And Breathe….
Enhancing Confidence in Radiotherapy treatment delivery using SGRT

Luke Rock MSc, DABR, CSci, MIPEM
Beacon Hospital
Dublin

This is Modern Medicine

Beacon Hospital

Before you start

Change management & staff buy-in essential

Physician sponsorship critical – Involve MDT

Share Data – Demonstrate improvement

Frame-based SRS – open face mask challenges established practice

Perception of reduced internal imaging

Beacon SGRT Experience

Year	Site	Setup	Intrafraction Monitoring
2014	Intracranial SRS	✓	✓
2017	Extremities/Thorax/Abdomen/ Pelvis	✓	✓
2018/2019	Breast DIBH & Tattooless	✓	✓
2019	Most sites tattooless	✓	✓
2019/2020	SABR Abdomen & Thorax	✓	✓

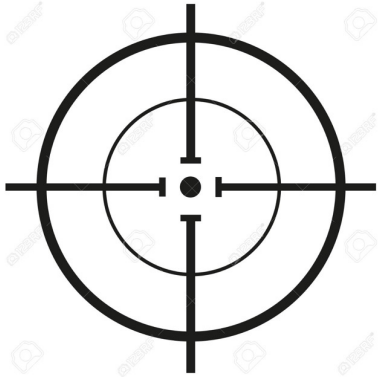
Varian EDGE

Varian Trilogy Tx

August 2021 Align RT Advance

Requirements for SRS/SABR

- Minimise interfraction localisation uncertainty
  - set-up patient accurately at isocentre
- Minimise intrafraction localisation uncertainty
  - drift away from isocentre during treatment delivery
  - Head Ring
  - Real time monitoring
- Allow for patient localisation at non-coplanar angles
- Reliable - treatment interruptions undesirable
- Ease of use
- Patient compatibility/experience is increasingly important



Requirements for Cranial SRS

TABLE II. Achievable Uncertainties in SRS

Stereotactic Frame	1.0 mm
Isocentric Alignment	1.0 mm
CT Image Resolution	1.7 mm
Tissue Motion	1.0 mm
Angio (Point Identification)	0.3 mm
Standard Deviation of Position Uncertainty (by Quadrature)	2.4 mm

AAPM TG 42
1995

Imaging, planning, and treatment typically are performed in close temporal proximity. Treatment delivery should be accurate to within approximately 1 mm. This leaves little room for error in the overall process. Strict protocols

ACR/ASTRO Practise Guideline
2016

Accurate $\leqslant$ 1mm (AAPM TG 101/ASTRO 2016)

Does SGRT meet these requirements?

Accuracy

- Phantom studies demonstrate AlignRT isocentre localization > 1mm

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

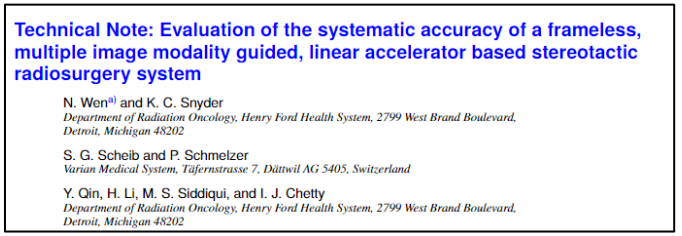
- AlignRT comparable to existing x-ray imaging techniques

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

Clinical Outcomes

- Comparable with conventional frame-based and frameless SRS

  [Pham et al Trans Can Res 2014; Pan et al Neurosurg 2014]

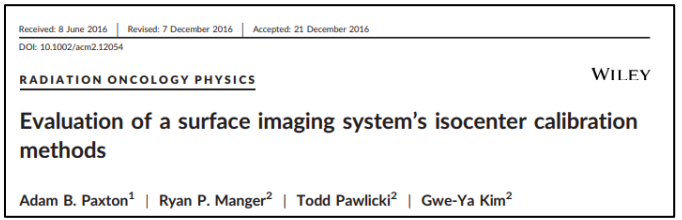


Technical Note: Evaluation of the systematic accuracy of a frameless, multiple image modality guided, linear accelerator based stereotactic radiosurgery system

N. Wen[a] and K. C. Snyder
Department of Radiation Oncology, Henry Ford Health System, 2799 West Brand Boulevard, Detroit, Michigan 48202

S. G. Scheib and P. Schmelzer
Varian Medical System, Täfernstrasse 7, Dättwil AG 5405, Switzerland

Y. Qin, H. Li, M. S. Siddiqui, and I. J. Chetty
Department of Radiation Oncology, Henry Ford Health System, 2799 West Brand Boulevard, Detroit, Michigan 48202



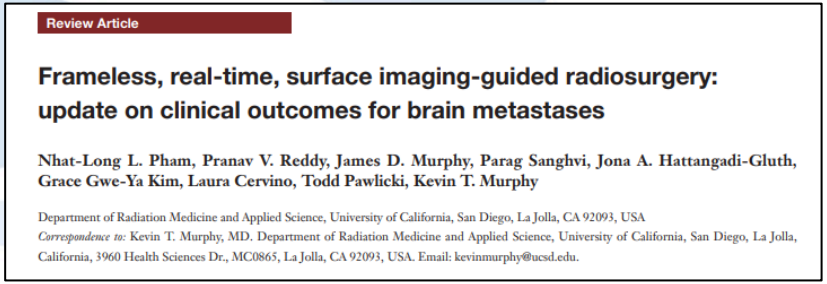
Received: 8 June 2016 | Revised: 7 December 2016 | Accepted: 21 December 2016
DOI: 10.1002/acm2.12054

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]



Review Article

Frameless, real-time, surface imaging-guided radiosurgery: update on clinical outcomes for brain metastases

Nhat-Long L. Pham, Pranav V. Reddy, James D. Murphy, Parag Sanghvi, Jona A. Hattangadi-Gluth, Grace Gwe-Ya Kim, Laura Cervino, Todd Pawlicki, Kevin T. Murphy

Department of Radiation Medicine and Applied Science, University of California, San Diego, La Jolla, CA 92093, USA
Correspondence to: Kevin T. Murphy, MD. Department of Radiation Medicine and Applied Science, University of California, San Diego, La Jolla, California, 3960 Health Sciences Dr., MC0865, La Jolla, CA 92093, USA. Email: kevinmurphy@ucsd.edu.

Beacon Hospital

Does SGRT meet these requirements?

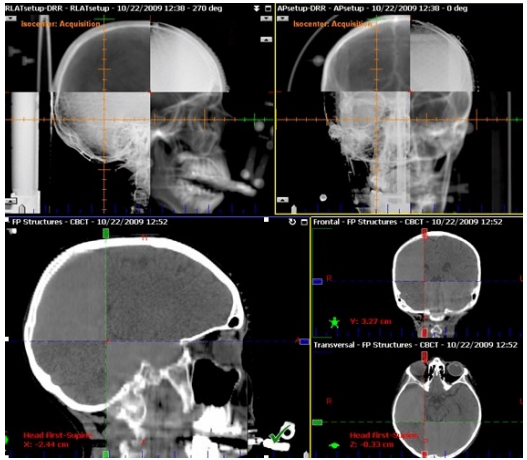
- Advanced camera optimisation
- Performed by VisionRT engineer at initial camera set-up
- Generates 3D calibration rather than single plane

Accuracy Test	Measured Data
Absolute phantom setup error	≤ 0.2 mm / 0.4°
Coplanar tracking accuracy	< 0.2 mm / 0.1°
Non-coplanar tracking accuracy (MAX-HD)	< 0.4 mm / 0.2°
○ Ave RTD change for varying isocenters	0.1 mm
○ RTD change due to pod occlusions	< 0.1 mm
Non-coplanar tracking accuracy (Cube)	≤ 0.3 mm / 0.2°

Beacon Hospital

So is SGRT all we need for Radiosurgery?

- 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
- Extra information increases confidence

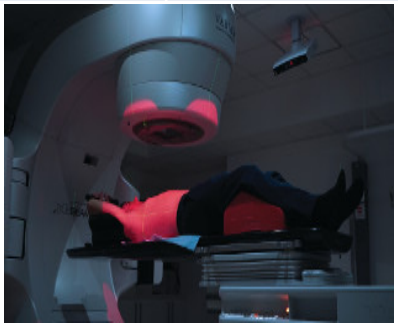


Beacon Hospital

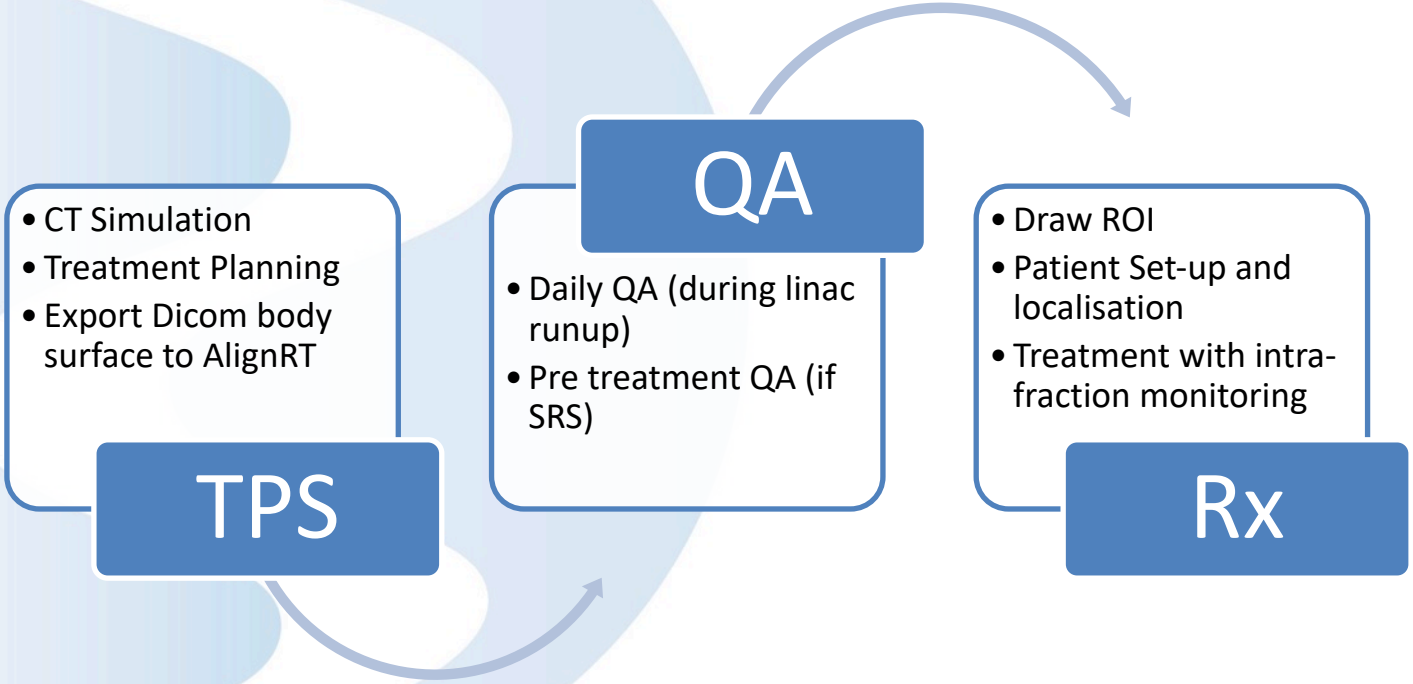
Beacon Hospital Experience SRS

Approx 1200+ treatments since 2007; 500+ with AlignRT

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

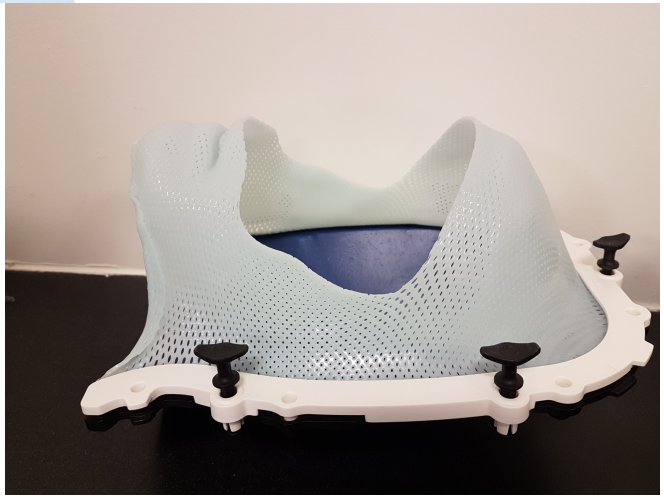


SGRT Workflow



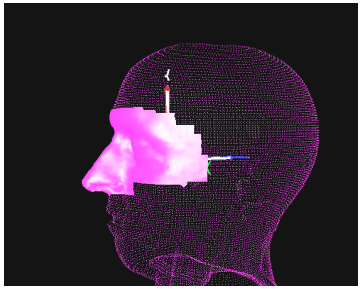
CT Simulation and Immobilization

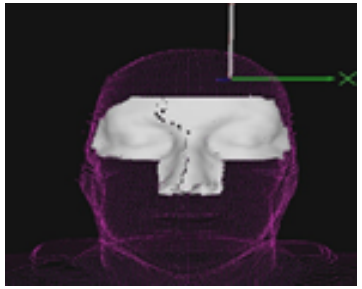
- MacroMedics DSPS open face mask
- Ensure enough of face is outside mask for ROI
- Chin down as far as possible
- Occipital section as deep as possible



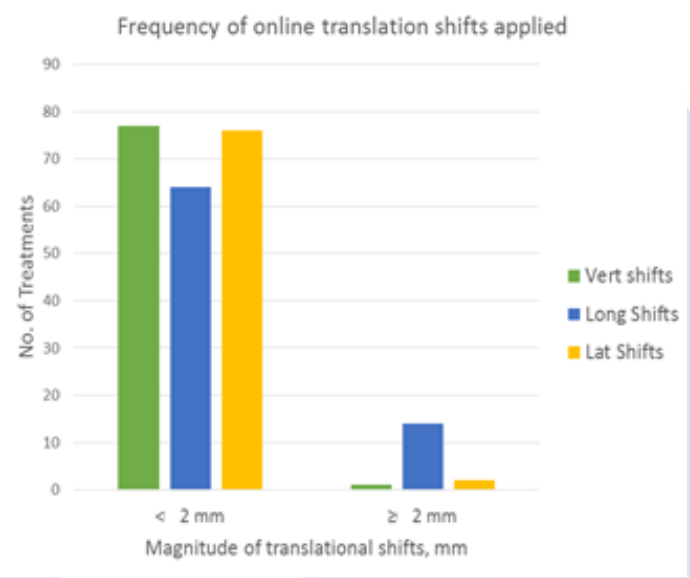
Cranial SRS ROI selection

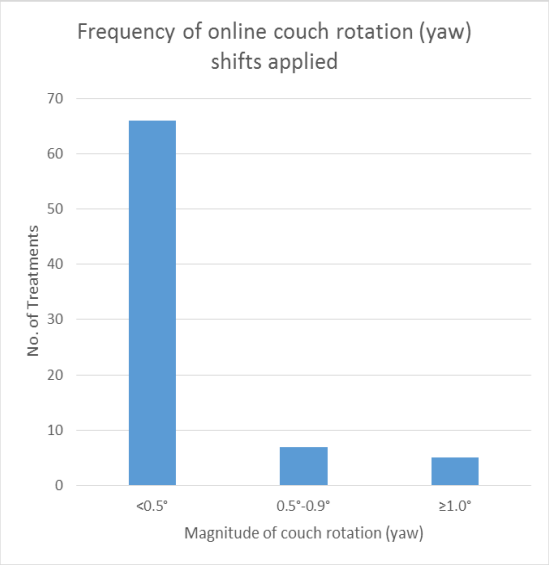
- Primary cause of poor setup
- ROI should only include rigid structures
  - include frontal bones (=> chin down)
  - exclude cheeks, hairline, prominent eyebrows
  - exclude mask
- No make-up or false eyelashes
- Bushy eyebrows….





CBCT vs AlignRT – early experience

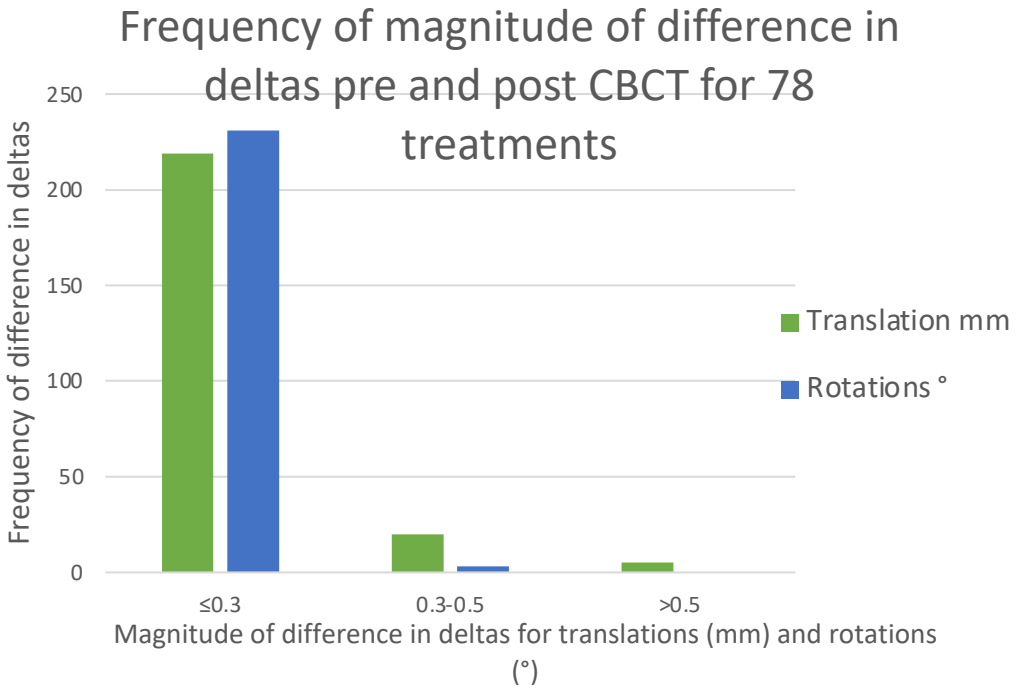




- Vert & Lat shifts: 98% < 2mm
- Long shifts: 82% < 2mm (correct for pitch)
- Couch rotation: 94% < 1°
- Similar result to Cervino et al *[Pract Radiat Oncol 2012]*

Beacon Hospital

Open face mask stability



- Patients are remaining still in open face mask
- Improved patient experience is important

Open face mask stability

EDGE machine 2019 data

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

- All translations less than 1mm on 2nd CBCT (Fig 1)
- Rotations -0.3° to 0.3° (Fig 2 & 3)

Fig 1

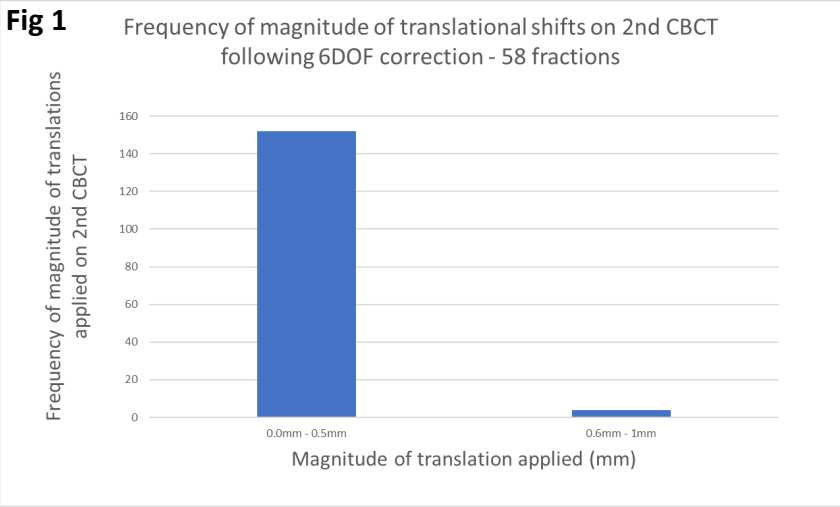


Fig 2

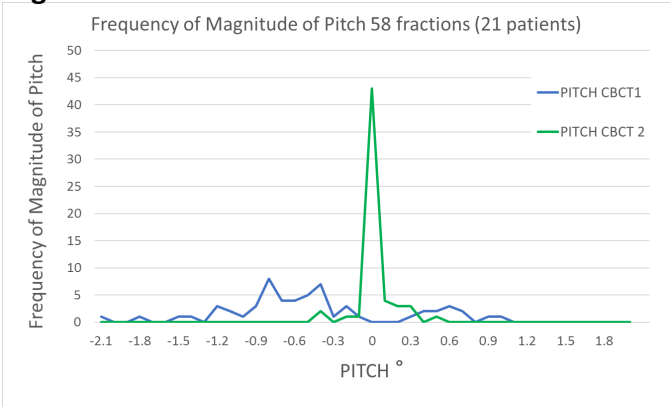
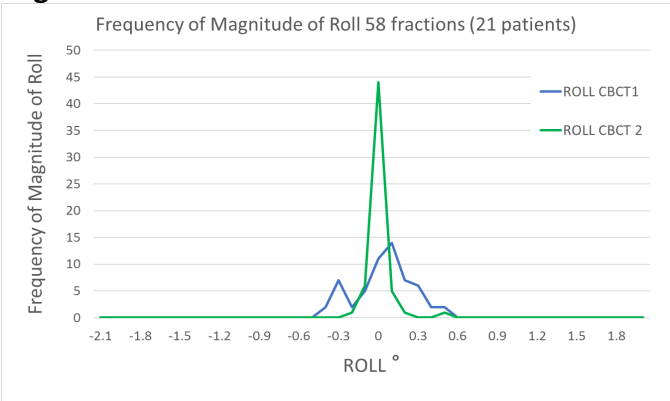


Fig 3



Beacon Hospital

Why is stability important – multi-target SRS

Larger distance to isocenter, larger impact of uncorrected rotations (Hanna, Mancini et al. 2019) (Roper, Chanyavanich et al. 2015) (Prentou, Pappas et al. 2020)

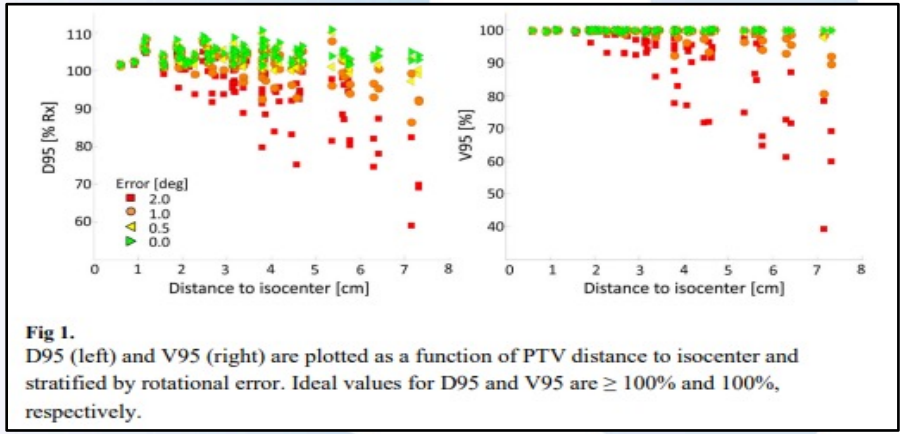
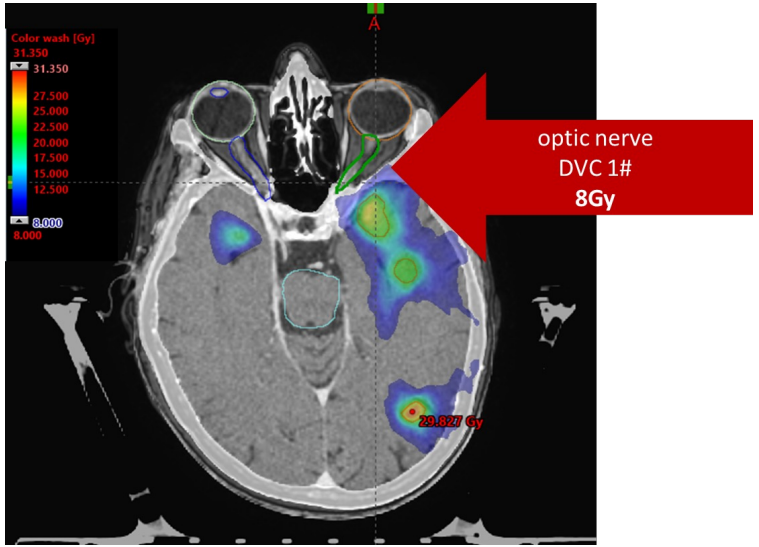


Fig 1.
D95 (left) and V95 (right) are plotted as a function of PTV distance to isocenter and stratified by rotational error. Ideal values for D95 and V95 are ≥ 100% and 100%, respectively.

(Roper, Chanyavanich et al. 2015)



OARs nearby – rotations ~0.5° could lead to a significant increase in D_{max} & $D_{0.02cc}$ (Prentou, Pappas et al. 2020)

Beacon Hospital

Cranial Case Study

52yo female – Breast ca. March 2018

Single Rt Cerebellar Metastasis

24Gy/3fr - **Claustrophobic**

Refused WBRT – no mask

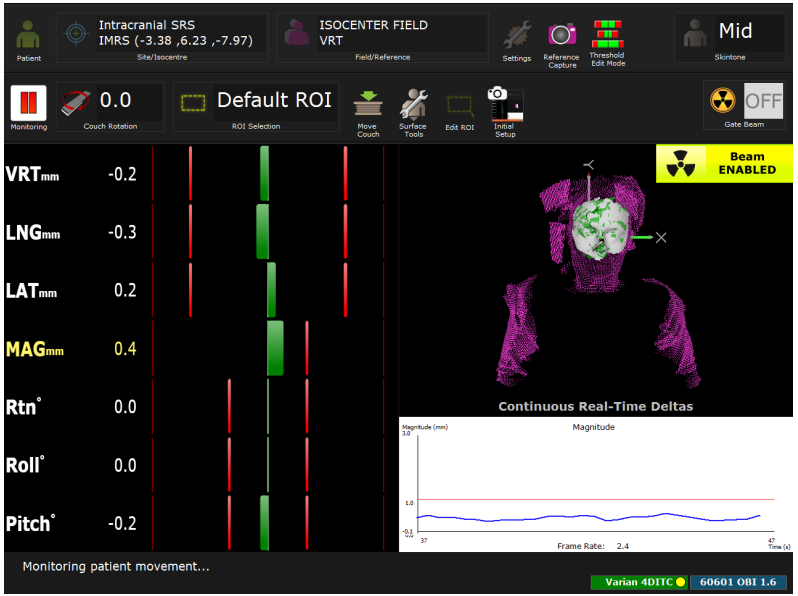
Increased PTV to 5mm – 30Gy in 10fr

Required real time monitoring of patient position

Beacon Hospital

Cranial Case Study

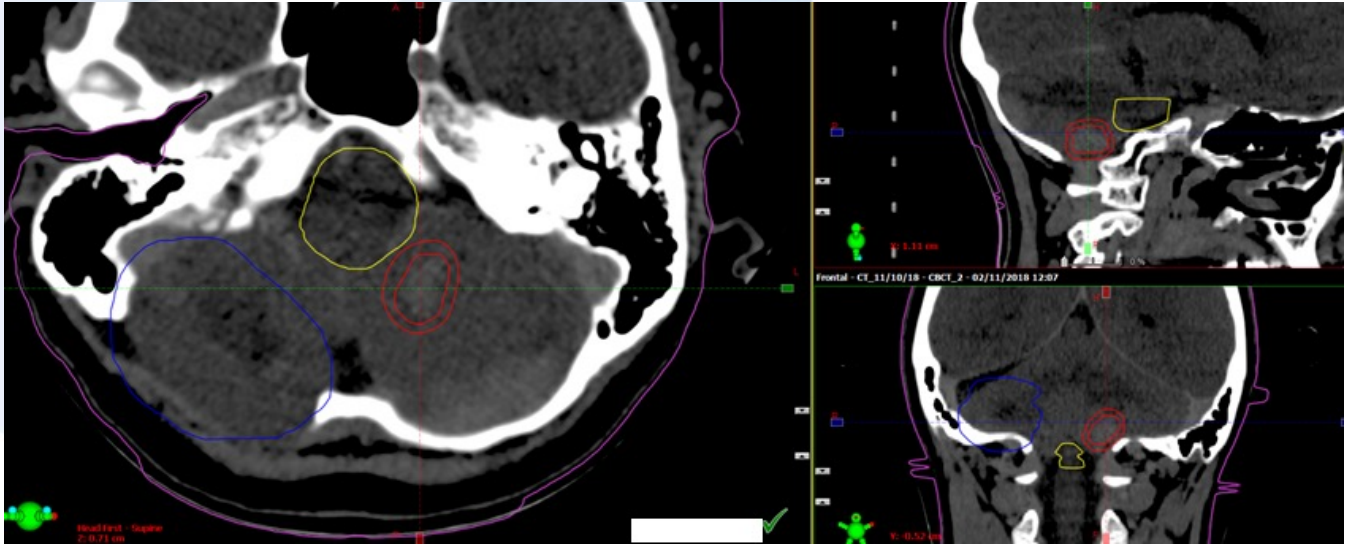
- Enhanced patient comfort – minimised patient movement
- Motion was observed to be <2mm
- Less conservative approach possible
- ***No treatment possible without AlignRT***



Beacon Hospital

Cranial Case Study

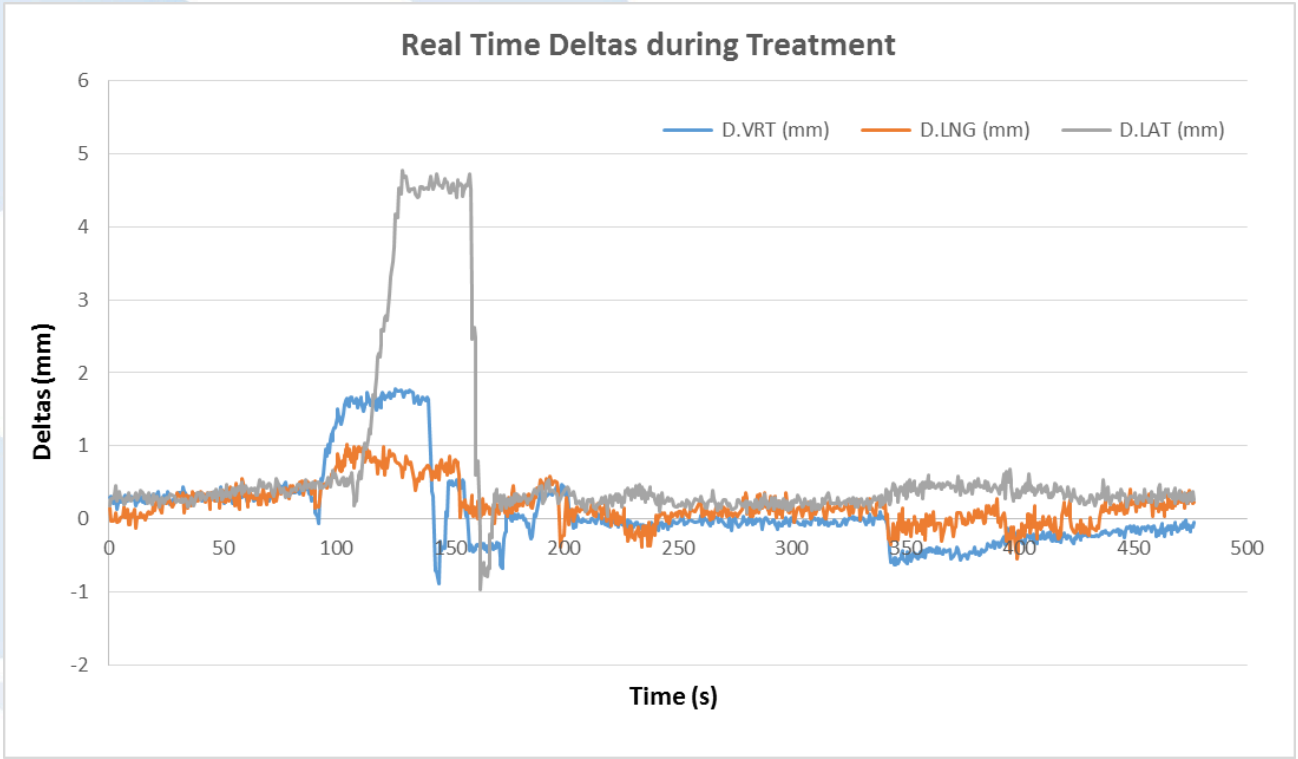
- 7 months later – new Lt cerebellum metastasis
- 25Gy/5 fx to PTV with 30Gy/5 fx SIB to GTV
- Close to brainstem – dose limit 25Gy (AAPM TG 101)



Beacon Hospital

Cranial Case Study

- AlignRT allowed for safe treatment delivery



Beacon Hospital

Beacon Hospital SABR Programme

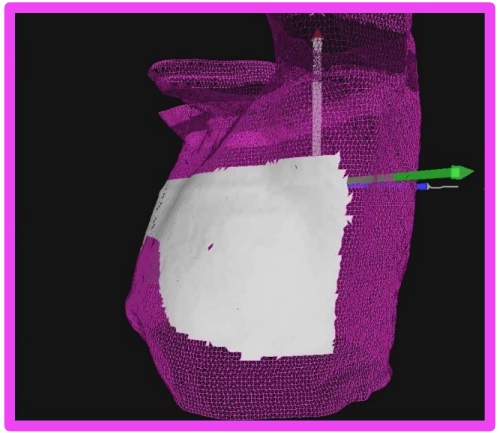
- Began early 2009
  - over 2000 patients & 10,000 fractions
- Varian RPM/RGSC for respiratory management
- BodyFix immobilisation (including body sheet)
- Mature programme, well established workflow
- 2019- integrate SGRT

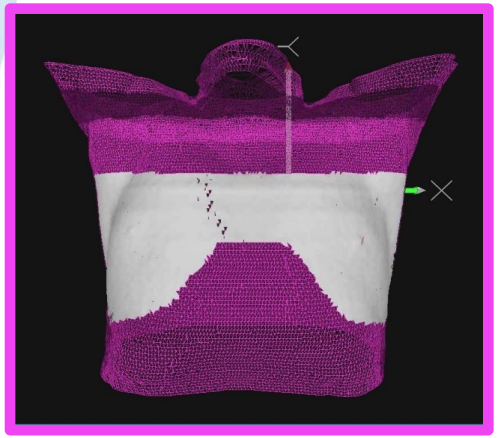
Integrating SGRT into SABR Programme

Advantages of SGRT for SABR
Tattooless setup
Intrafraction monitoring
“extra set of eyes on patient”
Minimize immobilization devices (remove body sheet)

SABR Patient Setup using AlignRT

- **Lung / Liver /Spine SABR**
- General rules apply:
  - use rigid structures only
  - do not include anything that is not part of the patient
- May have an impact on immobilisation device choice
- Include sternum, anterior and lateral ribs (to mid-coronal plane), heads of clavicle
- Do not include diaphragm or abdomen
- Any loose or mobile skin/tissue
- Requires training/experience

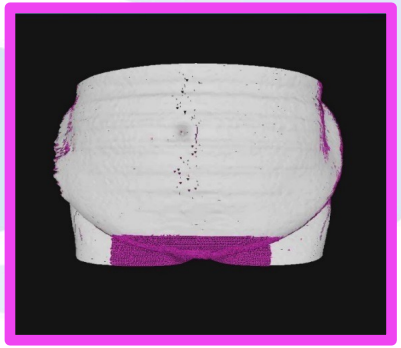


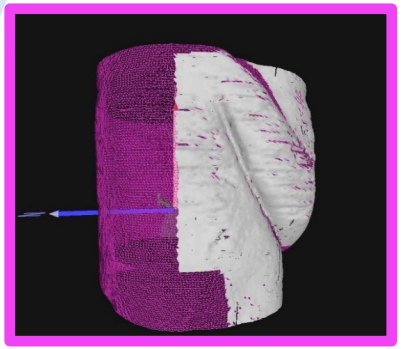


SABR Patient Setup using AlignRT

- **Pelvis / Prostate SABR**
- Include anterior and lateral portion of hips (to mid-coronal plane)

- Do not include excessive tissue

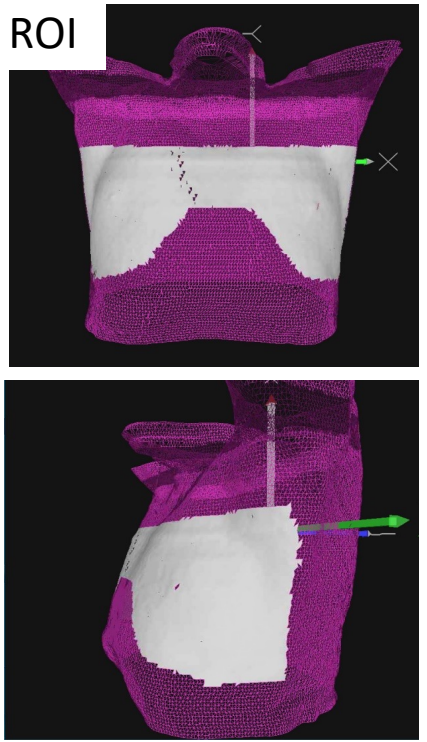




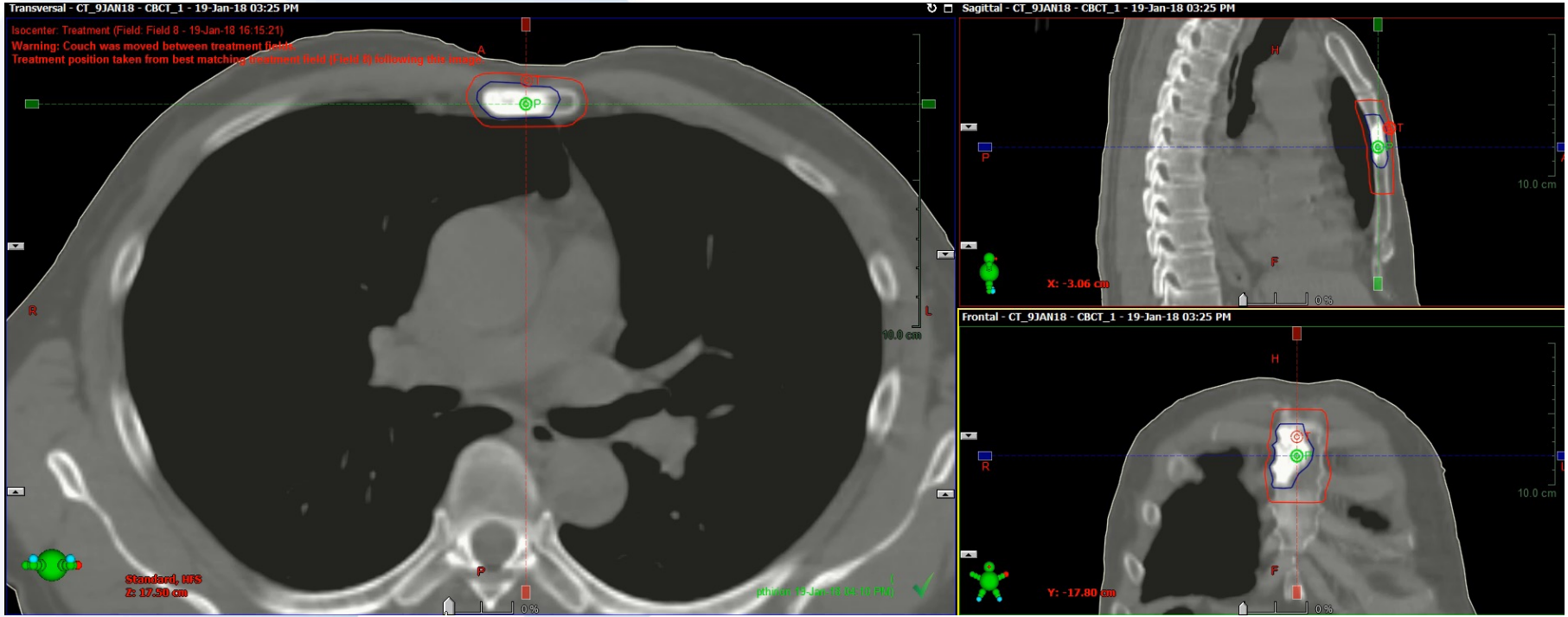
SABR Case Study - Intrafraction Motion

67yo male – Prostate ca.
EBRT 45Gy & I-125 Brachy
2017 – Sternum met (PET-CT)
18Gy Single fr (22Gy SIB to GTV)
Real time monitoring of patient position using SGRT due to single fraction

ROI



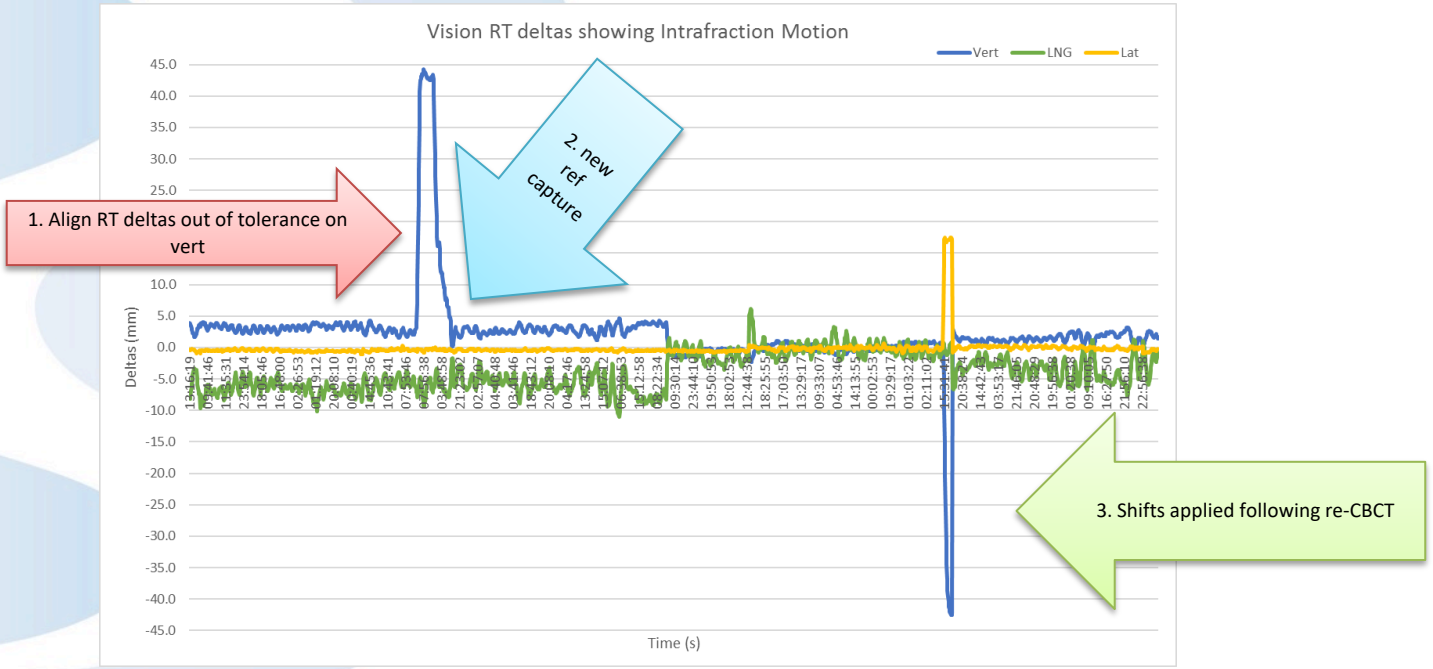
SABR Case Study



Beacon Hospital

SABR Case Study

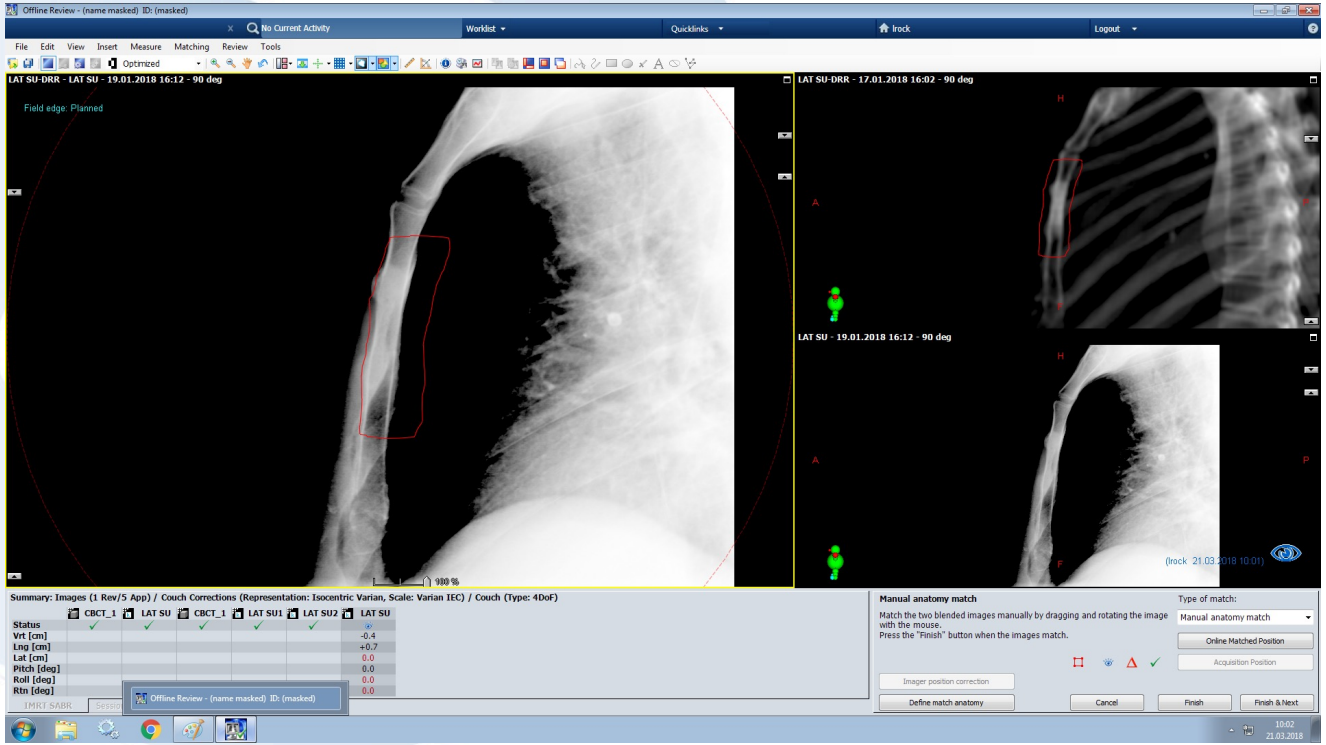
- AlignRT detected patient movement after CBCT shifts applied



Beacon Hospital

SABR Case Study

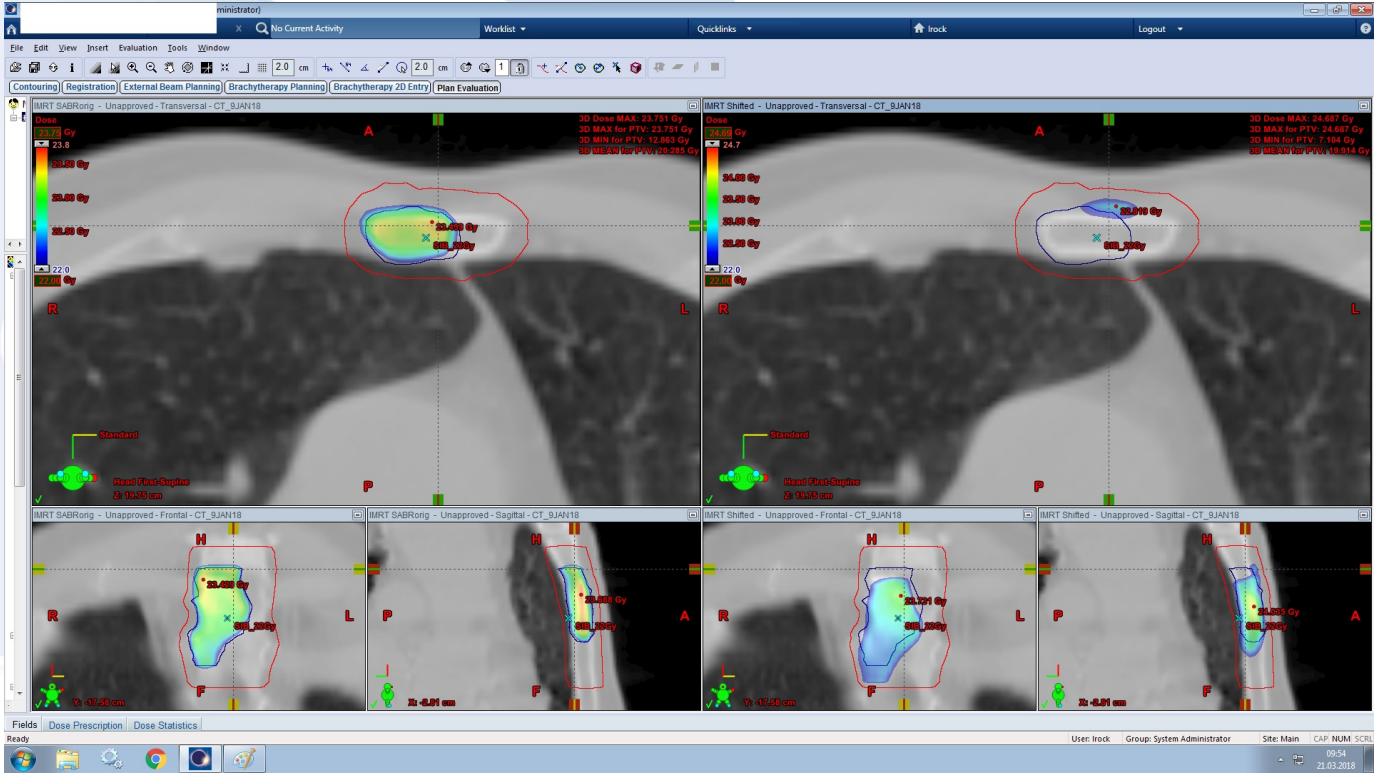
- Confirmed with kV image



Beacon Hospital

SABR Case Study

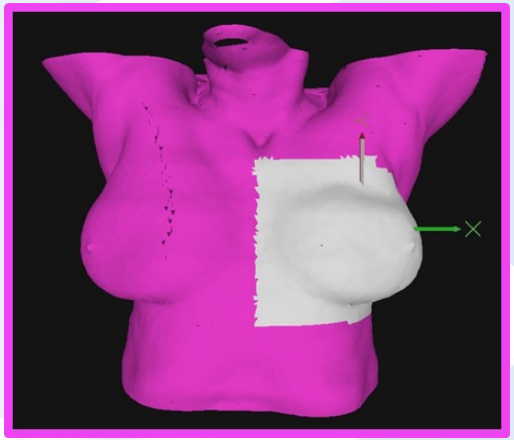
- Significant dosimetric effect if not detected

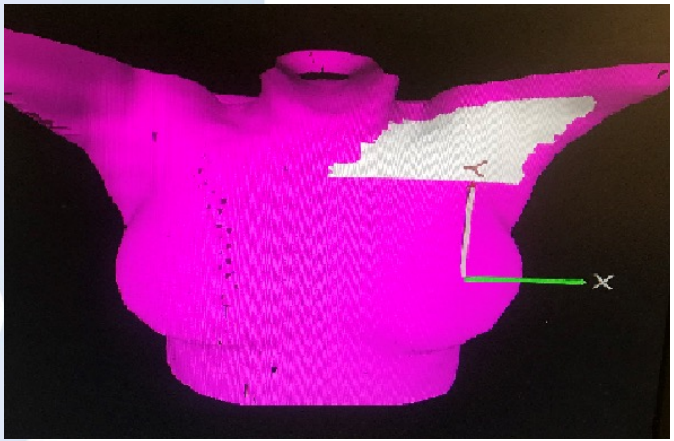


Beacon Hospital

SGRT for DIBH Breast

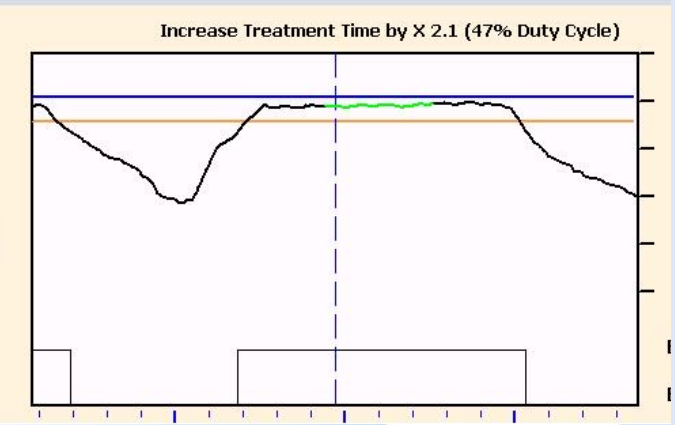
- Proven to reduce early cardiac side effects *[Zagar et al IJROBP 2017]*
- Free breathing contour for patient set-up (2 x CT scans required)
- Arm ROI used to aid set-up
- DIBH Surface contour for DIBH during imaging/treatment



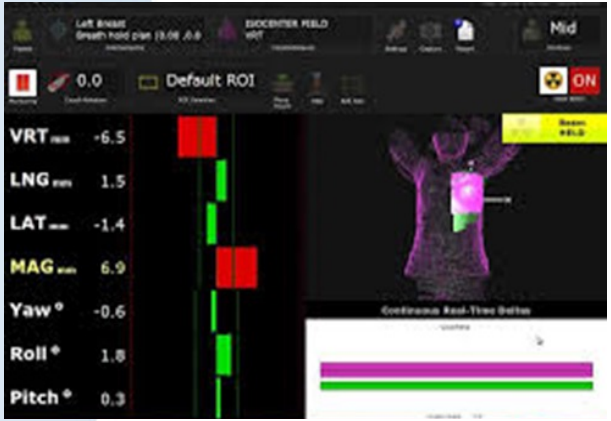


Comparison with Varian RPM for Breast DIBH

- Varian RPM for DIBH since 2008
- Well established workflow
- January 2019 – audit of first 10 patients, then one year later
- Tattooless also



Varian RPM 2D



AlignRT 3D

Beacon Hospital

Results – Magnitude of Shifts

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

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

Less pronounced but maintained for SGRT & 1 year

SGRT - more reliable for setup

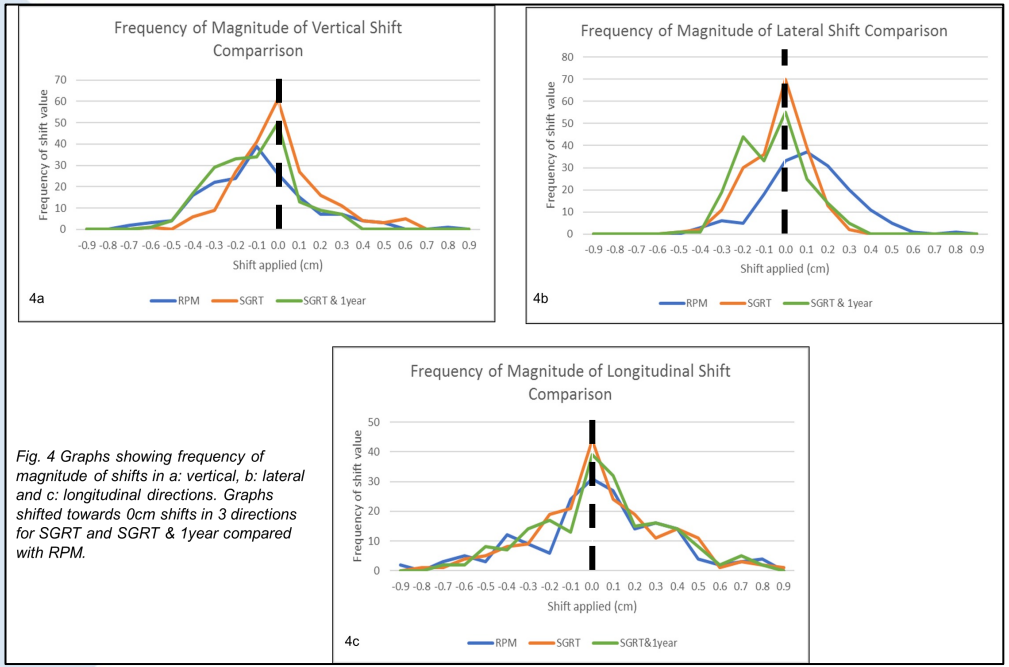


Fig. 4 Graphs showing frequency of magnitude of shifts in a: vertical, b: lateral and c: longitudinal directions. Graphs shifted towards 0cm shifts in 3 directions for SGRT and SGRT & 1year compared with RPM.

Results – Average Treatment Time

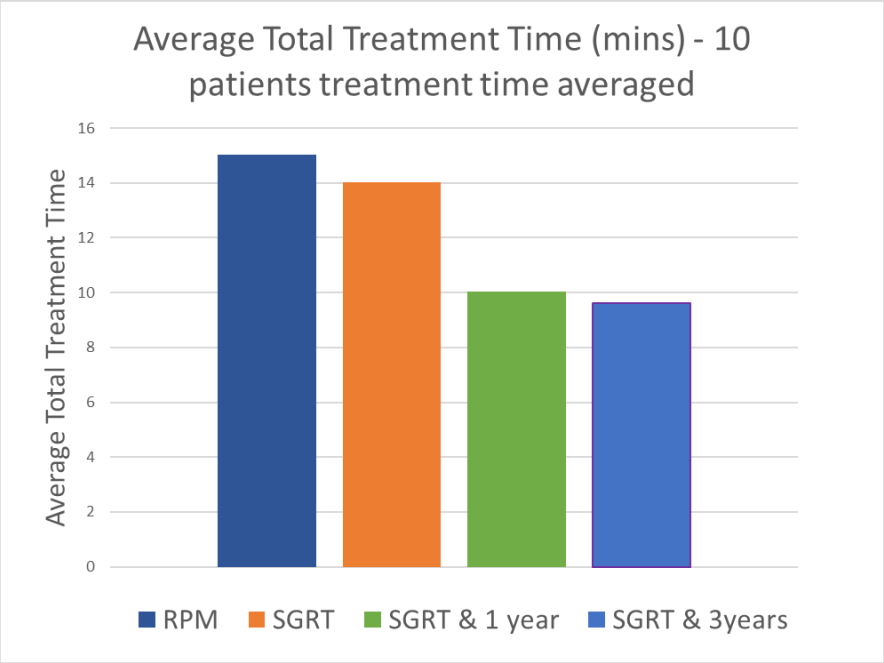


Fig. 5 Average total treatment time – reduced from 15 minutes with RPM to 10 minutes SGRT & 1 year

Treatment time reduced from

15 minutes per patient with RPM to

10 minutes per patient with SGRT

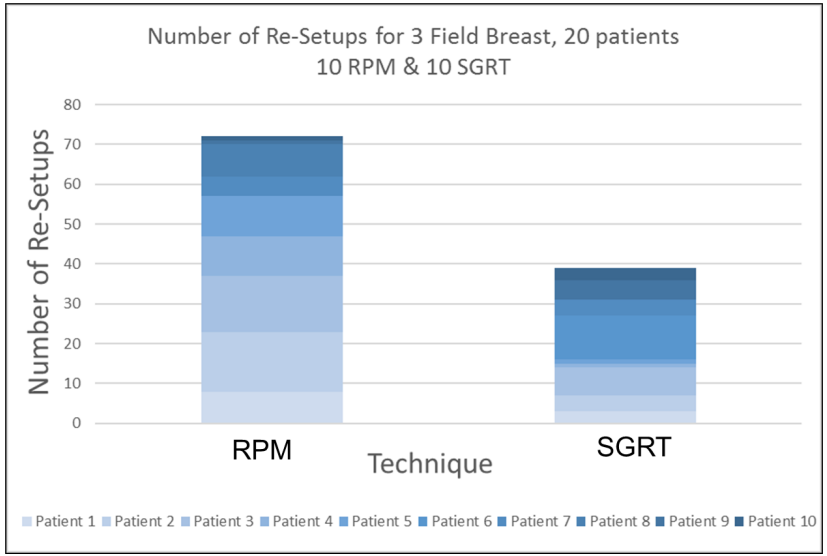
Results – Additional Setup Following Imaging

Unchanged for 2 field breasts

Graph shows a significant decrease in re-setups for 3 field treatments with SGRT.

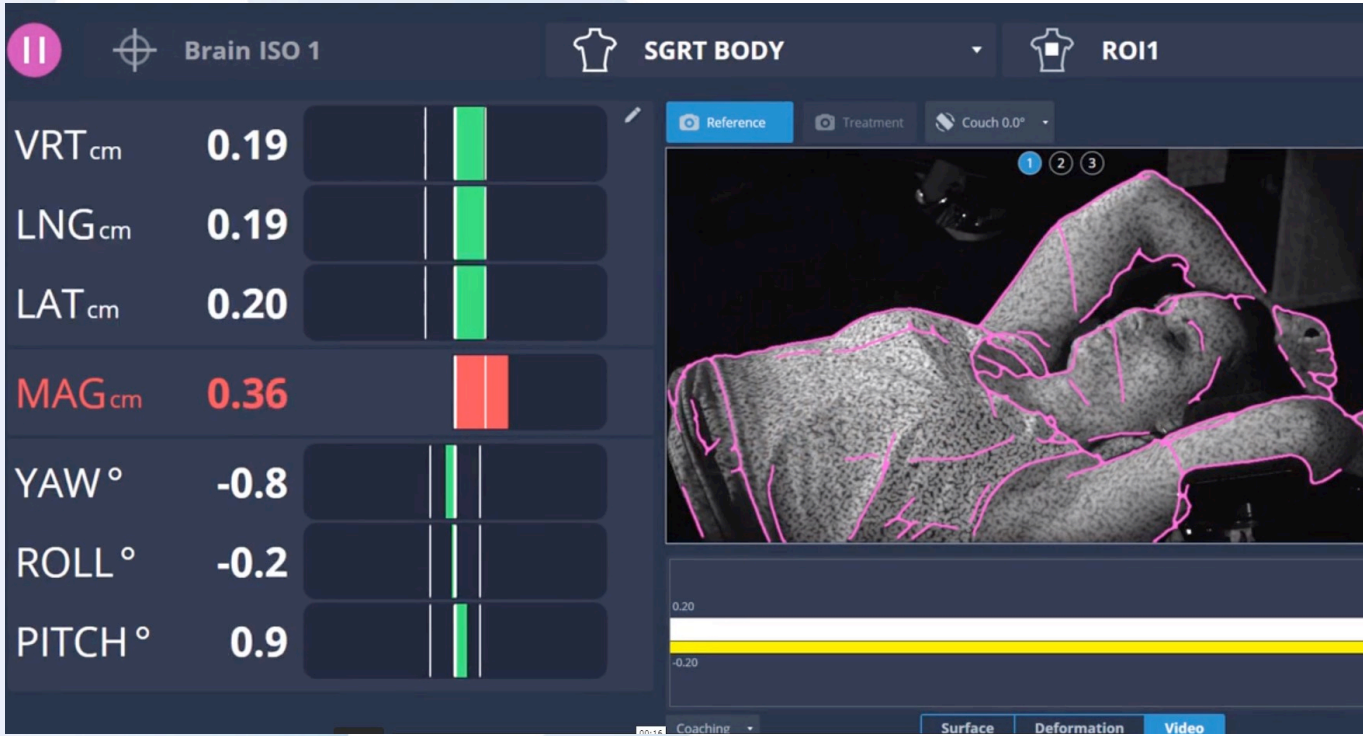
Use of the arm ROI in Align RT has yielded better supraclavicular setup

Intrafraction monitoring has not revealed patient motion during treatment



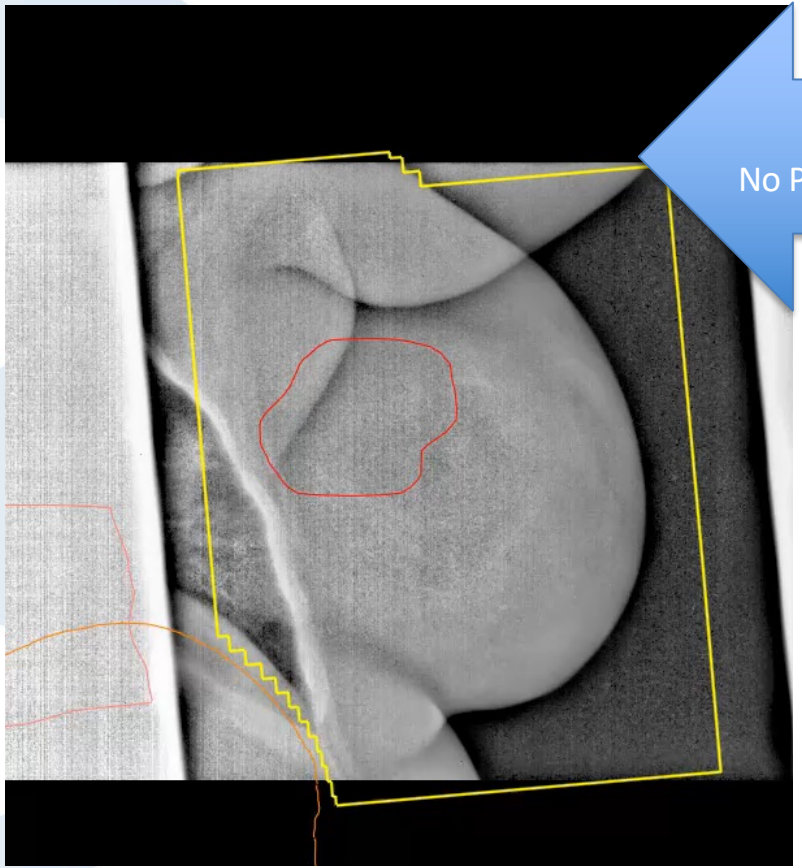
Beacon Hospital

Align RT Advance – Postural Video



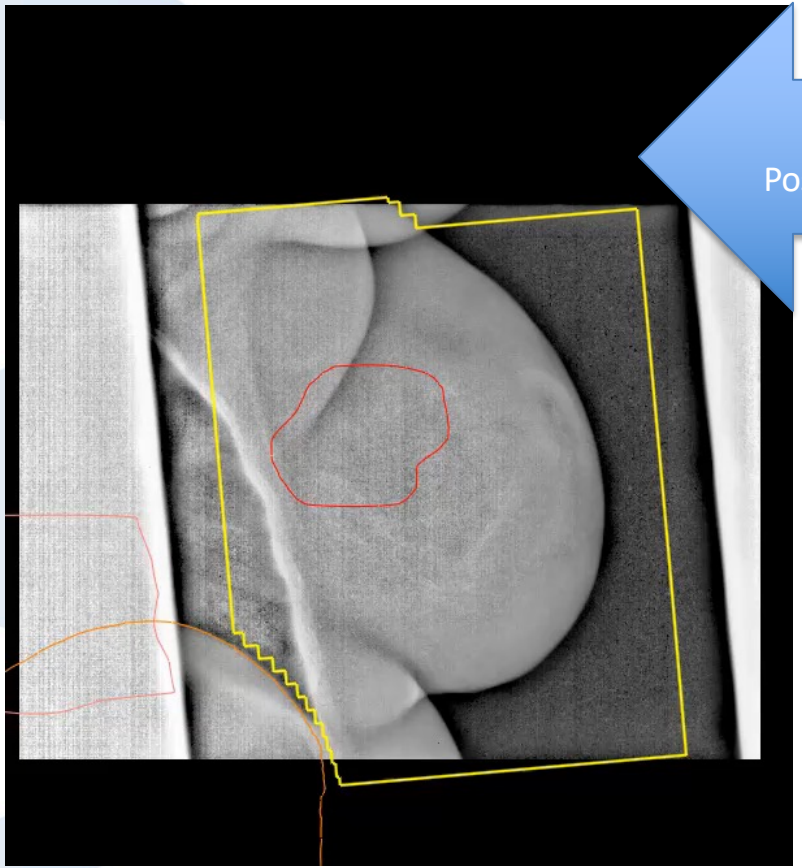
Beacon Hospital

Align RT Advance – Postural Video



Arm Position Day 1
No Postural Video to aid setup

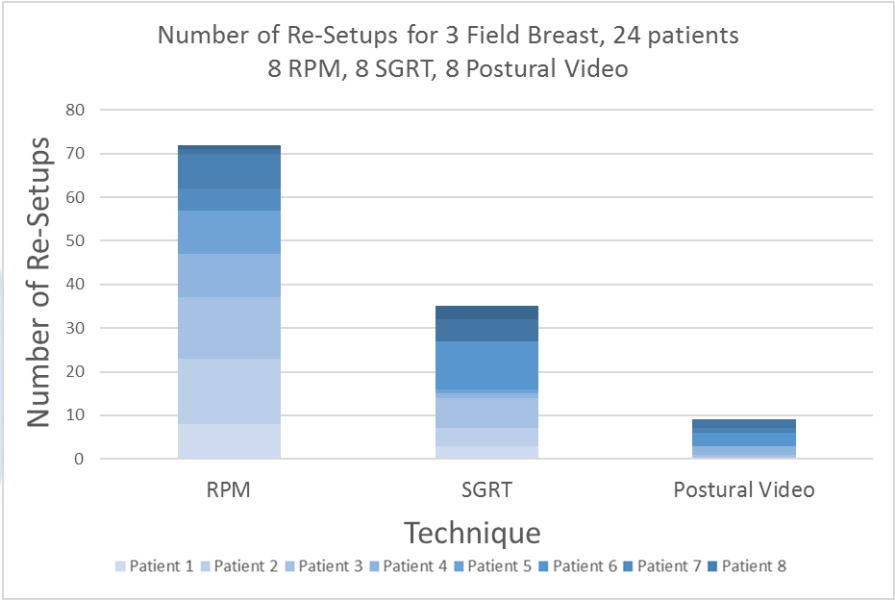
Align RT Advance – Postural Video



Arm Position Day 3
Postural Video to aid setup

Results – Supraclav Setups with Postural Video

Graph shows a significant decrease in re-setups for 3 field treatments with Postural Video

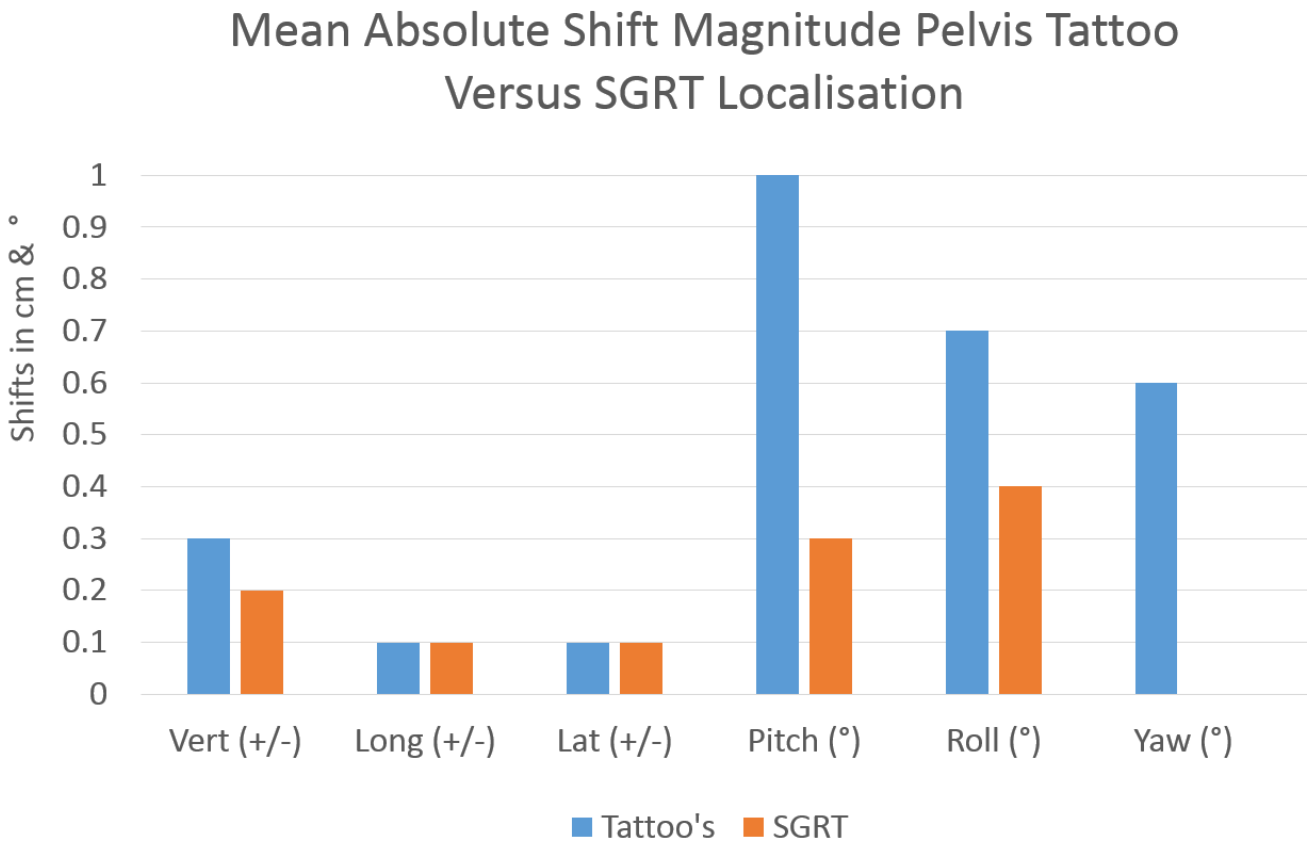


Beacon Hospital

Tattooless SGRT for Pelvis

- ROI Key: Take note of lateral topography, clothes/modesty towel strategically positioned, colostomy bag (empty +/- taped up)
- Excellent reproducibility - minimal OBI shifts
- Efficient localisation and verification time
- Reduction in manual handling reported by staff
- Improved patient experience

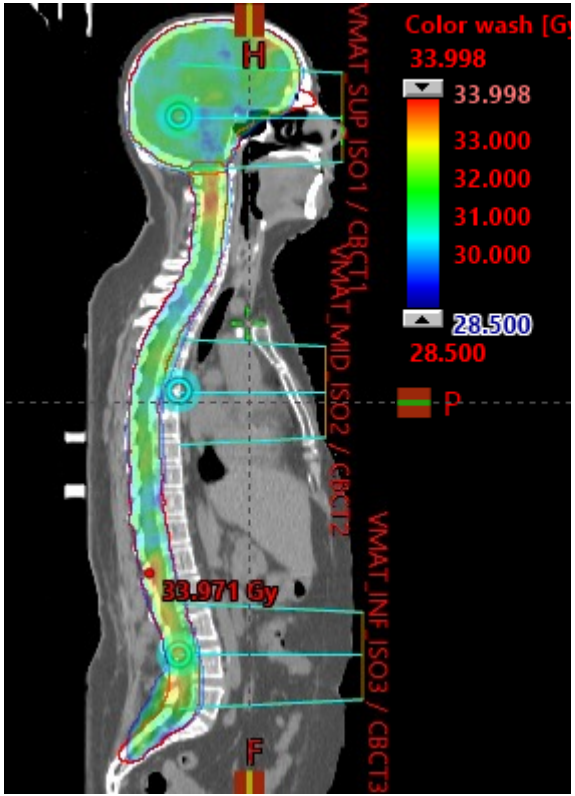
Tattooless SGRT for Pelvis



Beacon Hospital

Cranio-Spinal Irradiation - Case Study Nov 2022

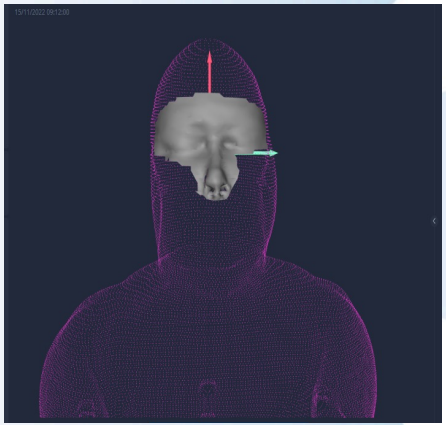
45yo female – Breast ca. June 2021
Secondary malignant neoplasm of brain and cerebral meninges
VMAT – 3 isocentres
30Gy in 10fr (7mm PTV)
Supine, H&N mask + knee lock
Imaging – extended CBCT, kVs
Required real time monitoring of patient position – ROIs



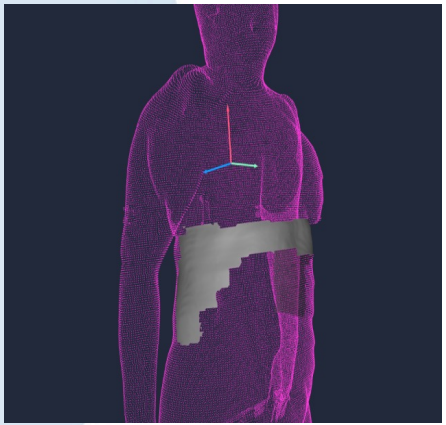
Beacon Hospital

Cranio-Spinal Irradiation - ROIs

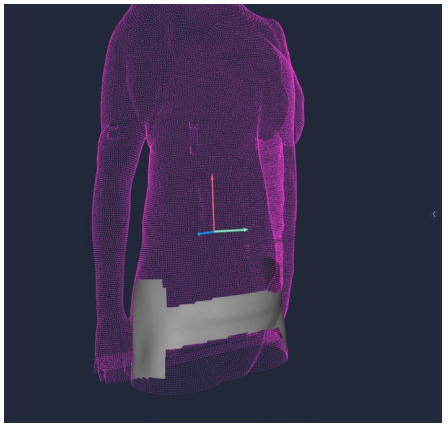
ROI 1
Cut out H&N mask



ROI 2
exclude abdomen

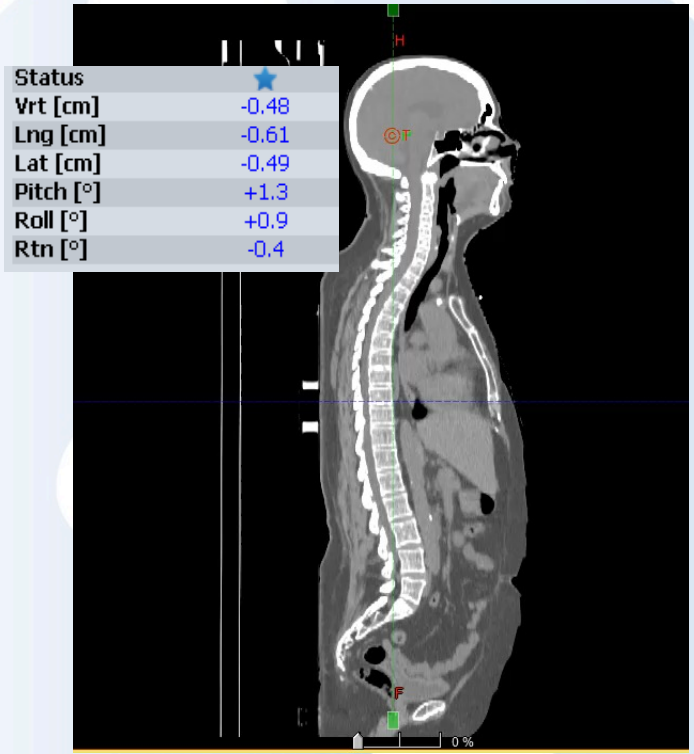


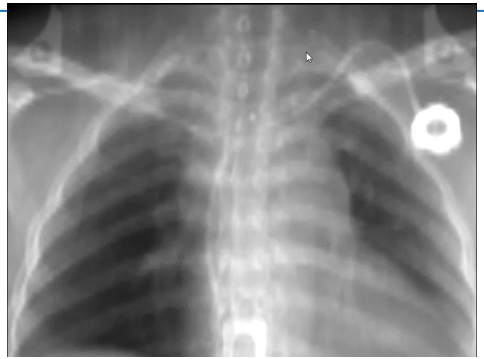
ROI 3
exclude abdomen

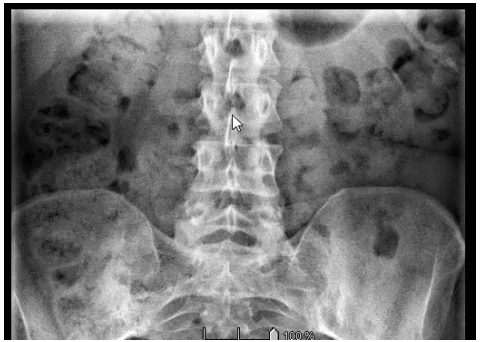


Align RT tolerance - Translations: 0.7cm
Rotations: 3°

Cranio-Spinal Irradiation – Image Verification

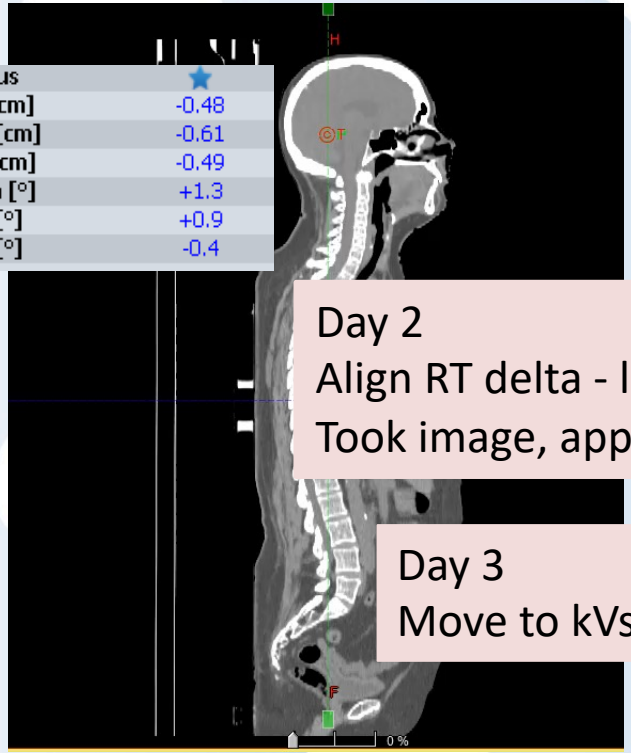


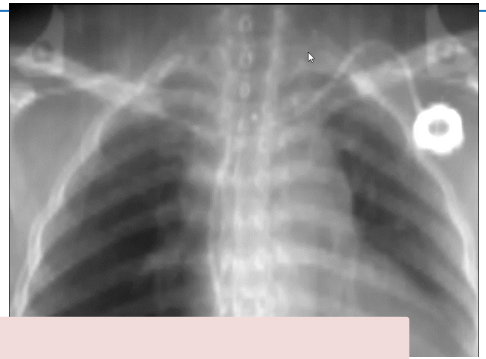


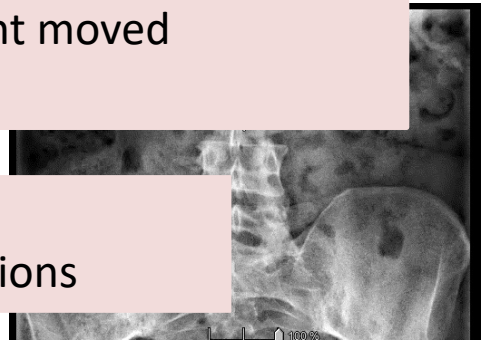


Beacon Hospital

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

Beacon Hospital

Conclusion

- SGRT has proven beneficial across all our Radiotherapy programme
- Straight forward workflow integration
- Complementary not alternative to x-ray imaging
- Faster, more accurate setup
- Real time monitoring – necessary for SRS & SABR
- Helps to improve the patient experience
- Improved staff welfare

Enhanced confidence in our Treatment Delivery

Acknowledgements

- Beacon Hospital Radiotherapy team

  - Darina Hickey (Senior Medical Physicist)

  - Marie Coffey (Clinical Specialist RT)

- luke.rock@beaconhospital.ie

Bedankt voor uw aandacht!

Beacon Hospital