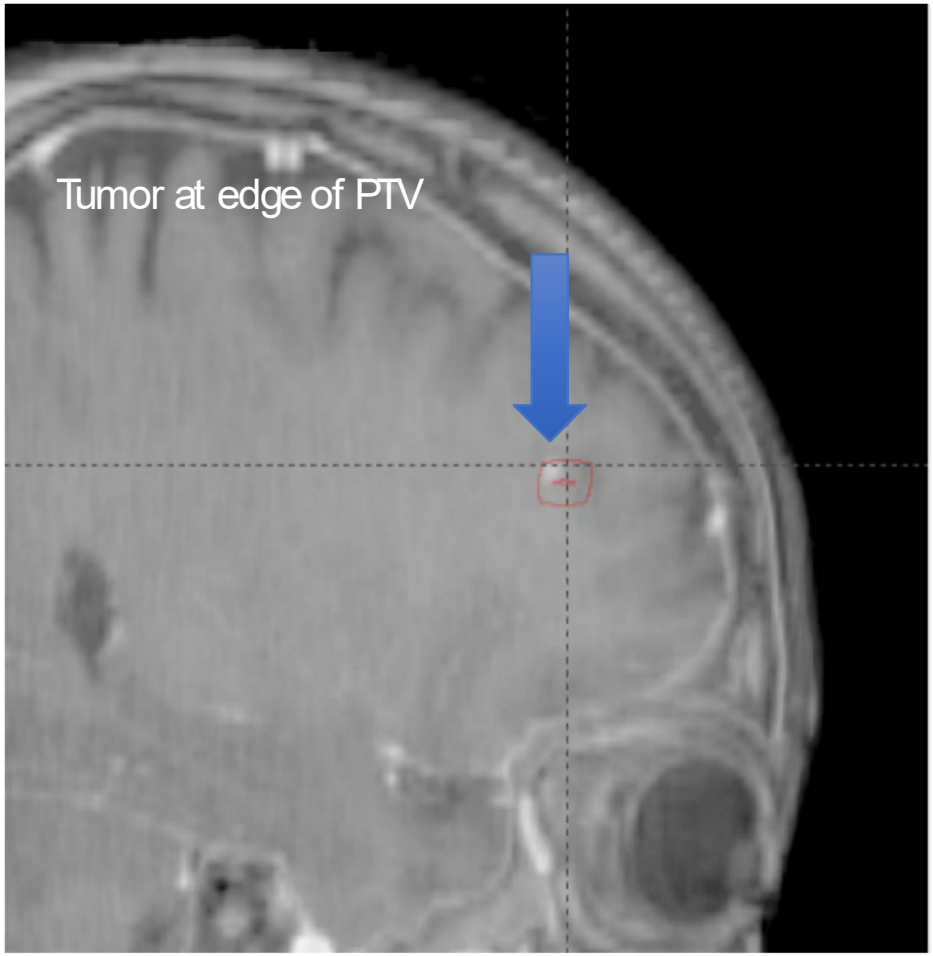




What effect does Pitch have?

- AlignRT uses surface for setup
- CBCT used to check internal structures
- If rotations not applied

  - Possible to miss target



Why stability is important - SRS for Multiple Intracranial Metastases (MIM)

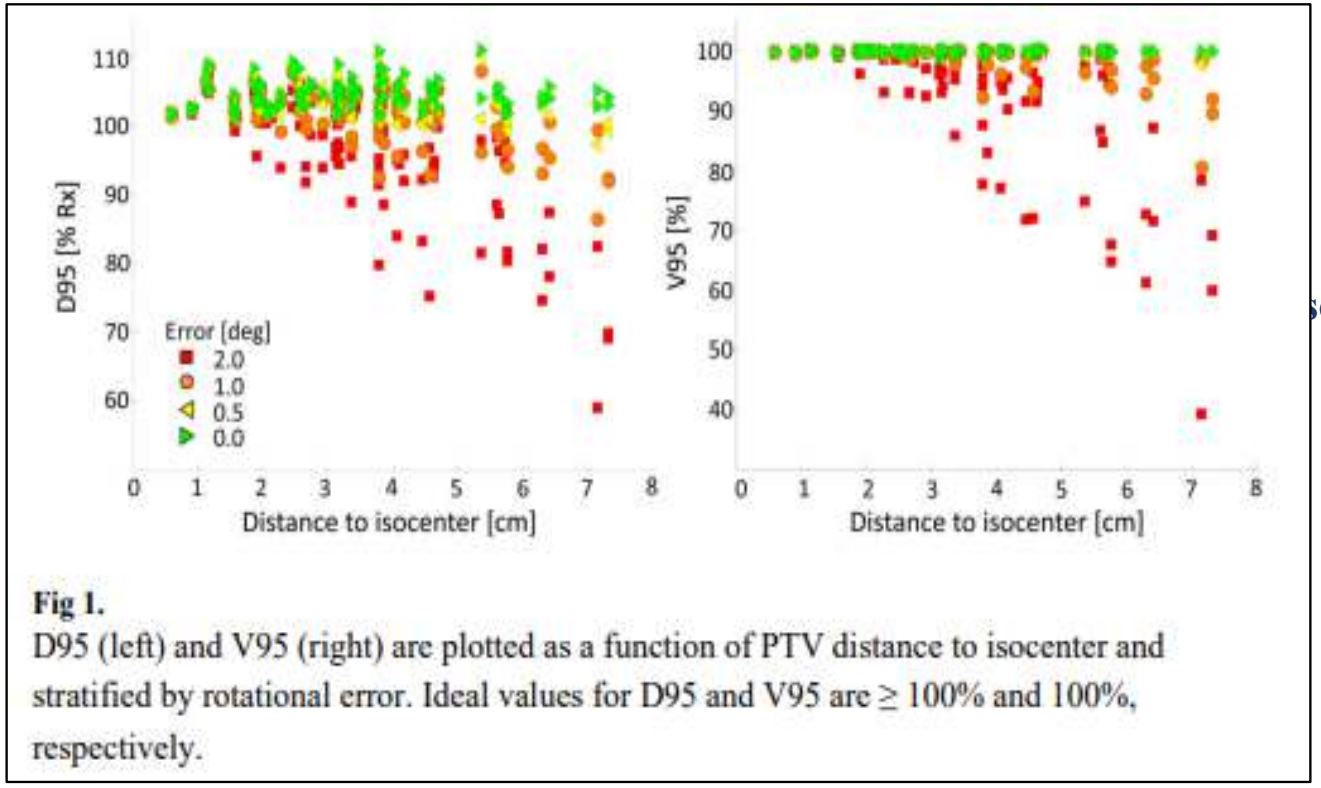
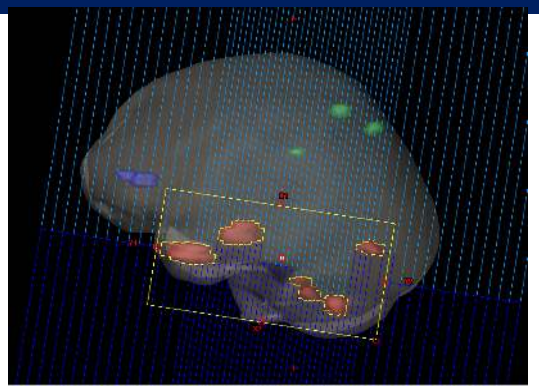
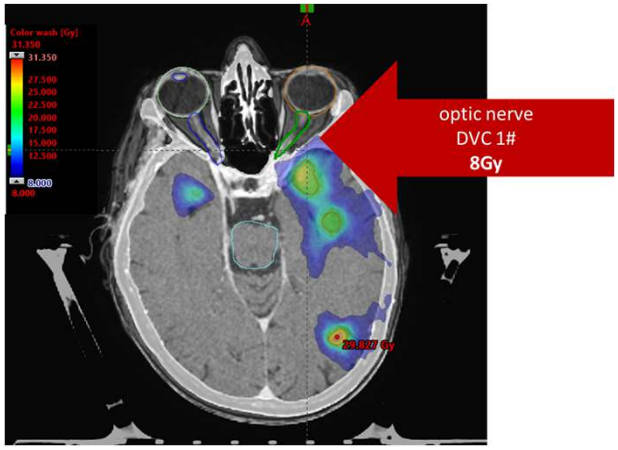


Fig 1.
D95 (left) and V95 (right) are plotted as a function of PTV distance to isocenter and stratified by rotational error. Ideal values for D95 and V95 are ≥ 100% and 100%, respectively.

Roper, Chanyavanich et al. 2015



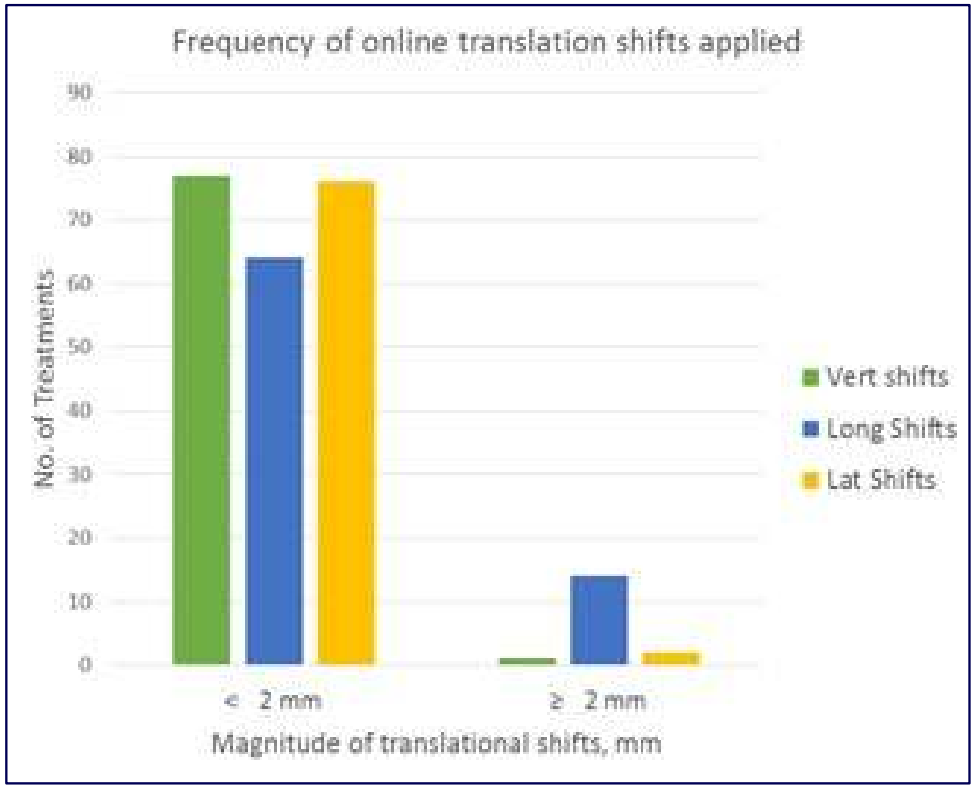
so is away from the treated area – monitor rotations

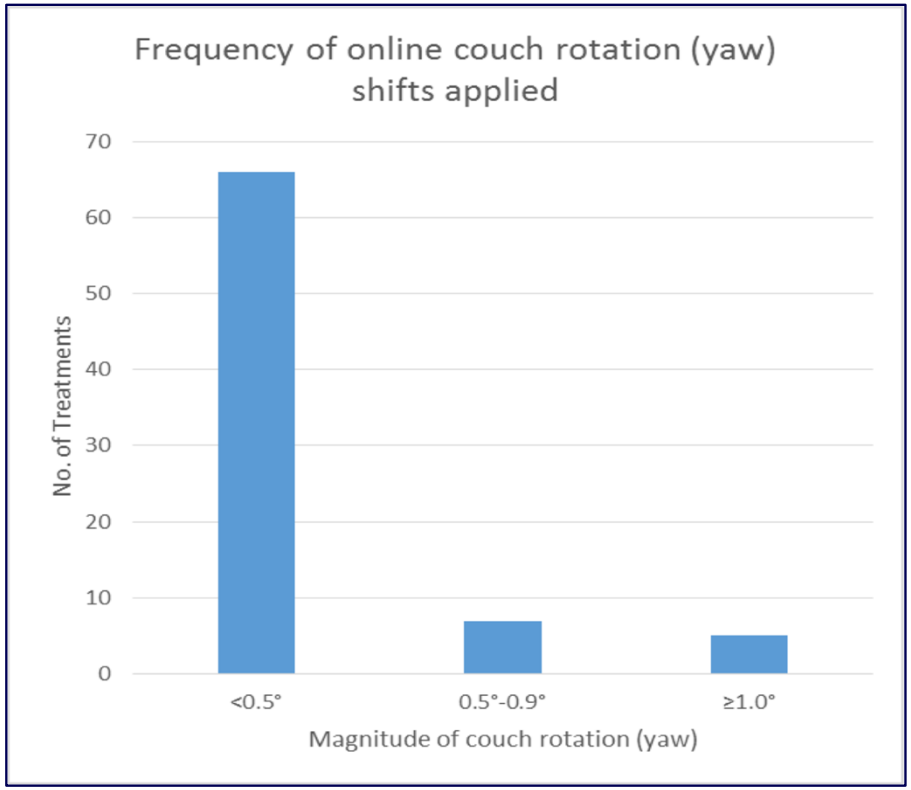


Align RT for couch rotations

OARs nearby – rotations ~0.5° could lead to a significant increase in D_{max} & $D_{0.02cc}$

Beacon Experience: CBCT vs AlignRT



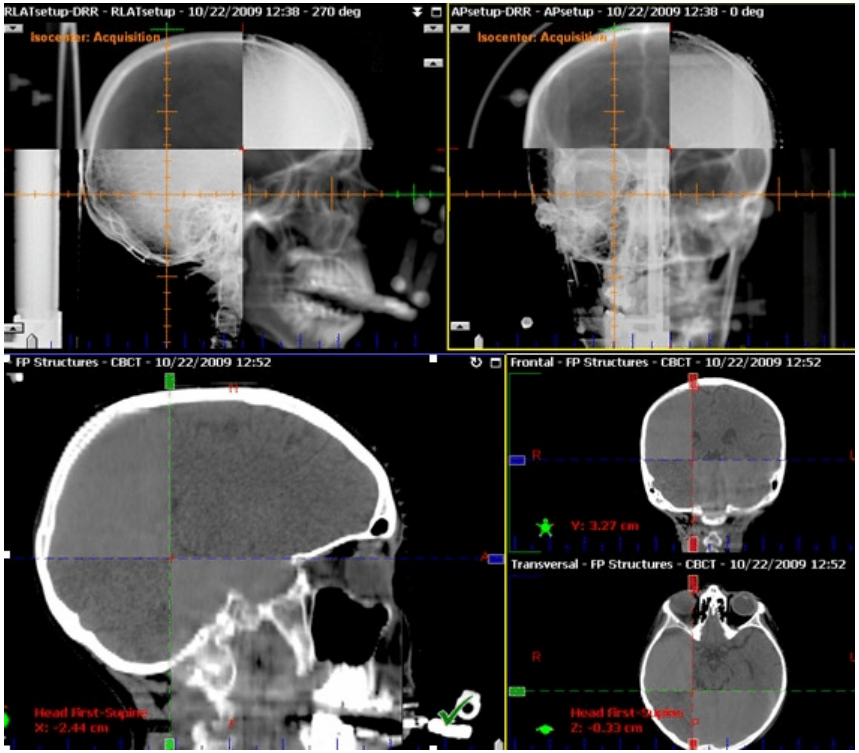


- Vert & Lat shifts: 98% < 2mm
- Long shifts: 82% < 2mm (correct for pitch)
- Couch rotation: 94% < 1°

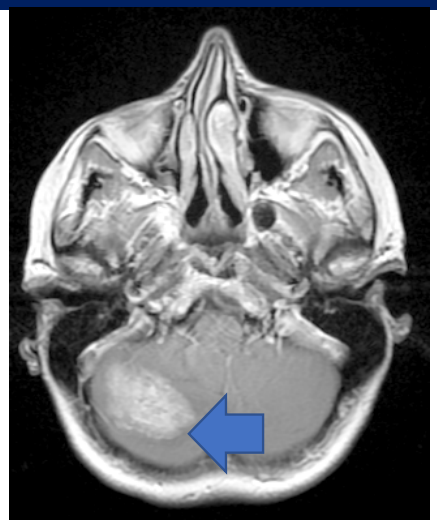
Does AlignRT replaces CBCT?

- Volumetric imaging for soft tissue matching
  - **CBCT localisation remains the gold standard**

- SGRT **is complementary,** not alternative
  - patient positioning / initial setup
  - monitoring for intrafraction patient movement
  - reduced imaging dose
  - reduced anesthetic needs

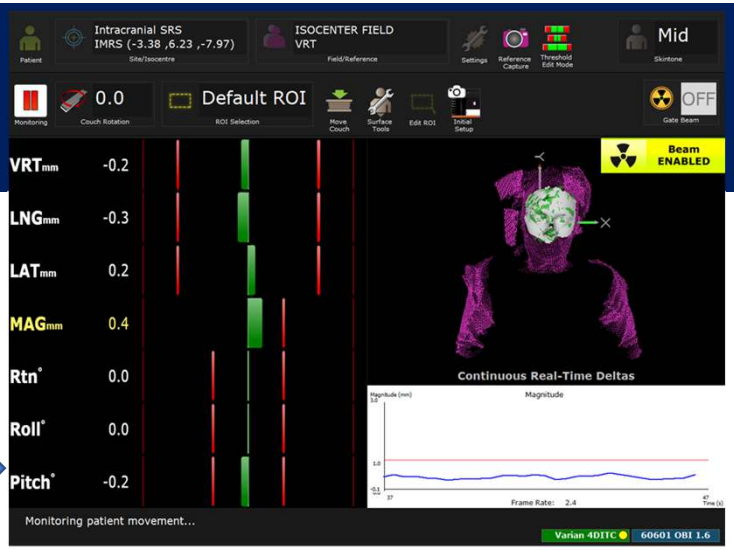


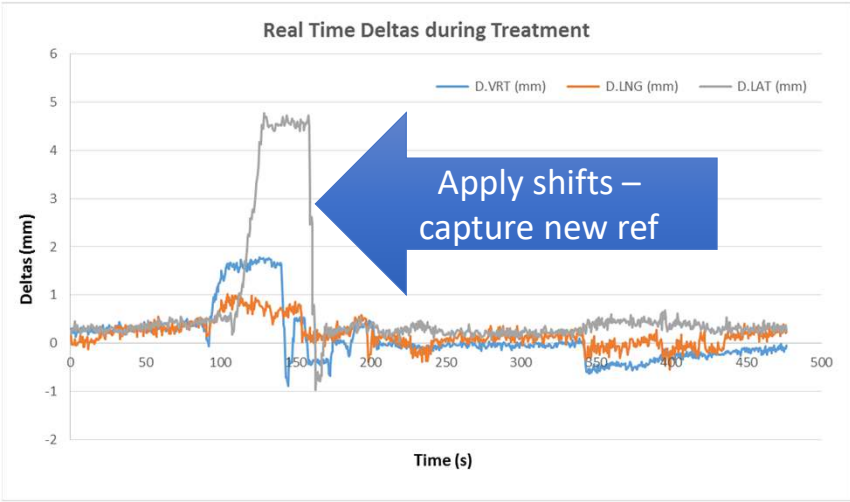
Case study



- 52 y.o. female, claustrophobic
- Met Breast Ca; Mar 2018
- for 24Gy in 3 fractions

- Unable to tolerate open face mask
- incomplete immobilization
- Increased PTV to 5mm and reverted to std fractionation (30Gy/10fx)
- Required real time monitoring of patient position





Beacon SRS Program Results

- Align RT installed Sept 2014
- **1000+ patients treated** (largest SRS series in Europe)
- Well tolerated – successfully treated over **98% of patients**
- Maintained similar tolerances to Varian OGP

SGRT for SABR/ hypo-fractionated treatments and tattooless techniques

SABR / hypofractionation- SGRT becomes a necessity/mandatory

- High dose per fraction, very conformal – risk of geographic miss/significant toxicities
  - Longer treatments- potential for patient movements

- Rigorous image review time for SABR cases
  - time consuming process- longer than standard image review

- Factors provoking patient motion
  - sleeping, sneezing, coughing, arm/back pain,
  - hard couch top
  - unnatural position
  - room temperature
  - worry, watch check,
  - image review and treatment time

- RGSC does not have patient motion functionality (re-tracks based on block position)

SGRT for Thorax and Abdomen

Date	Cohort	Sites	SGRT
January 2019	Non-RPM SABR	SABR Sites except Thorax & Abdomen	Intra-Fraction Motion Monitoring
February 2019	EEBH SABR	Abdomen	Synchronised with RPM
June 2019	IMRT & 3DCRT	Thorax, Abdomen (Markerless)	Localisation & Intra# Motion Monitoring
January 2020	IMRT & 3DCRT	Thorax, Abdomen	Set up & Motion Monitoring- Integrated RGSC Single Ant Tattoo
June 2020	Case by case #1 SABR	Thorax	Synchronised with RGSC check Varied Breath-holds
Aim 2021	SABR, IMRT & 3DCRT	Thorax, Abdomen	Synchronised with RPM check Varied Breath-holds & Gross Error

Moving towards tatooless techniques….

1. To assess effectivity of AlignRT surface guidance as a set up tool.

2. To use AlignRT to monitor patient intra-fraction motion, SABR treatment tolerance 0.3 cm, 3.0 degrees.

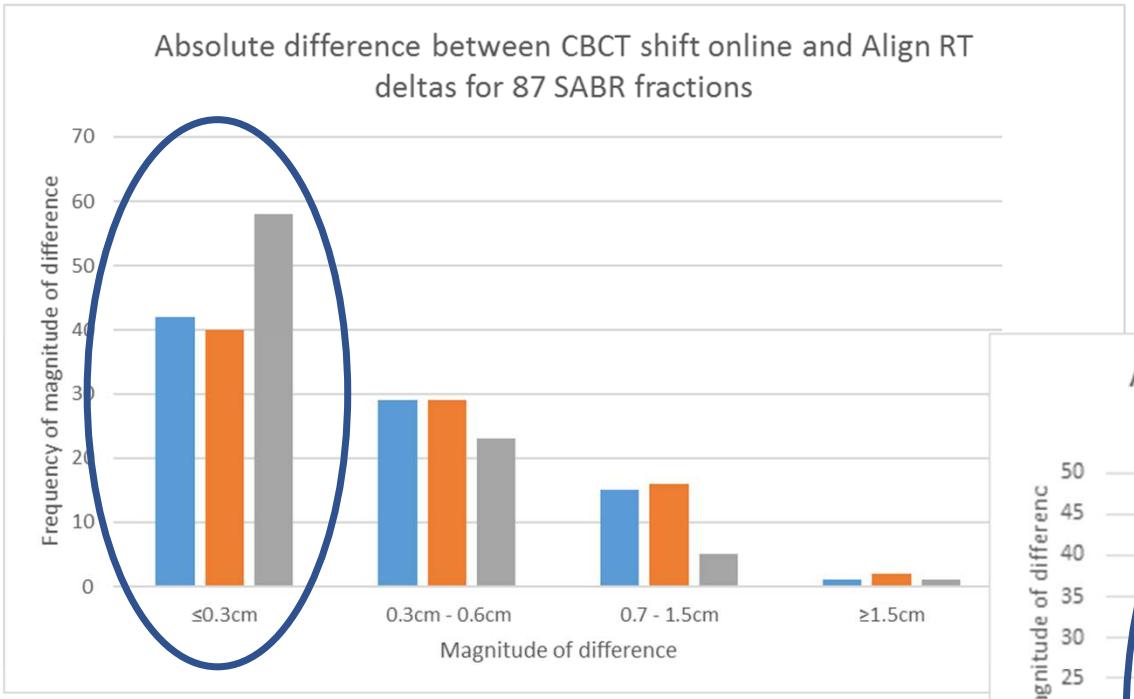
3. To increase safety when delivering SABR doses.

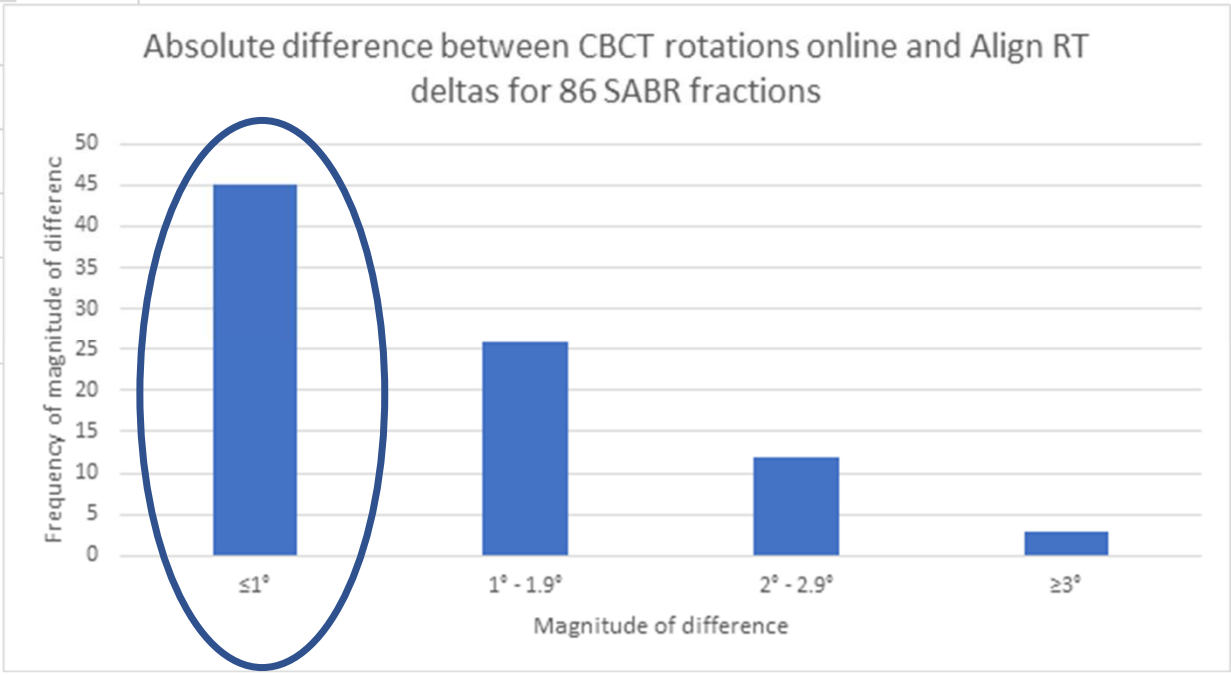
1. Record shifts indicated by AlignRT following set up

2. Record shifts indicated by OBI system following set up

3. Check for correlation (recorded shifts within 0.5cm and 2°)

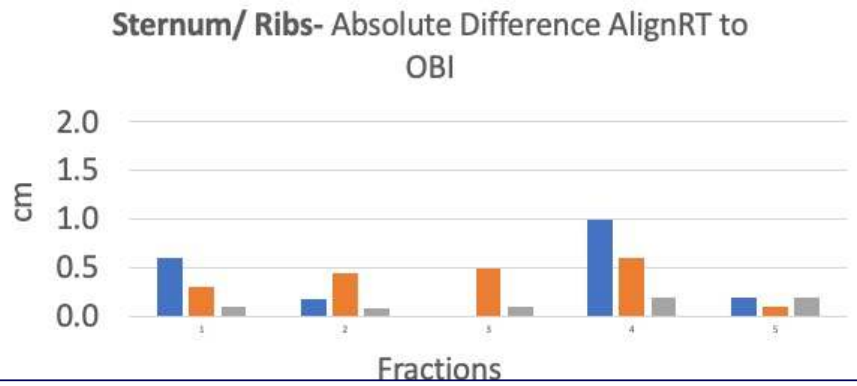
SGRT for SABR



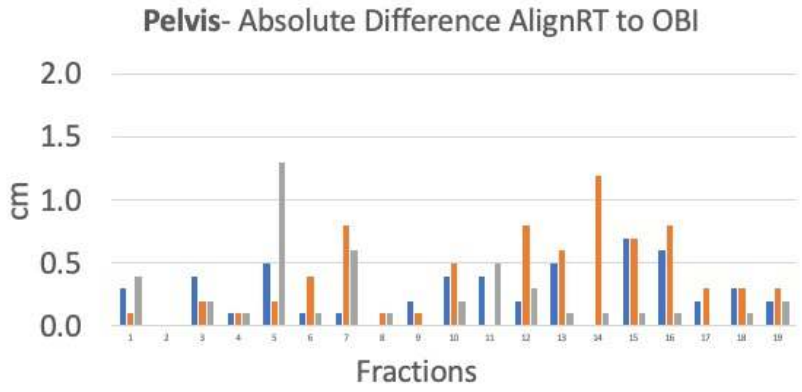


Absolute difference between AlignRT and OBI

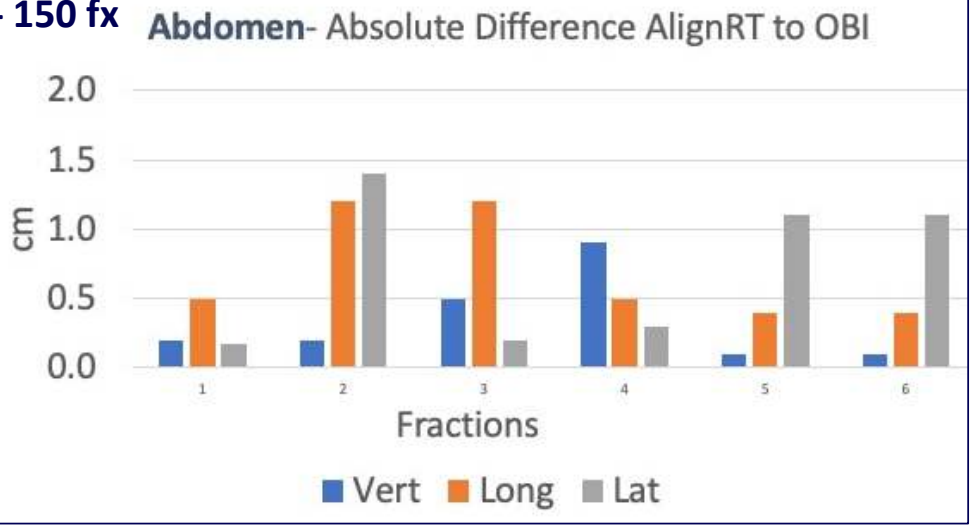
15 patients- 15fx



55 patients- 275fx



29 patients- 150 fx

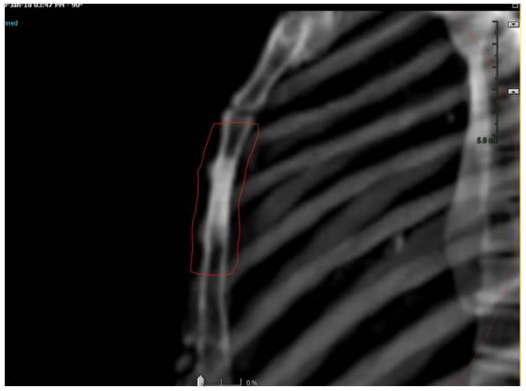


Findings

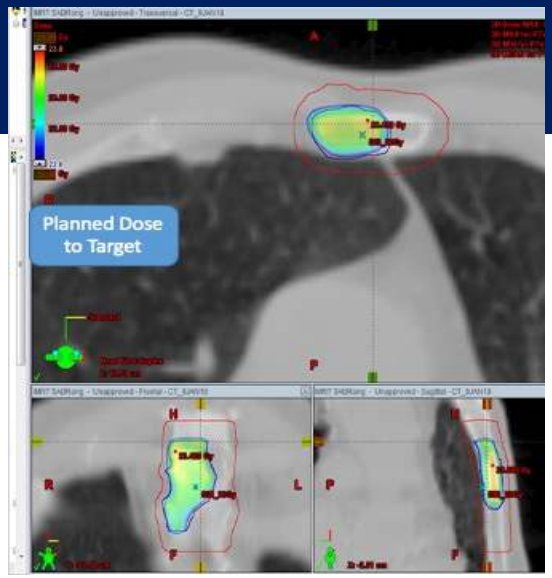
- **Heavy breathing** caused rotational and translational differences, this improved following ROI education session, across all sites.
- Chest/Abdomen:
  - **Vertical discrepancy** noted where there is **not enough lateral topography**, due to immobilization Bodyfix bags.

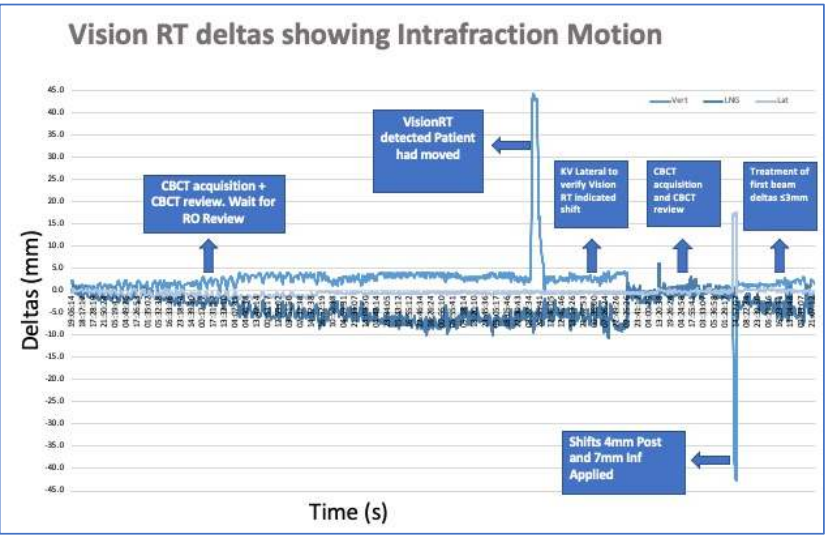
SGRT for SABR- retreat SABR 18Gy/1fx/SIB 22Gy

CBCT –Align RT

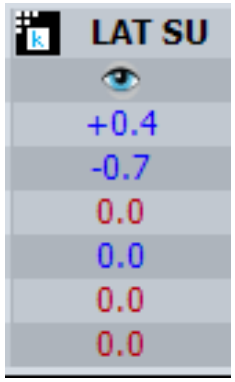


Kv imaging -

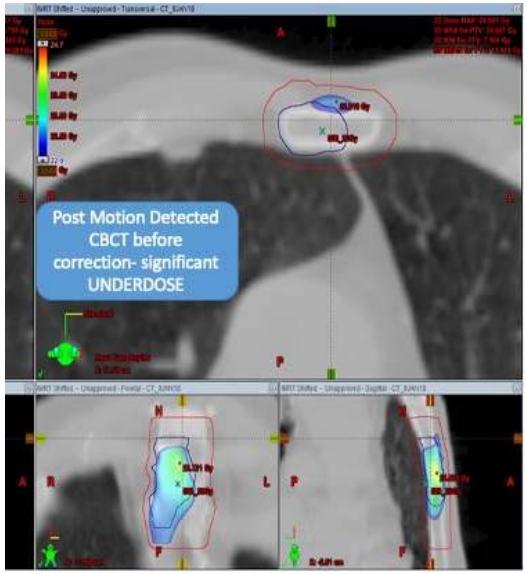




Align RT detects motion patient during image analysis



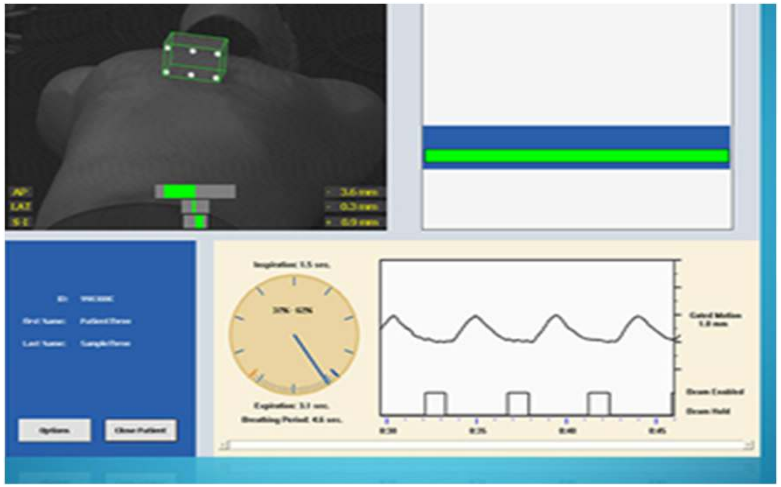
Applied shift and confirmatory CBCT



Breast/chest wall irradiation- DIBH tattooless technique

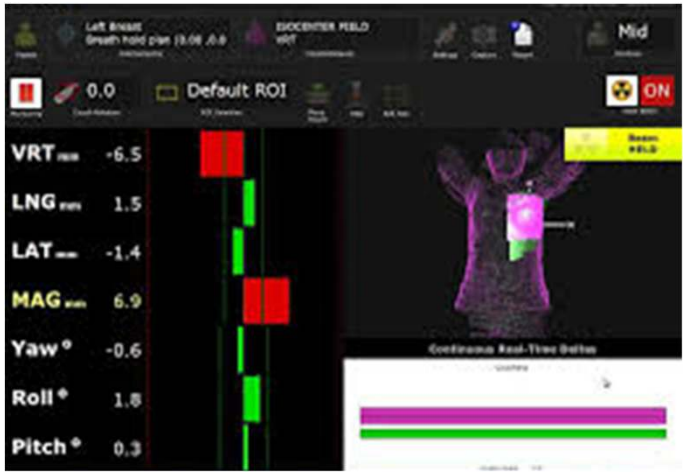
SGRT for Breast, Chest wall, SCF

2007-2014



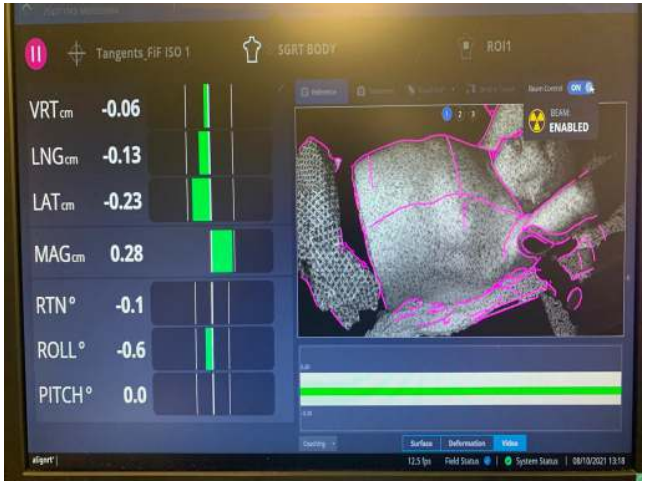
- Surrogate for lung filling
- Does not track patient motion
- Retrack block position

2018-2021

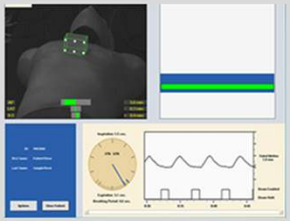
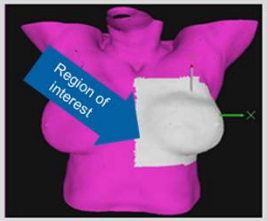


- Tracks actual breast tissue
- Highly accurate for FB and DIBH
- Able to identify bending back, rotations, etc

Since 2021- AlignRT Advance



Compare RPM to SGRT

Varian RPM	Align RT
marker block as surrogate for motion 	patient skin surface 
Tattoos	Tattooless
10 years experience 10 patients 2018	audit first 10 patients audit 10 patients at 1 year

Daily Imaging with RPM & SGRT

COMPARE
Magnitude of shifts
Total treatment time
Number of re-setups for 3 field

Repeated analysis 1 year later

Results – Magnitude of shifts

SGRT - peak shifted towards 0.0cm imaging shift in three directions (dashed line)

SGRT - increased frequency of (0.2cm) –imaging shifts in three directions

Less pronounced but maintained for SGRT & 1 year

SGRT - more reliable for setup

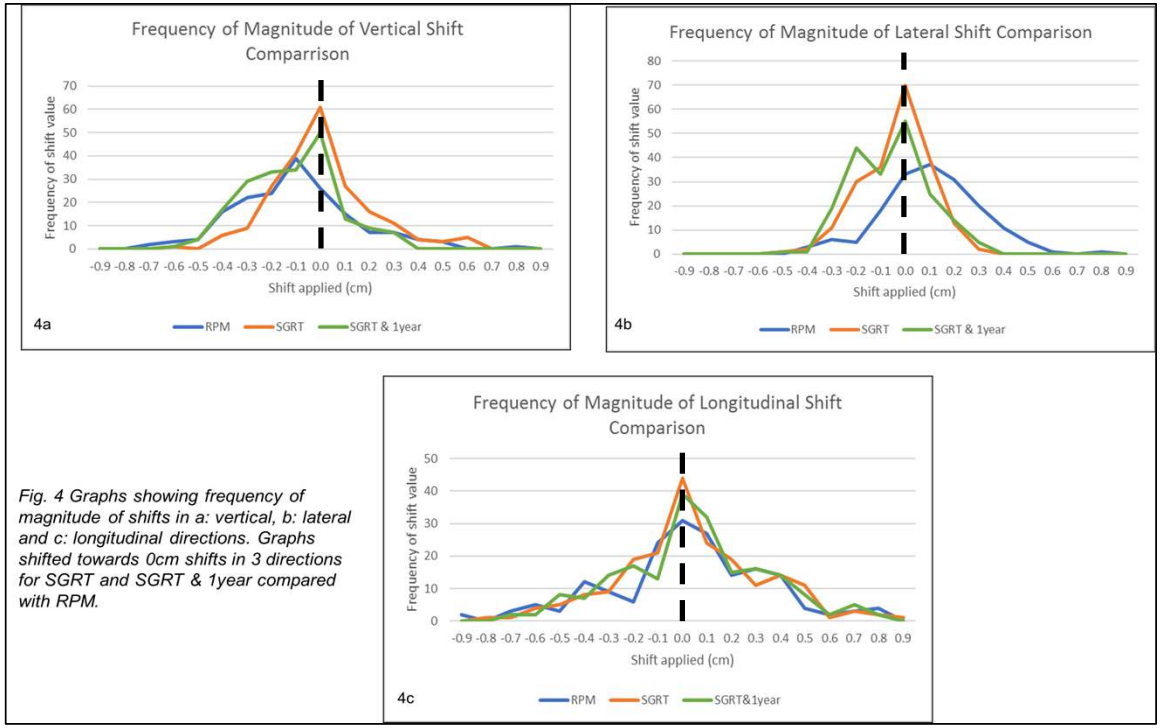


Fig. 4 Graphs showing frequency of magnitude of shifts in a: vertical, b: lateral and c: longitudinal directions. Graphs shifted towards 0cm shifts in 3 directions for SGRT and SGRT & 1year compared with RPM.

Results – Average Treatment Time

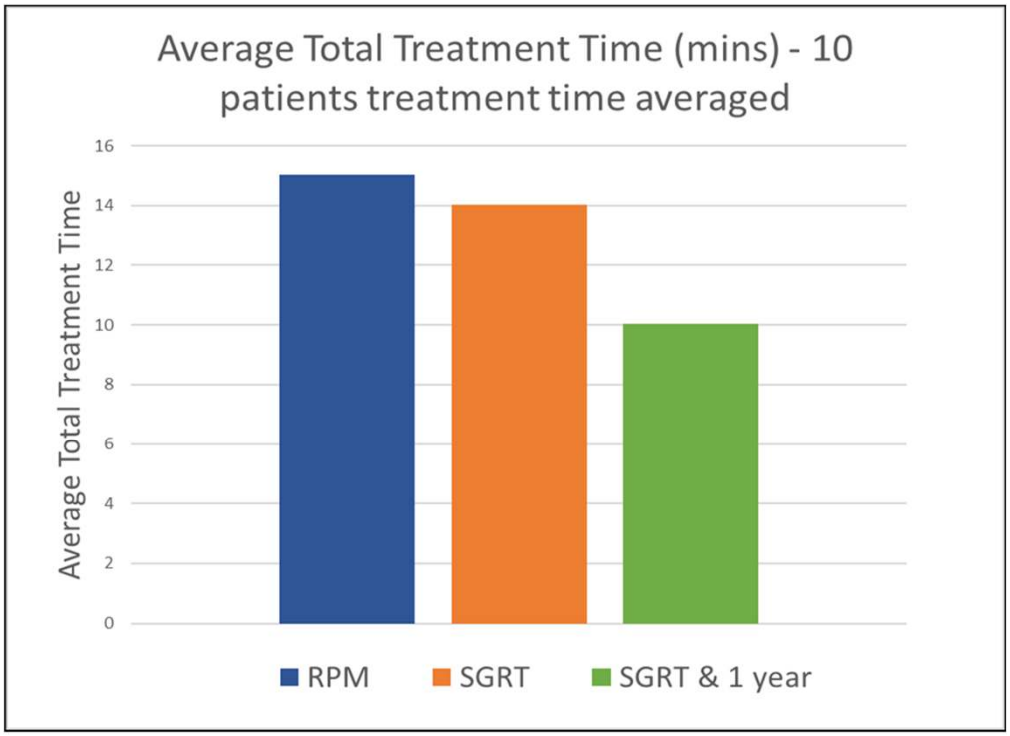


Fig. 5 Average total treatment time – reduced from 15 minutes with RPM to 10 minutes SGRT & 1 year

Treatment time reduced from

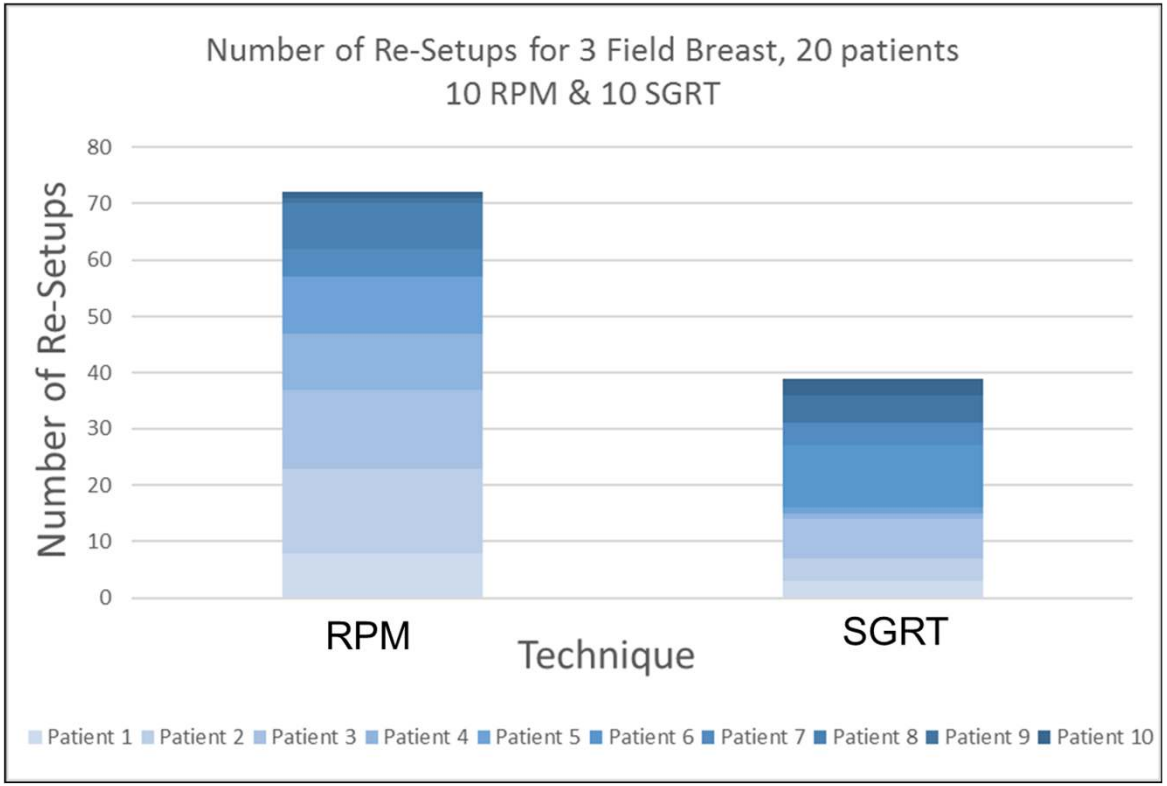
15 minutes per patient with RPM to **10 minutes per patient with SGRT**

Results – Additional Setup Following Imaging

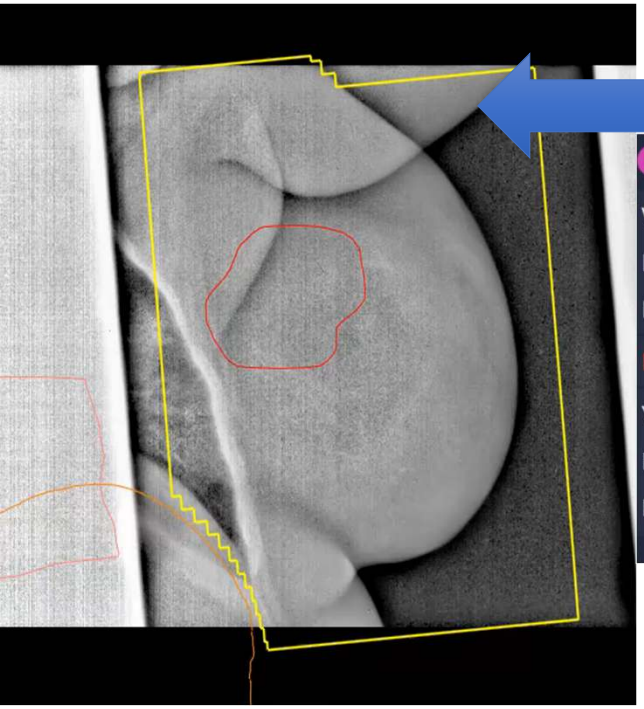
Unchanged for 2 field breasts

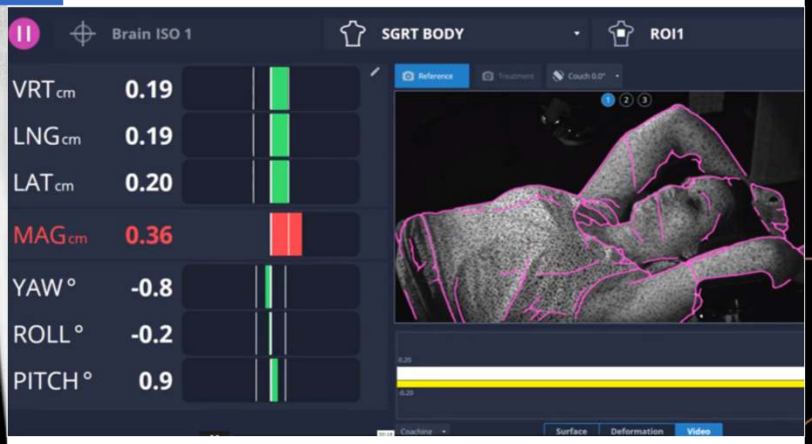
Graph shows a significant decrease in re-setups for 3 field treatments with SGRT. Use of the arm ROI in Align RT has yielded better supraclavicular setup

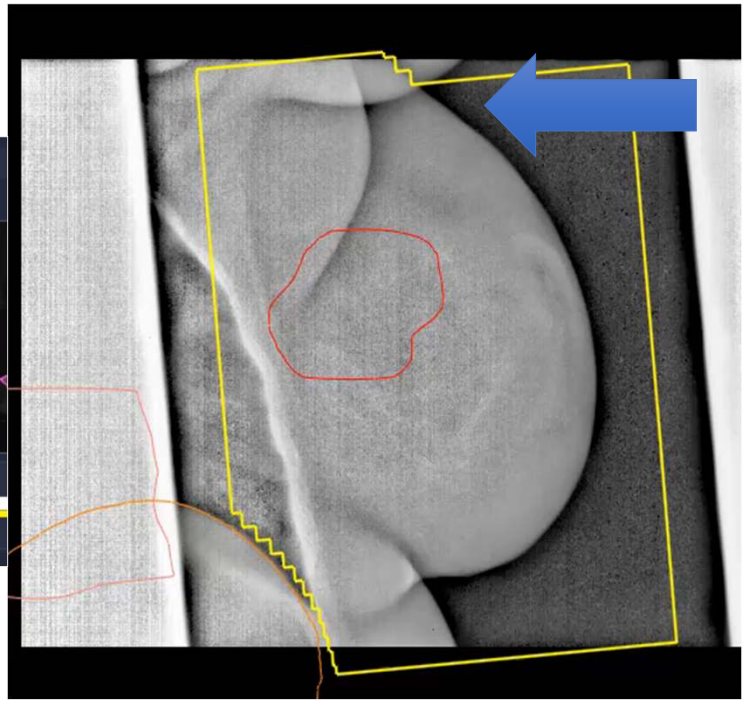
Intrafraction monitoring has not revealed patient motion during treatment



Align RT Advantage – set-up of 3 fields breast







Day 1-no postural video to aid set-up

Day 3 - postural video to aid set-up

Conclusion

Improved accuracy with reduction in magnitude of shifts

Reliable set up – daily imaging required?

Faster setup, saving on average 5 minutes per patient

Tattooless treatments – more patient friendly

Improved safety standards with real time intrafraction monitoring

Positive staff experience, user friendly & easy to implement

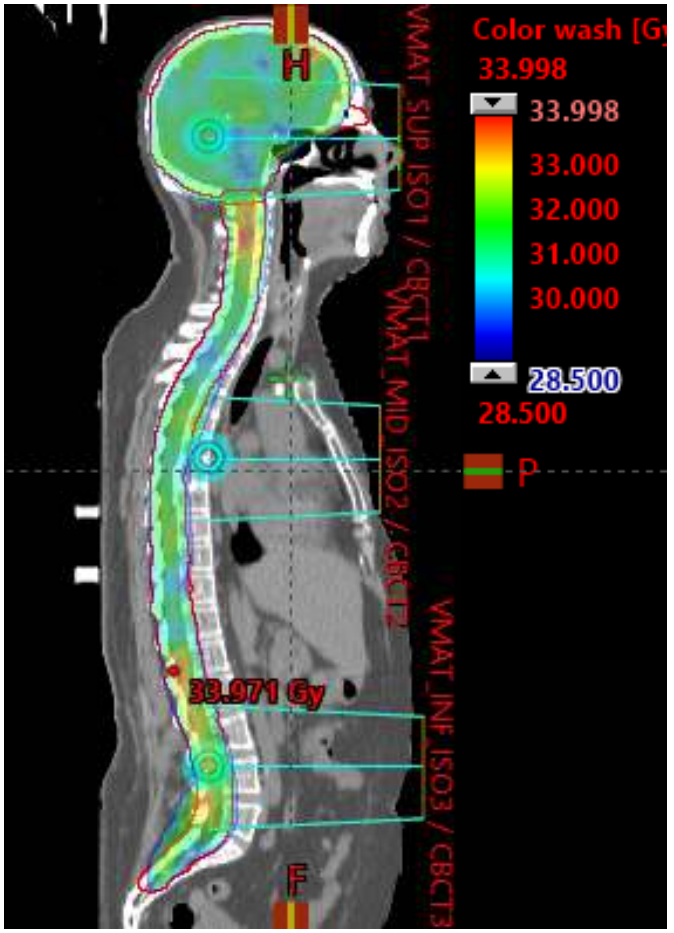
Beacon's Top 5 Benefits from AlignRT

- Improved efficiency, reduction in patient localisation time
- Improved accuracy, reduction in shift magnitude, reduction gross error
- Improved consistency of breath-hold
- Improved safety standards using real-time intra-fraction monitoring
- Improved staff welfare: reduction in patient manipulation, staff reported reduction in wrist and back pains

Special Thanks
Bogdan and Alex
Radiotherapy team Beacon
Hospital, especially Darina,
Marie, Katie

Cranio-Spinal Irradiation - Case Study Nov 2022

45yo female – Breast ca. June 2021
Secondary malignant neoplasm of brain and cerebral meninges
VMAT – 3 isocentres
30Gy in 10fr (7mm PTV)
Supine, H&N mask + knee lock
Imaging – extended CBCT, kVs
Required real time monitoring of patient position – ROIs



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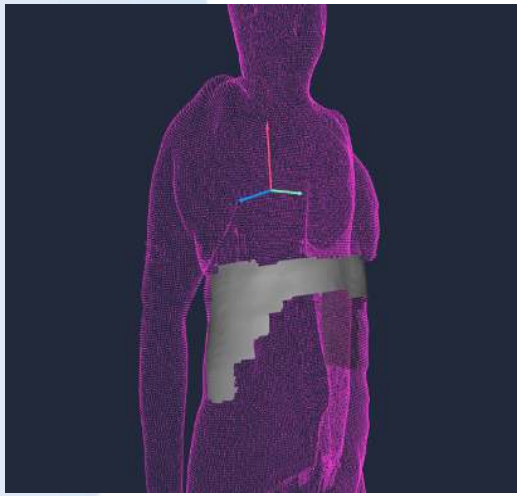
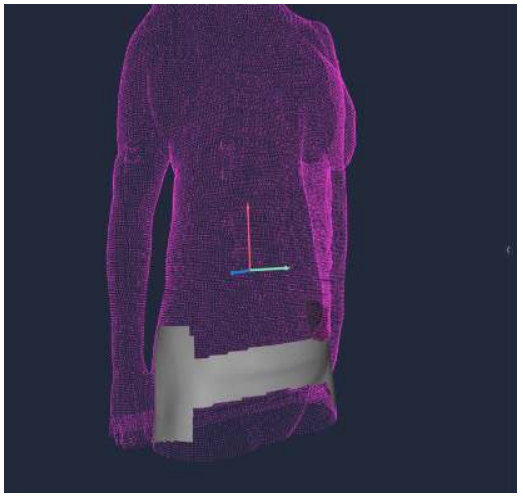
Cranio-Spinal Irradiation - ROIs

ROI 1
Cut out H&N mask

ROI 2
exclude abdomen

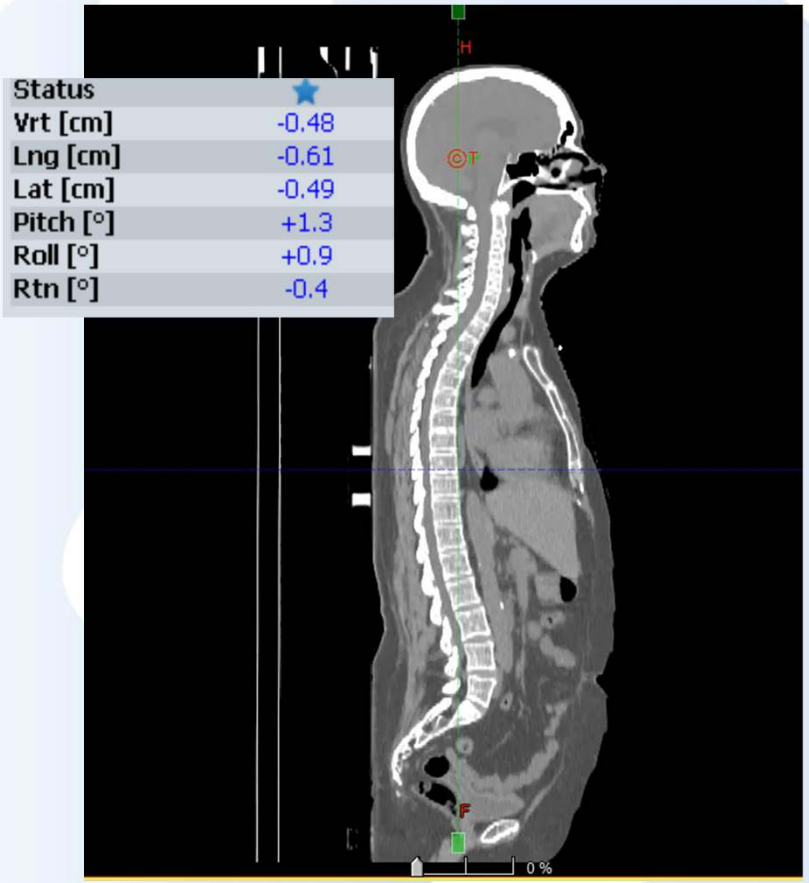


ROI 3
exclude abdomen



Align RT tolerance - Translations: 0.7cm
Rotations: 3°

Cranio-Spinal Irradiation – Image Verification



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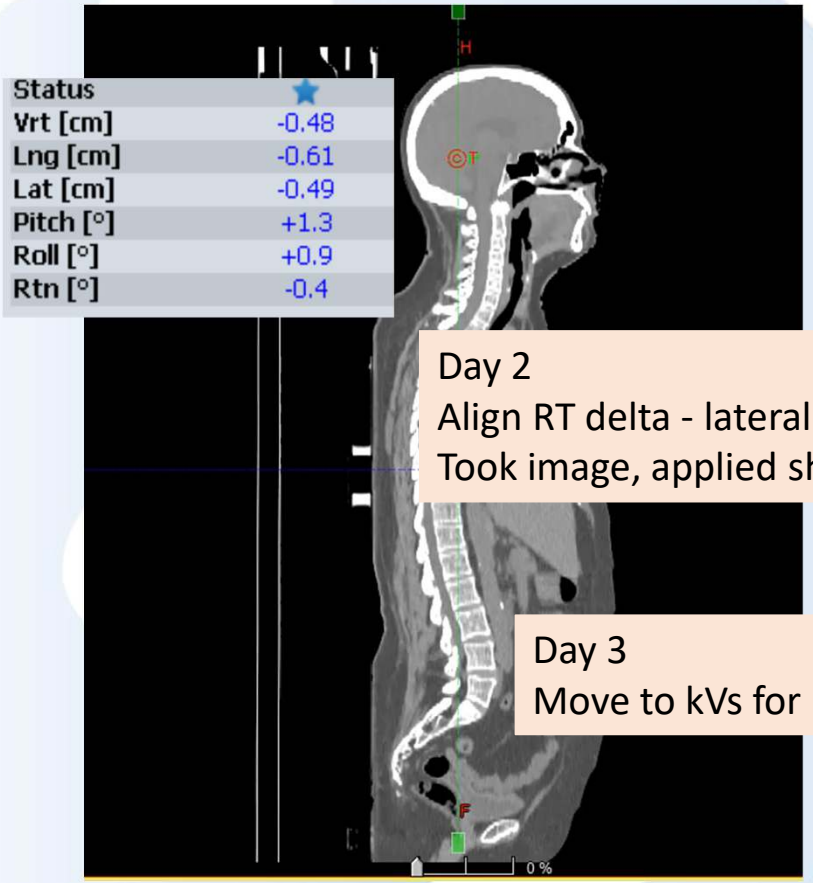
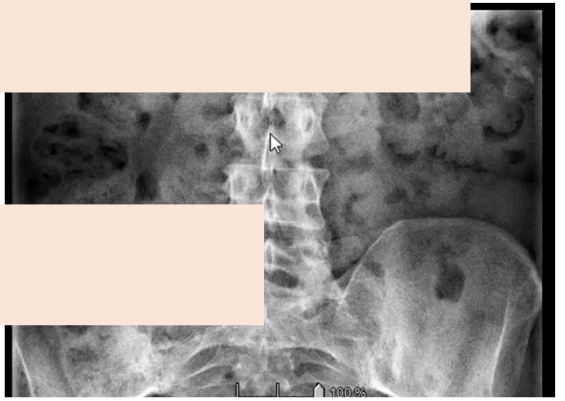
Cranio-Spinal Irradiation – Image Verification



Day 2
Align RT delta - lateral 7mm – patient moved
Took image, applied shift 7mm



Day 3
Move to kVs for remaining fractions

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