

Trials and Tribulations of Image Registration in Brachytherapy

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Objectives

- Understand types of brachytherapy image registration use cases
- Recognize unique challenges of image registration for brachytherapy
- Appreciate the advantages/disadvantages of DIR in brachytherapy
- Review current status in the literature
- Discuss future directions and needs that must be met for clinical implementation

When is image registration performed in brachytherapy?

1. Contour propagation

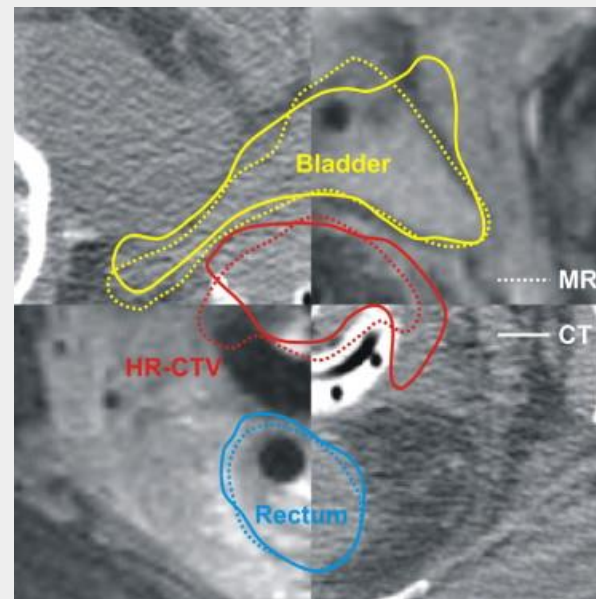
- **MRI – CT for cervix brachytherapy**
- MRI – CT for HDR prostate brachytherapy
- TRUS – CT for post-implant dosimetry in LDR prostate

2. Dose accumulation in same course

- Cervix brachytherapy + EBRT
- Prostate brachytherapy + EBRT

3. Dose accumulation to account for previous dose

- Brachytherapy + previous EBRT course
- Brachytherapy + previous brachytherapy



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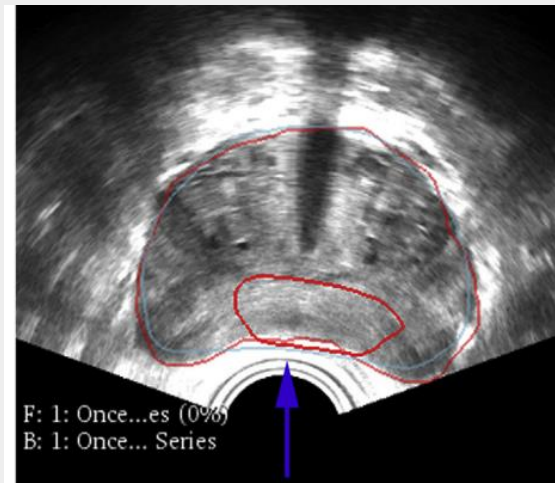
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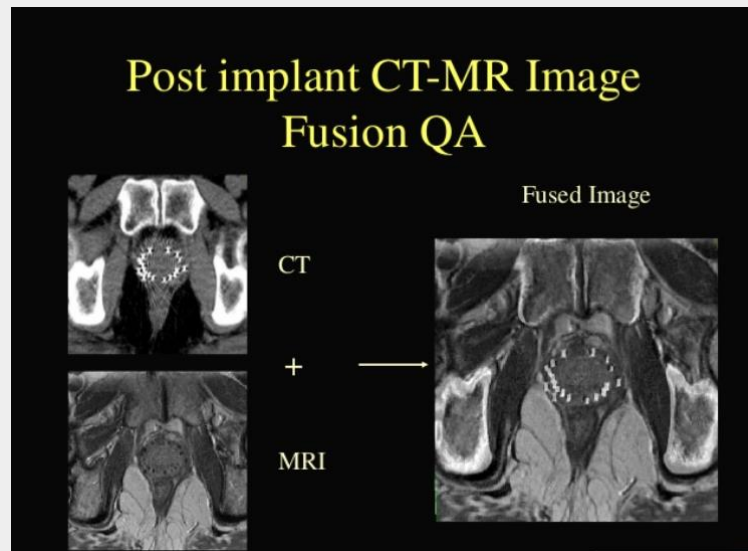
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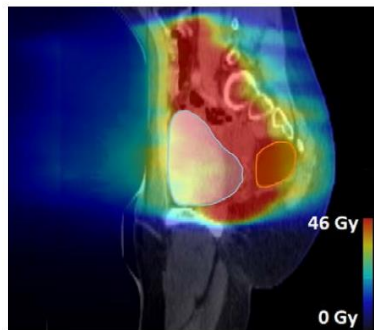
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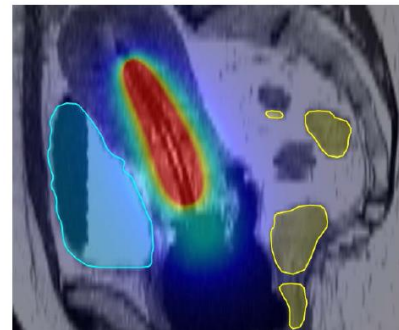
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External beam radiotherapy



Brachytherapy



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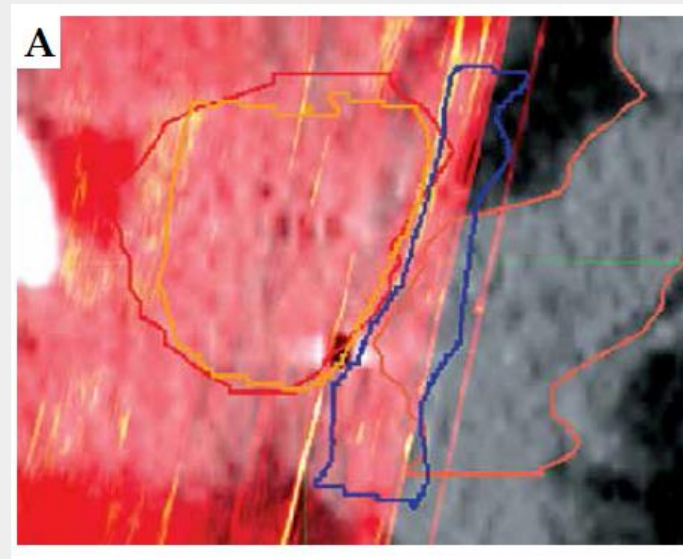
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Risks and challenges associated with image registration in brachytherapy

1. **Most use cases involve multi-modality images, e.g. CT-MRI, TRUS-MRI, etc.**
2. Presence of brachytherapy applicators in different images results in significant deformation of anatomy
3. Steep dose gradients associated with brachytherapy place strict demands on accuracy of image registration at voxel level
4. Time constraints in theatre require efficient solutions and QA methods

DIR not reliable?

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DIR not reliable?

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No DIR in BT TPS

Use Case – DIR for cervical HDR + EBRT dose accumulation

FULL TEXT ARTICLE

Deformable image registration for cervical cancer brachytherapy dose accumulation: Organ at risk dose–volume histogram parameter reproducibility and anatomic position stability  

E. Flower, V. Do, J. Sykes, C. Dempsey, L. Holloway, K. Summerhayes and D.I. Thwaites

Brachytherapy, 2017-03-01, Volume 16, Issue 2, Pages 387-392, Copyright © 2017

Abstract



Brachytherapy
Volume 16, Issue 2

- 39 patients, BT CT -> EBRT CT deformable image registration
- Combined BT + EBRT EQD2 dose assessed for OAR doses

Use Case – DIR for cervical HDR + EBRT dose accumulation

DIR_{image}, the entire image set was deformed using a free form deformable image registration algorithm with a normalised intensity similarity metric.

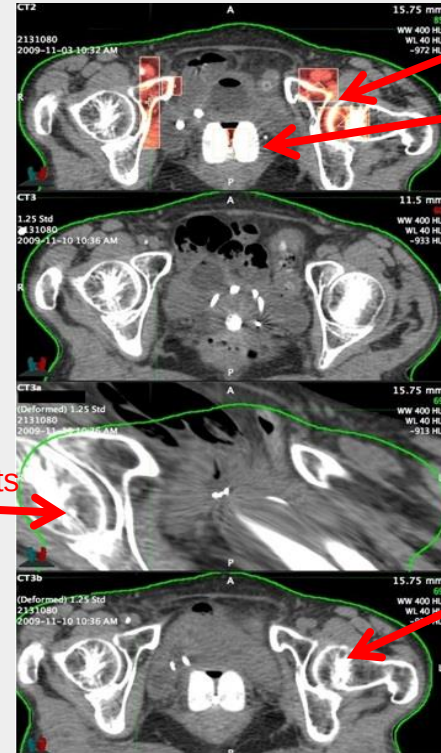
DIR_{cbd}, the bladder contour was given a higher bias for the free form DIR

DIR_{masked}, masked the bladder contour to a value of 1000 HU and then the entire image was deformed using free form DIR

Sometimes DIR algorithm produces visually unacceptable results

Locally locked adjustments based on bones and ovoids

Visually acceptable result achieved with RegRefine



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Use Case – DIR for cervical HDR + EBRT dose accumulation

		DIR_{image}	DIR_{cbd}	DIR_{masked}
Average dose accumulation consistency	Bladder D2cc	2.2	1.4	0.7
	Bladder D0.1cc	3.4	1.5	1.5

Additional weightings in algorithm leads to more reproducible results. **NB: it is critical to ensure there are contour weightings in a DIR algorithm for Gynae brachy DIR**

	DIR_{masked}
Percent difference in bladder D2cc (accumulated over three fractions) with and without DIR	-2.9
Percent difference in bladder D0.1cc (accumulated over three fractions)	-4.2
Percent difference in rectum D2cc (accumulated over three fractions) with and without DIR	-2.3
Percent difference in rectum D0.1cc (accumulated over three fractions)	-2.6

Use Case – DIR for prostate HDR + EBRT dose accumulation

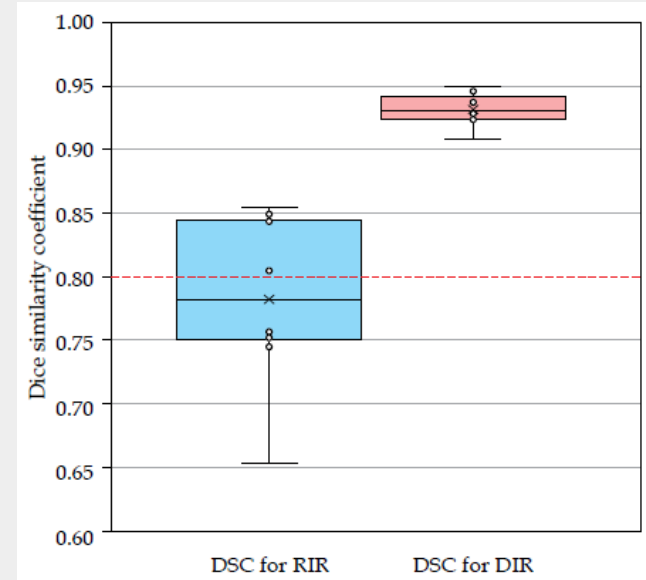
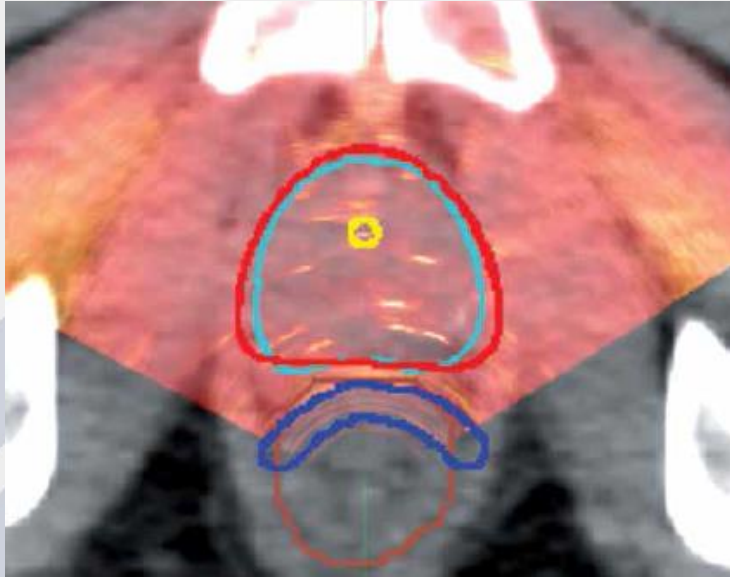
Use of deformable image registration techniques to estimate dose to organs at risk following prostate external beam radiation therapy and high-dose-rate brachytherapy

Marie Vozzo, BSc/BEng (hons), MSc¹, Joel Poder, MSc, PhD^{2,3}, Johnson Yuen, MSc^{2,4,5}, Joseph Bucci, MBBS FRACP FRANZCR², Annette Haworth, BSc (hons), MSc, PhD¹

¹School of Physics, University of Sydney, Sydney, Australia. ²St George Cancer Care Centre, Kogarah, Australia. ³Centre for Medical Radiation Physics, University of Wollongong, Wollongong, Australia. ⁴South Western Clinical School, University of New South Wales, Sydney, Australia. ⁵Ingham Institute for Applied Medical Research, Sydney, Australia

- 10 patients, BT TRUS -> EBRT CT rigid and deformable image registration (structure guided)
- Combined BT + EBRT EQD2 dose assessed for rectum

Use Case – DIR for prostate HDR + EBRT dose accumulation



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Use Case – DIR for prostate HDR + EBRT dose accumulation

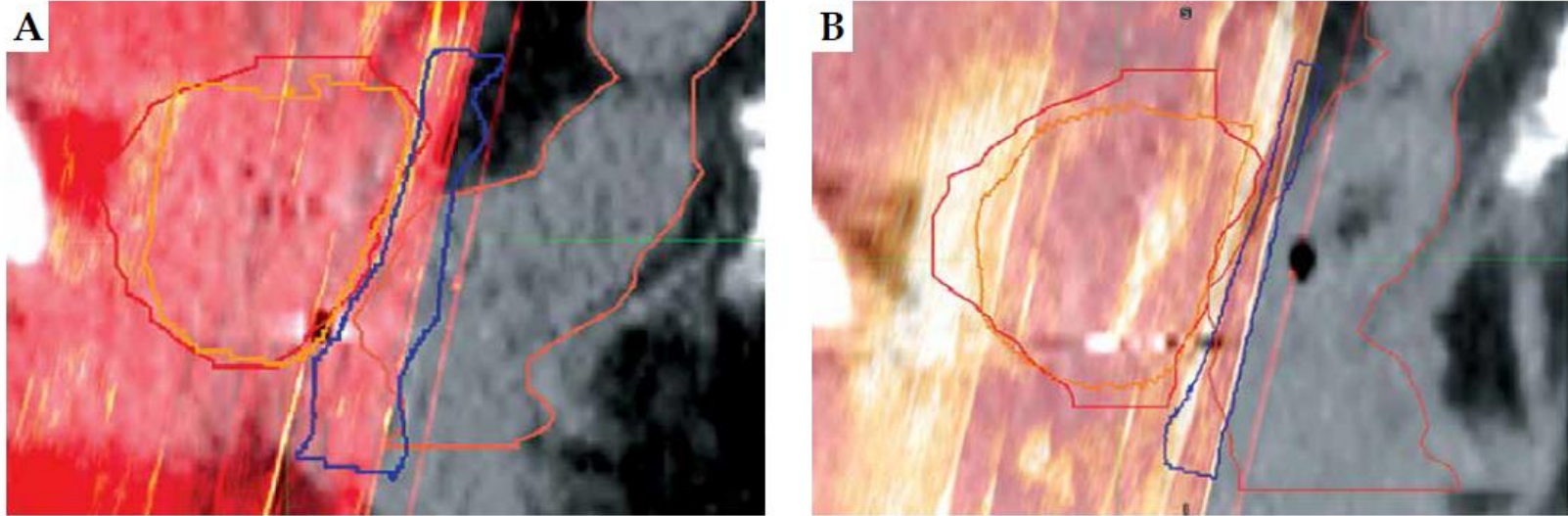
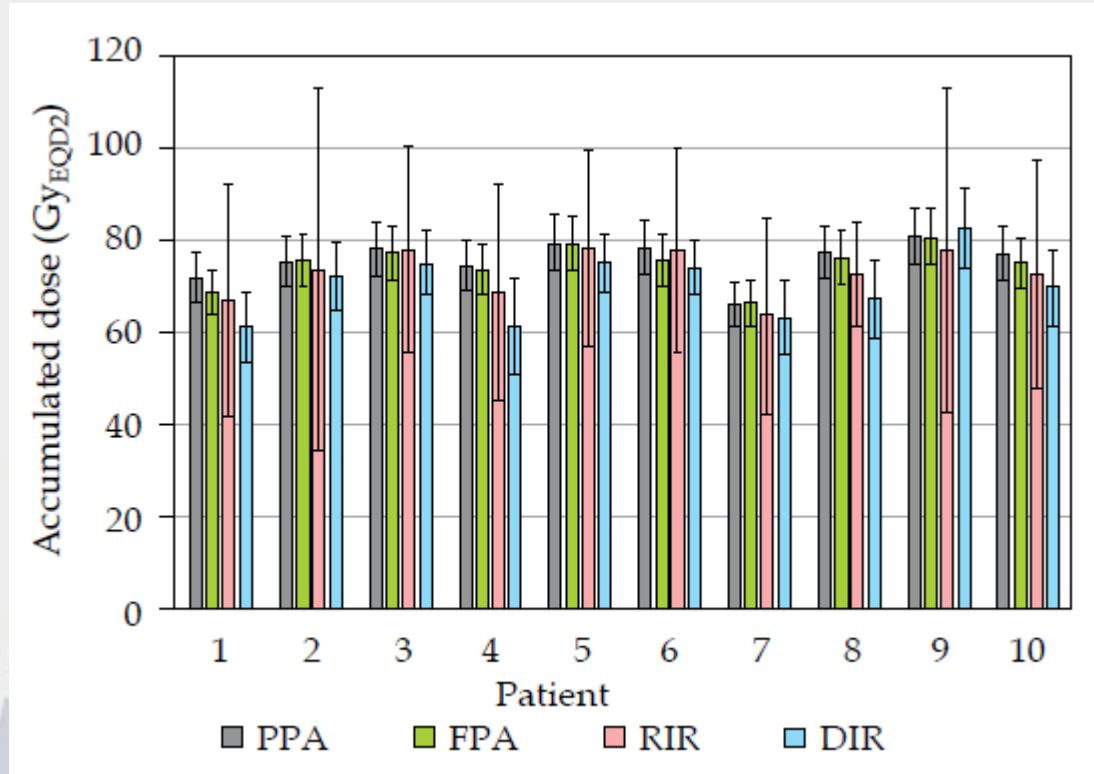


Fig. 2. A) Sagittal section, example of successful rigid image registration method (RIR). B) Sagittal section, example of unsuccessful RIR. Contours: orange – TRUS prostate, blue – TRUS rectum, red – CT prostate, brown – CT rectum

Use Case – DIR for prostate HDR + EBRT dose accumulation



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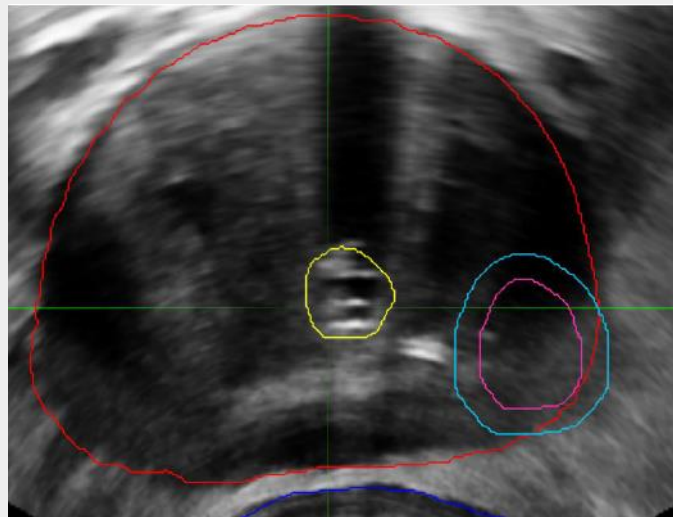


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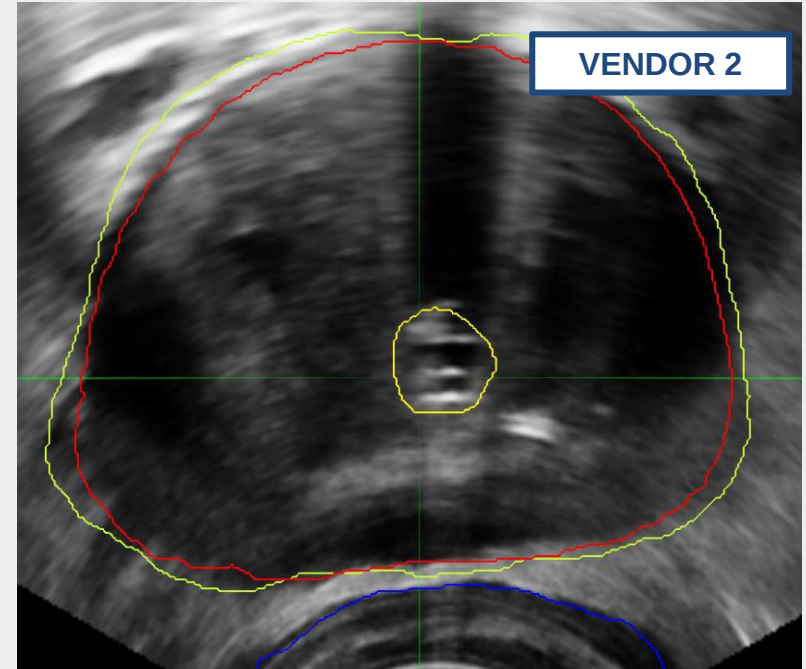
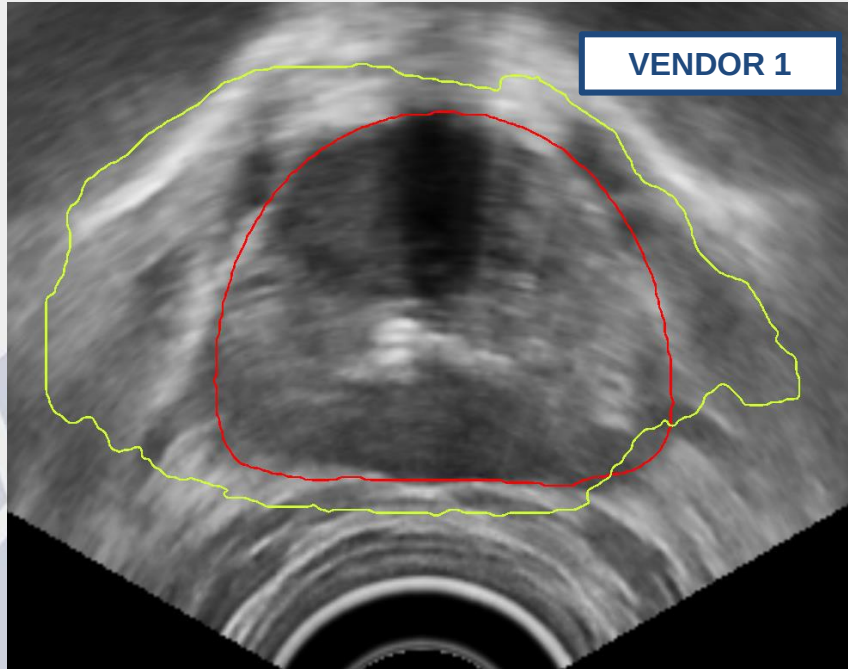
Use Case – DIR for intra-prostatic lesion boost in HDR prostate BT

- 10 patients prev. treated at STGCC with HDR prostate BT
- Retrospectively register diagnostic mpMRI & PET PSMA to BT planning TRUS image
- Compare RIR and DIR

Courtesy of Sam Radvan, USyd



Use Case – DIR for intra-prostatic lesion boost in HDR prostate BT



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Use Case – DIR for intra-prostatic lesion boost in HDR prostate BT

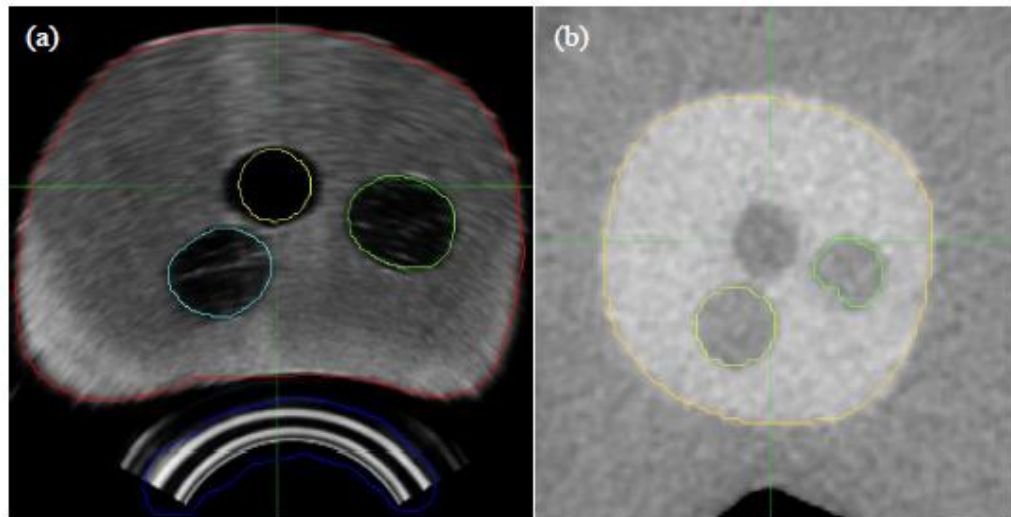
JACOBIAN DETERMINANT

	VENDOR 1						VENDOR 2					
	PET/CT			MRI			PET/CT			MRI		
Pt.	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
1	-5.65	0.72	7.11	-3.61	0.96	7.03	0.45	0.83	1.65	0.00	0.63	1.36
2	-8.37	1.12	10.24	-5.93	1.15	7.76	0.71	0.94	1.41	0.00	0.58	1.25
3	-4.22	0.44	6.93	-2.90	1.17	6.14	1.08	1.48	1.82	0.00	1.00	1.54
4	-17.64	0.05	5.13	-2.36	1.16	8.2	0.96	1.39	2.09	0.00	0.96	1.68
5	-4.22	1.02	14.48	-3.44	1.00	7.45	0.89	1.25	1.89	0.00	0.86	1.98
6	-9.18	0.30	7.82	-4.52	0.78	5.68	0.96	1.44	2.14	0.00	0.81	1.29
7	-5.33	0.21	10.59	-3.72	1.13	9.31	0.72	1.05	1.43	0.00	1.01	1.64
8	-5.83	0.57	11.44	-2.68	0.76	4.77	1.17	1.59	2.10	0.00	0.73	1.54

Use Case – DIR for intra-prostatic lesion boost in HDR prostate BT

Pt.	PET/CT			MRI		
	DSC	MDA (mm)	HD (mm)	DSC	MDA (mm)	HD (mm)
1	0.94	0.8	4.2	0.95	0.6	3.1
2	0.92	0.8	3.9	0.93	0.7	2.8
3	0.89	1.0	4.5	0.91	0.9	3.6
4	0.91	0.9	4.0	0.93	0.7	3.3
5	0.92	0.8	3.7	0.94	0.7	4.3
6	0.92	0.8	3.7	0.93	0.7	3.0
7	0.93	0.7	2.9	0.95	0.6	3.2
8	0.91	0.8	4.2	0.92	0.7	3.0
Avg. ± 1 sd.	0.92 ± 0.01	0.8 ± 0.1	3.9 ± 0.5	0.93 ± 0.01	0.7 ± 0.1	3.3 ± 0.4

Use Case – DIR for intra-prostatic lesion boost in HDR prostate BT



Prostate Contour

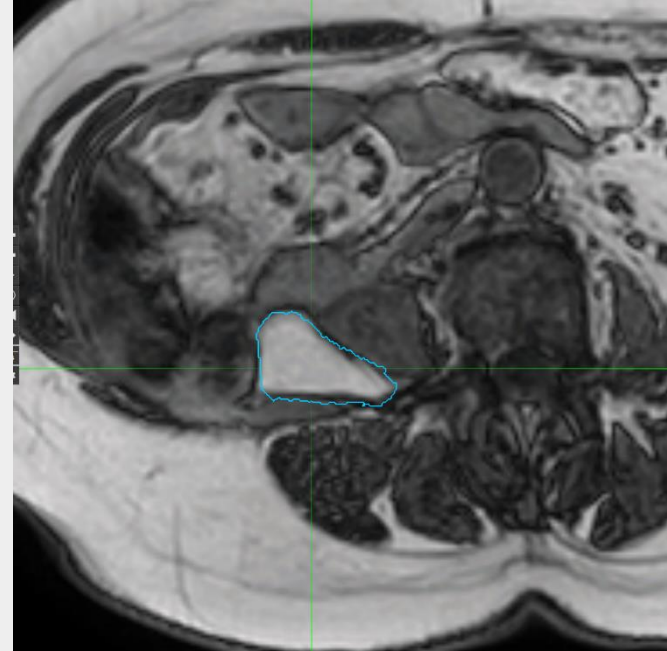
DSC	MDA (mm)	HD (mm)
0.95	0.6	2.6

DIL Contours

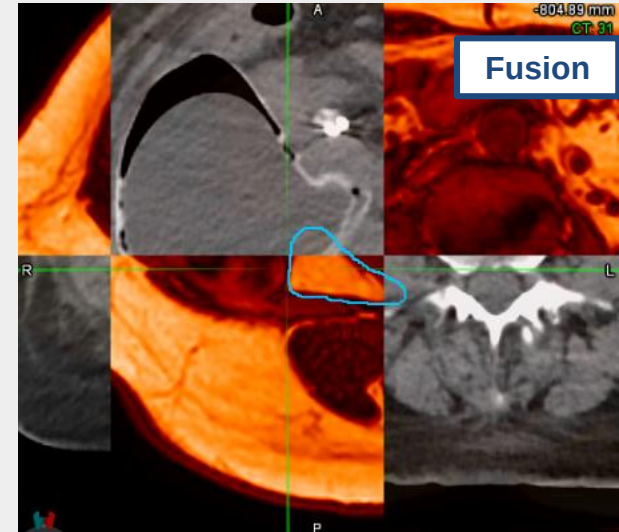
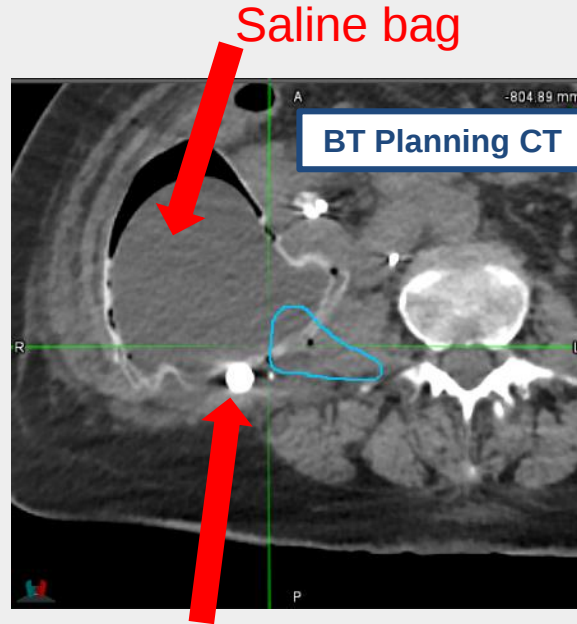
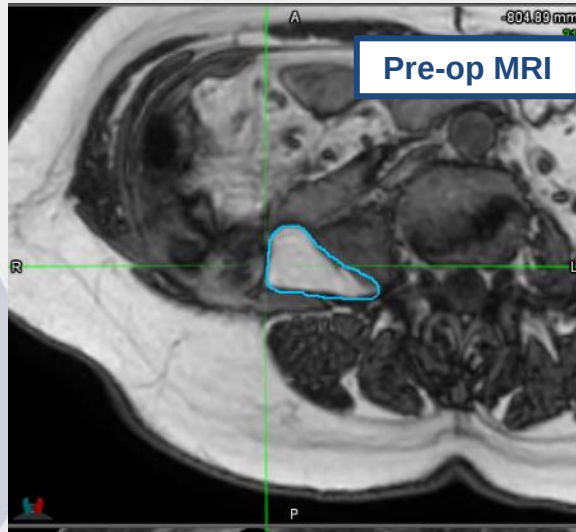
DSC	MDA (mm)	HD (mm)
0.85 ± 0.05	0.4 ± 0.1	2.0 ± 0.2

Use Case – Retroperitoneal BT + EBRT

- Retroperitoneal sarcoma
- Peritonectomy followed by interstitial brachytherapy to tumour bed
- 10 Gy / 1 Fx
- Sub-optimal coverage due to limitations in applicator placement necessitated EBRT treatment to untreated GTV.



Use Case – Retroperitoneal BT + EBRT



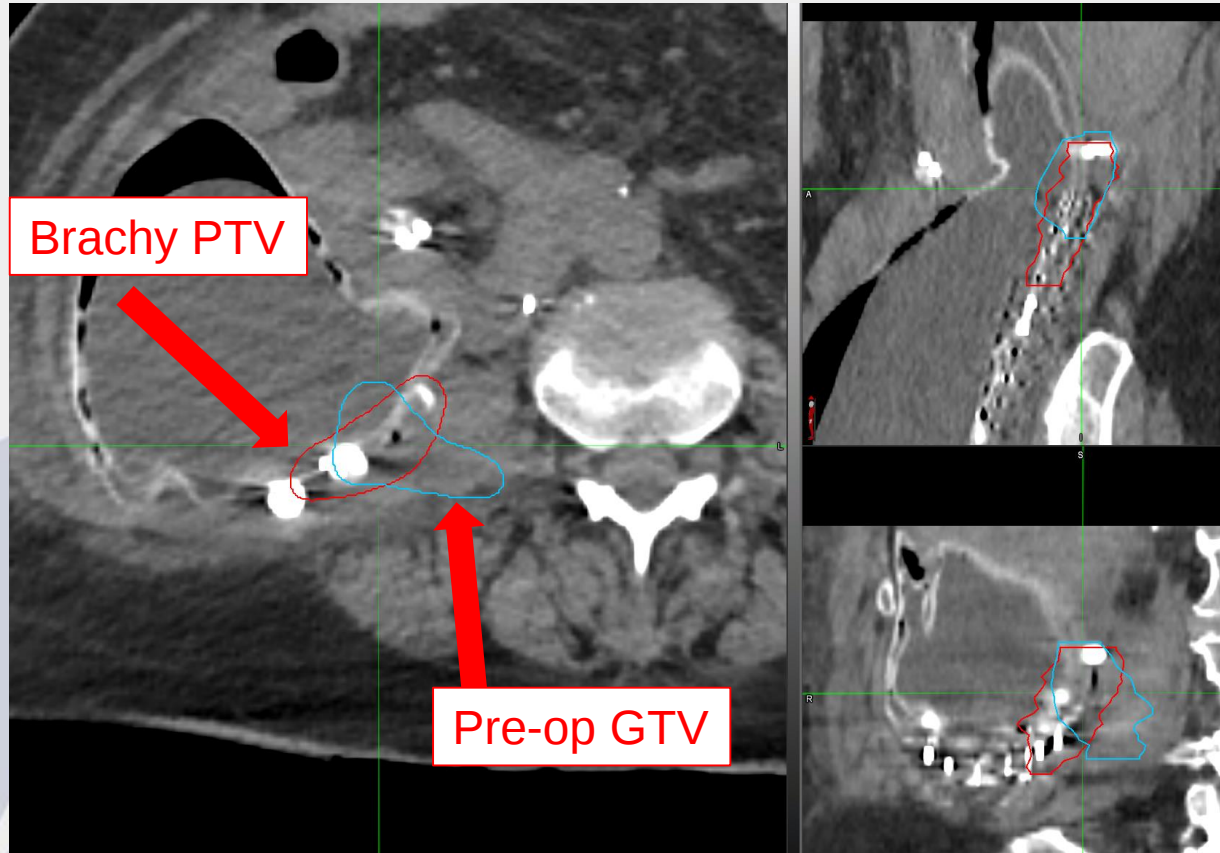
Brachy catheter
button

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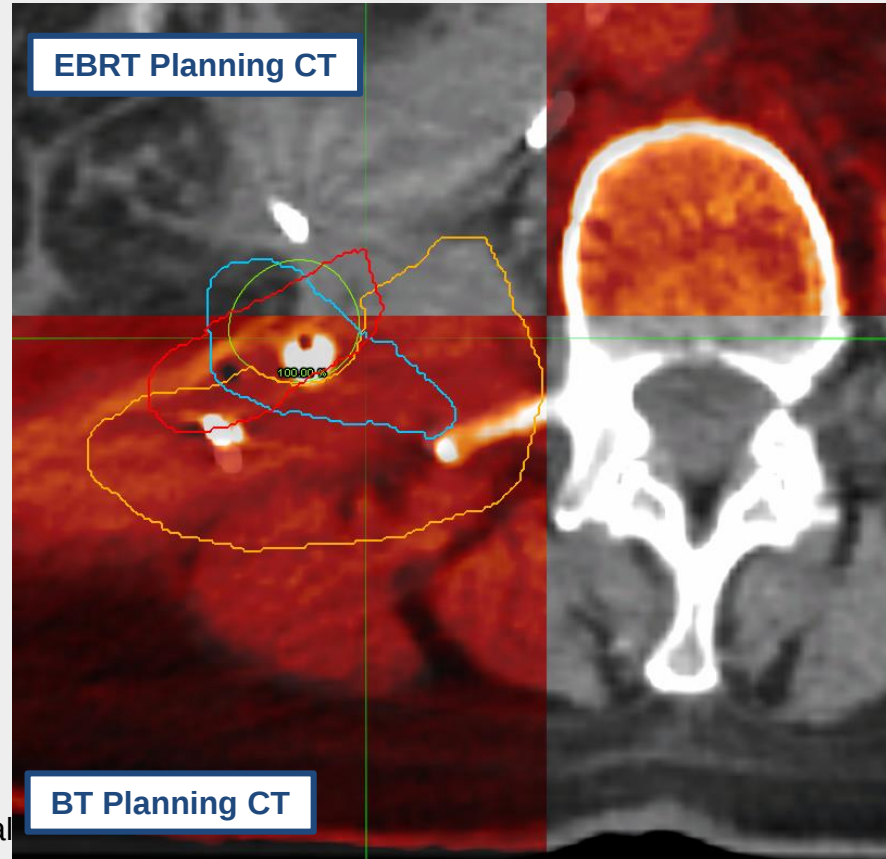
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Use Case – Retroperitoneal BT + EBRT



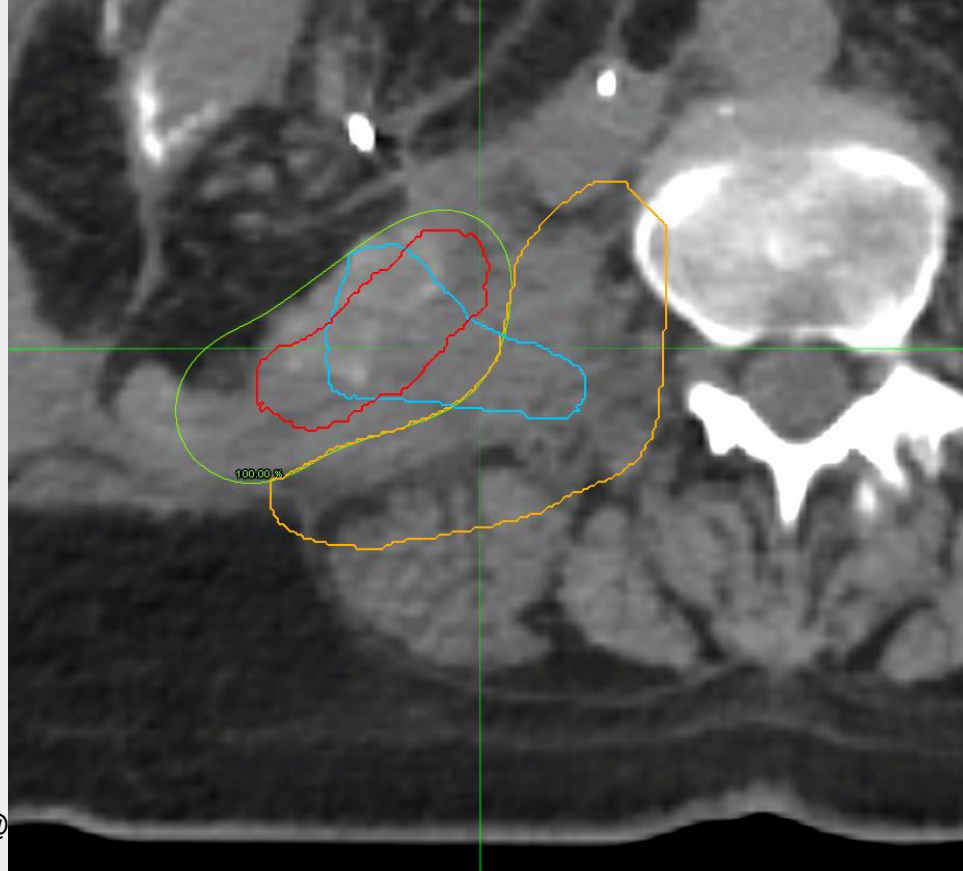
Use Case – Retroperitoneal BT + EBRT

- Blue = MRI GTV
- Red = BT PTV
- Green = BT 100% isodose
- Orange = EBRT PTV

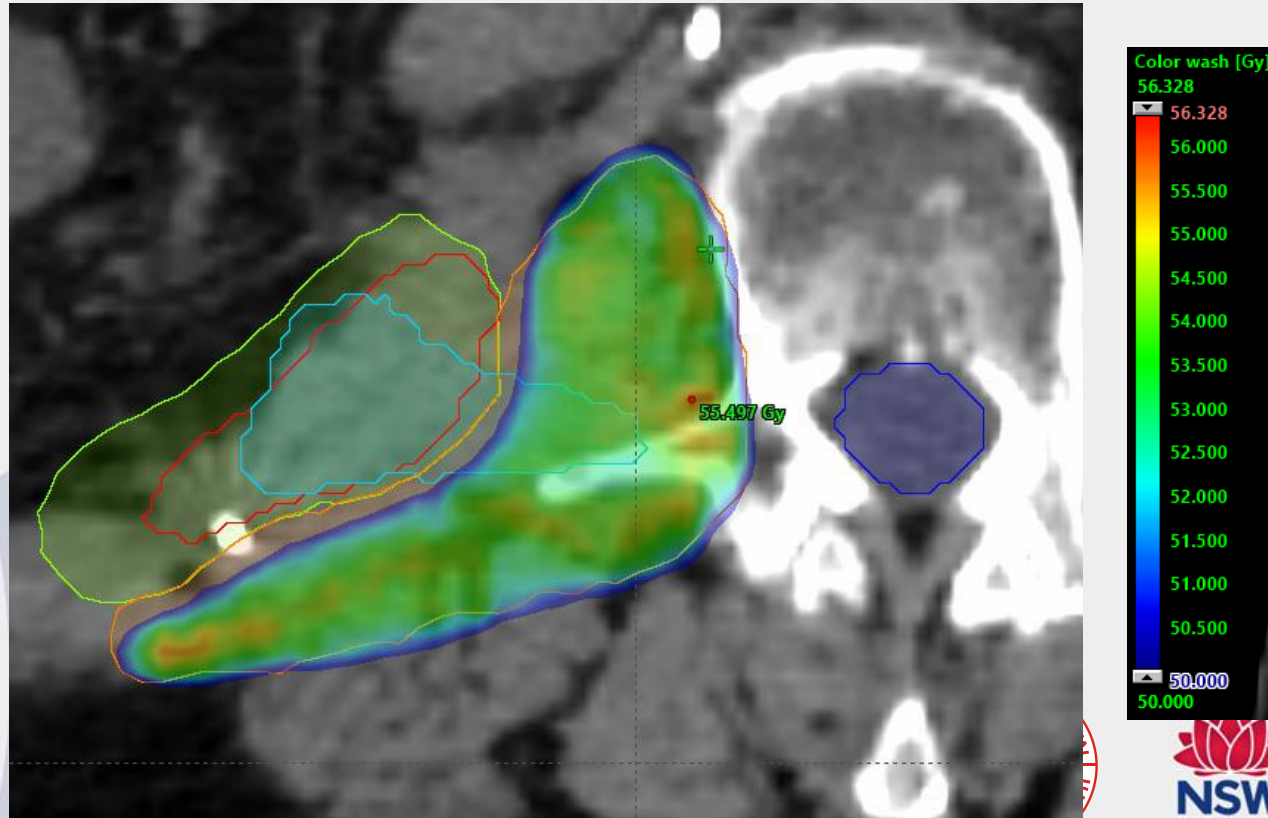


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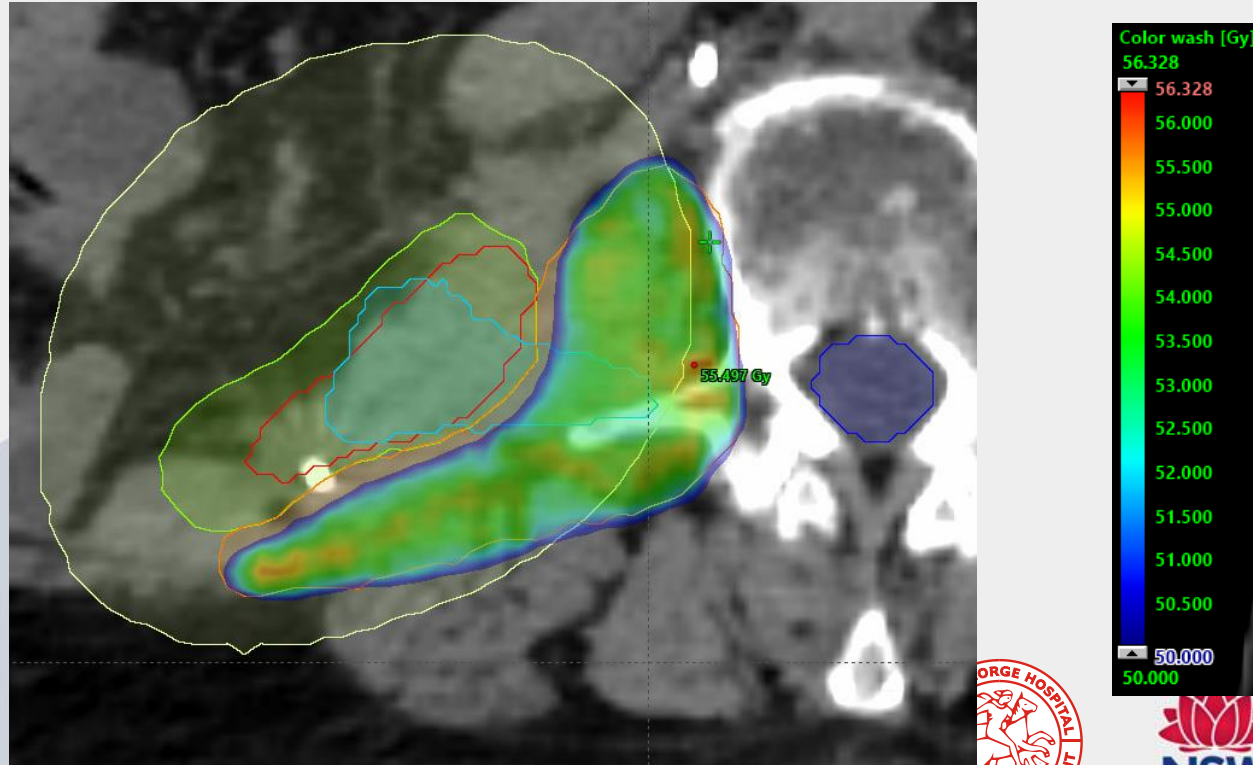


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Use Case – Retroperitoneal BT + EBRT



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Future Directions

- DIR for BT is still largely confined to research space
- Improvement in multi-modality DIR algorithms required
- Tools to overcome presence of BT applicators in images are required
- DIR functionality in BTPS is very limited, vendors should implement DIR within BTPS
- Image registration QA tools in BTPS are very limited, vendors should implement these tools within BTPS

Thanks for your attention!

Questions?

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The ACPSEM Medical Image Registration Special Interest Group (MIRSIG) Online Webinars

Questions and Answers from the September 2021 Webinar Chaired by Johnson Yuen (Talk 1 by Joel Poder on Brachytherapy Image Registration)

Question 1: How is training managed?

Answers: Training is managed by having a core team of 'expert' users who are well trained and routinely rostered onto image registration tasks. This core team is then responsible for training other staff in these tasks.