Using iDose to optimise image quality in radiotherapy planning CT scans

Adam Frankland, Radiotherapy Physicist
The Royal Wolverhampton NHS Trust
Email: adam.frankland@nhs.net

Working in partnership
The Royal Wolverhampton NHS Trust
Walsall Healthcare NHS Trust

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Contents

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iDose

- iDose is an iterative reconstruction algorithm on Philips CT scanners
- Removes noise while preserving edges in the image
- iDose level 1-7 – where 7 has the most aggressive noise removal

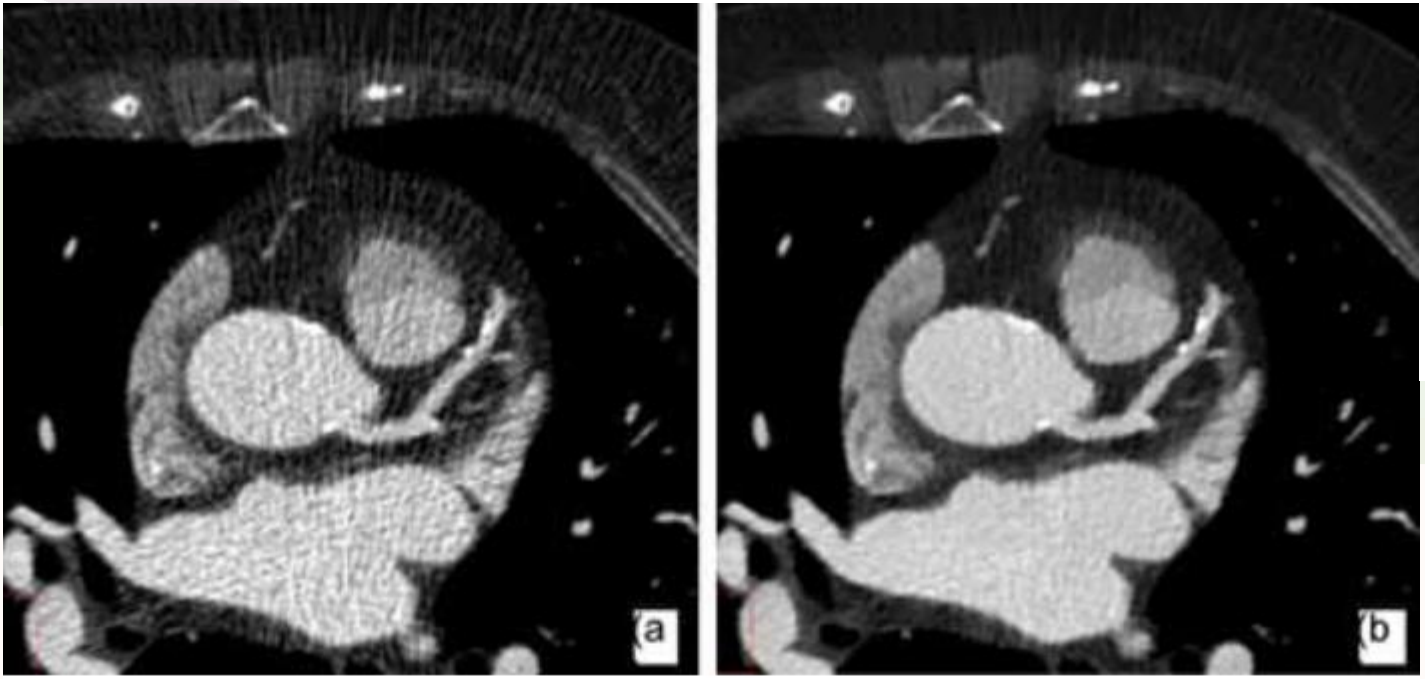

Figure 12: 0.25 mSv Cardiac CTA, 80 kVp, 80 mAs, 0.25 mSv, Step & Shoot Cardiac (a) FBP (b) iDose[4]

iDose Level	Noise Removed From Images (%)
1	10.6
2	16.3
3	22.5
4	29.3
5	36.8
6	45.2
7	55.3

Table 1: Theoretical noise reduction compared to a corresponding FBP reconstruction. From Philips.

iDose white paper

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Motivation

- RWT radiotherapy department has 2 Philips Big Bore CT scanners
- Every patient coming for treatment will have a planning CT
- IR(ME)R guidance 2024 update - **Regulation 12(3)(d):**
- *As for regulation 12(3)(d), the requirement to adhere to <u>dose reference levels</u>, where they are established by the employer, <u>relates to typical planning</u> or verification exposures for radiotherapeutic practice. These should not be applied to individual patient procedures.*

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Motivation

- Want to keep planning scan doses as low as possible while still having clinically useful images
- With iDose, can reduce the tube current and preserve the same image quality compared to FBP
- RWT planning CT protocols all currently use iDose level 3 reconstruction
- Project question: can a higher iDose level be used to maintain image quality and reduce patient dose by lowering the mAs?

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iDose and DRIs

- Philips user guide has a table showing iDose level and mAs values that give *equivalent* image quality
- E.g. when going from level 3 to level 4, can reduce mAs by ~16% and get the same IQ
- Planning scans are helical scans with a surview
- Can adjust mAs by changing the DoseRight Index (DRI)
- Changing DRI by 1 changes the mAs by ~10% across the scan length

	iDose^4 Level and Preferred mAs							
Original mAs	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**IQ Improvement**
20	16	14	12					
25	20	18	15	12				
30	24	21	18	15	12			
35	28	25	21	18	14			
40	32	28	24	20	16	12		
45	36	32	27	23	18	14		
50	40	35	30	25	20	15	10	
75	60	53	45	38	30	23	15	
100	80	70	60	50	40	30	20	
125	100	88	75	63	50	38	25	
150	120	105	90	75	60	45	30	
175	140	123	105	88	70	53	35	Original mAs
200	160	140	120	100	80	60	40	+
225	180	158	135	113	90	68	45	iDose^4 Level (1-7)

Things to check when changing CT protocol

- HU – CT-density table
- Image quality
- Dose calculation
- Autocontouring

- Catphan and CIRS measurements
- Catphan/CIRS/RANDO
- Anonymised patients recalculated
- Contour volumes

JOURNAL ARTICLE

Can CT scan protocols used for radiotherapy treatment planning be adjusted to optimize image quality and patient dose? A systematic review

Anne T Davis, BSc, MIPEM, Antony L Palmer, PhD, FIPEM, Andrew Nisbet, PhD, MSc

British Journal of Radiology, Volume 90, Issue 1076, 1 August 2017, 20160406,
https://doi.org/10.1259/bjr.20160406
Published: 23 May 2017 **Article history** ▾

There is limited published work on CT scan protocol optimization in radiotherapy. Publications suggest that HU tolerances of ±20 HU for soft tissue and of ±50 HU for the lung and bone would restrict dose changes in the treatment plan to <1%. Literature related to the use of CT images in

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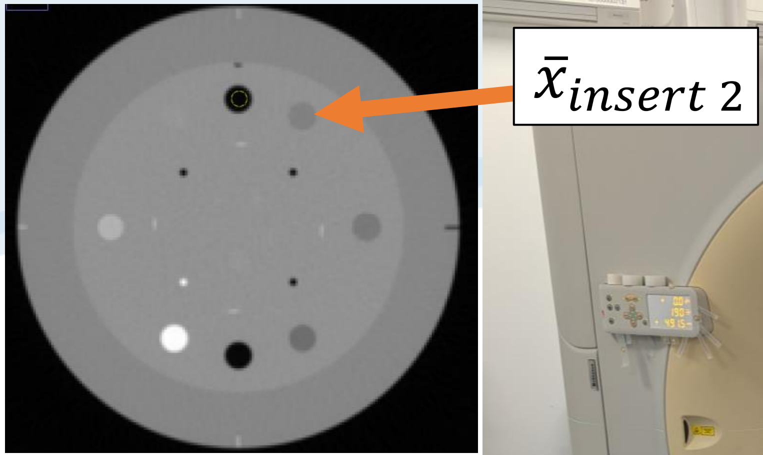
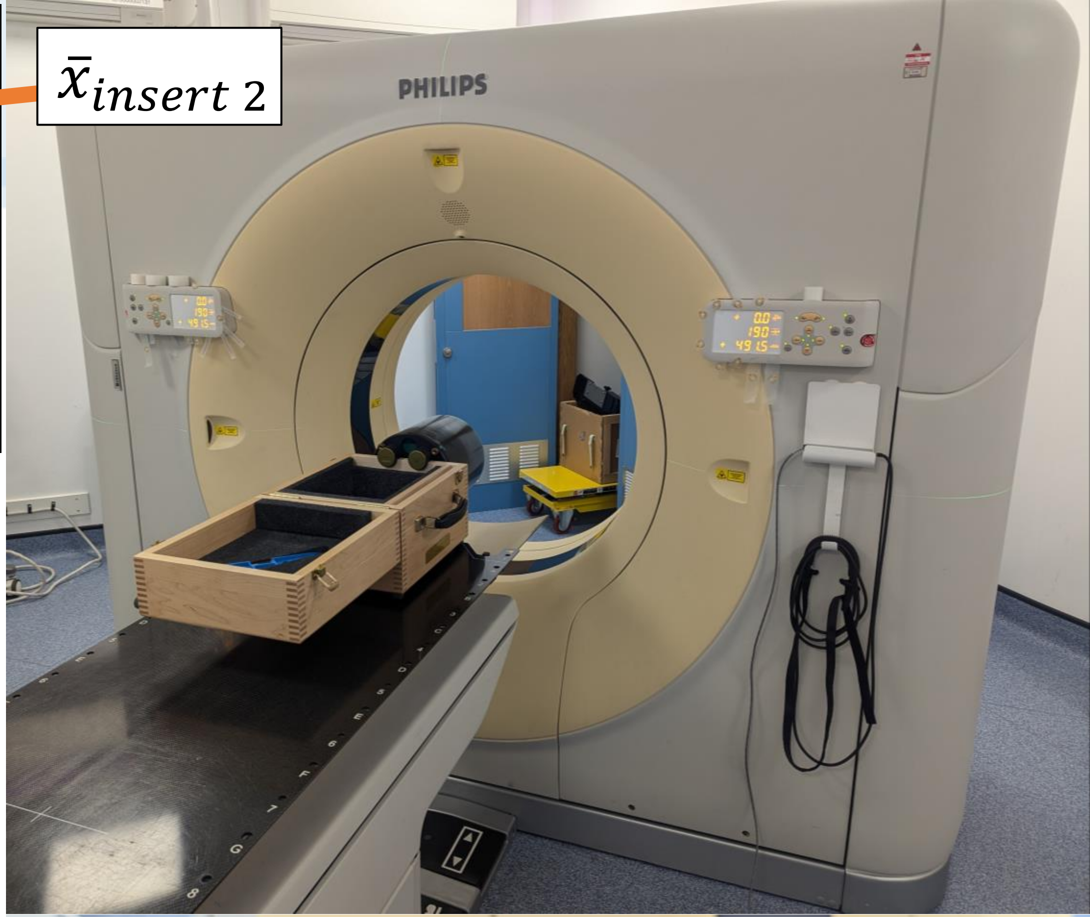
Image Quality





- $CNR = \frac{\bar{x}_{insert\ 2} - \bar{x}_{uniformity}}{\sqrt{\left(\sigma^2_{insert\ 2} + \sigma^2_{uniformity}\right)}}$
- Scanned Catphan and reconstructed the same images at each iDose level
- Measured mean pixel value for each insert using oval ROI (44-pixel area)
- Largest mean HU variation was ± 0.5, most within ± 0.1
- Standard dev. ↓ and CNR ↑ as iDose level ↑

Image Quality (Catphan)

- For head and neck, thorax and pelvis protocols, there was no significant difference in CNR values between the clinical protocol and iDose 4 reconstructions at 12% lower mAs (p = 0.321) or iDose 5 with 30% lower mAs (p = 0.372)

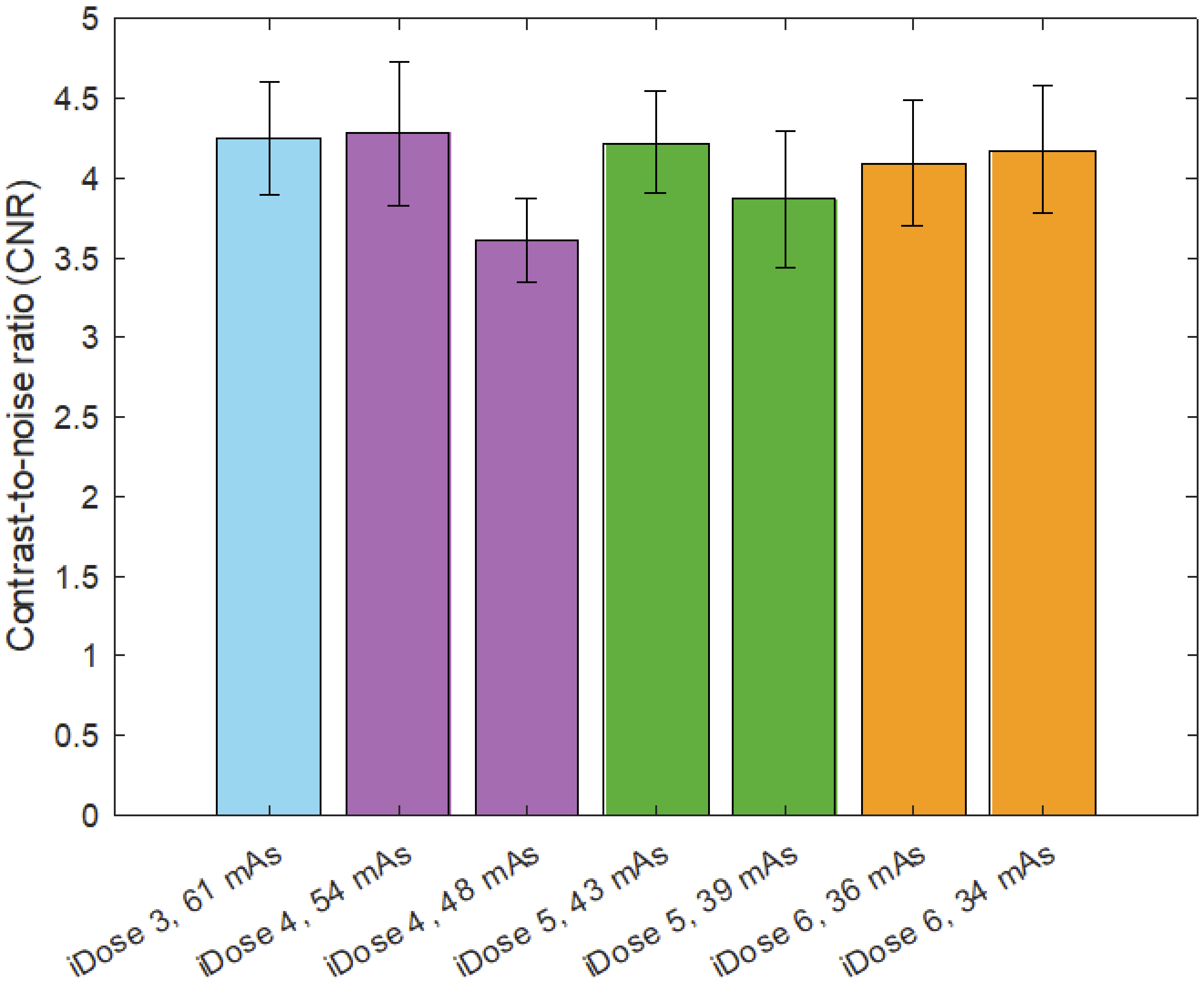
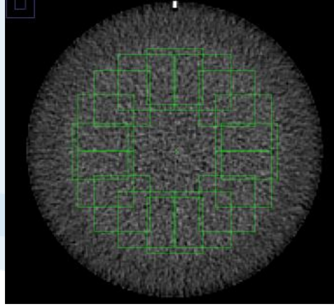


Image Quality (Catphan)

- Noise power spectrum of Catphan uniformity module
- ImageJ plugin by David Platten
- Noise peak changes when changing iDose level
  - Explains image texture difference / “plastickyness” of high level iDose recons?



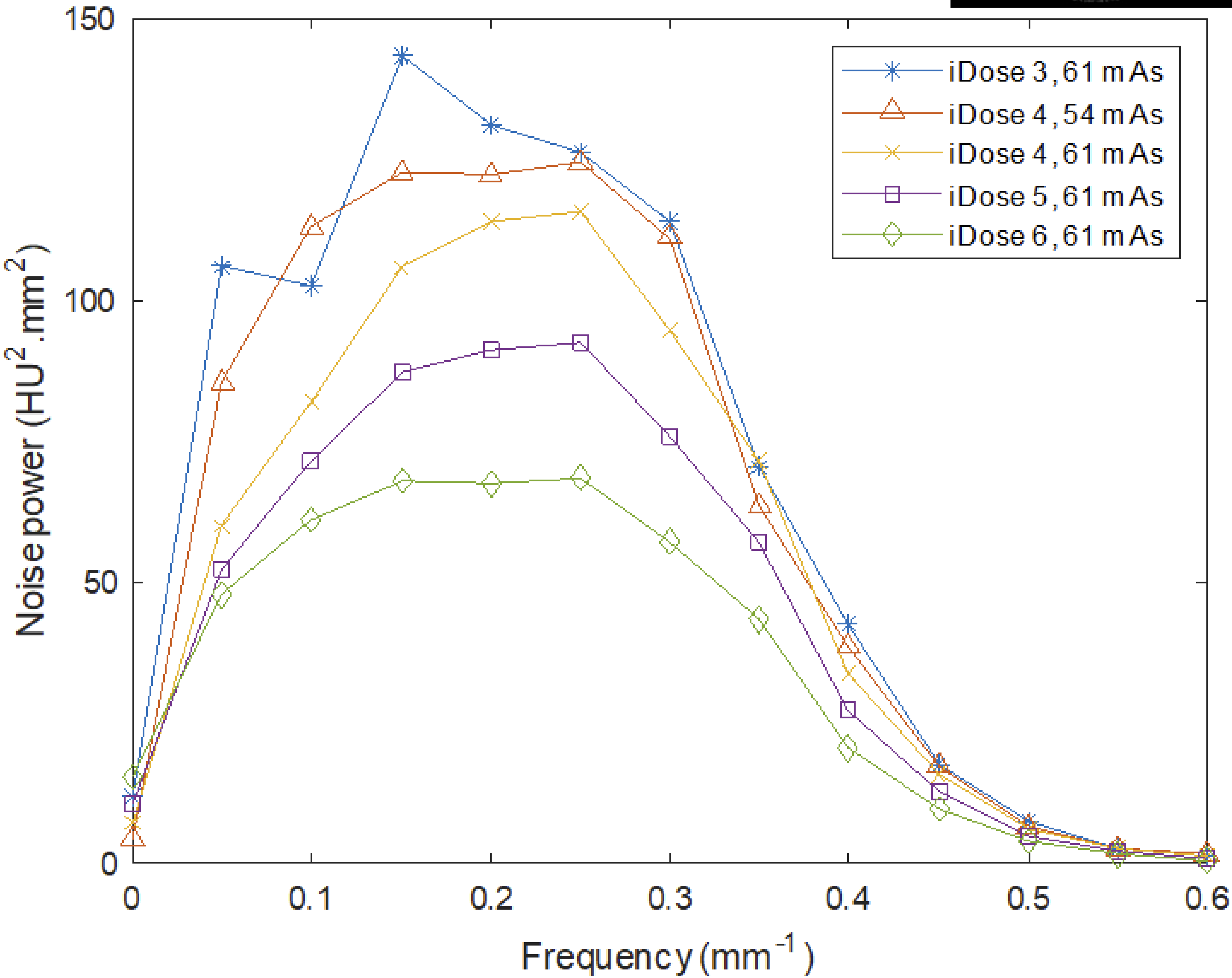
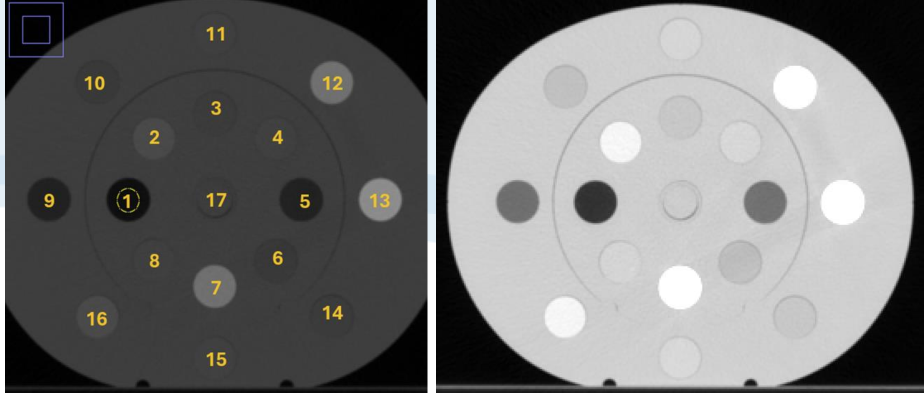
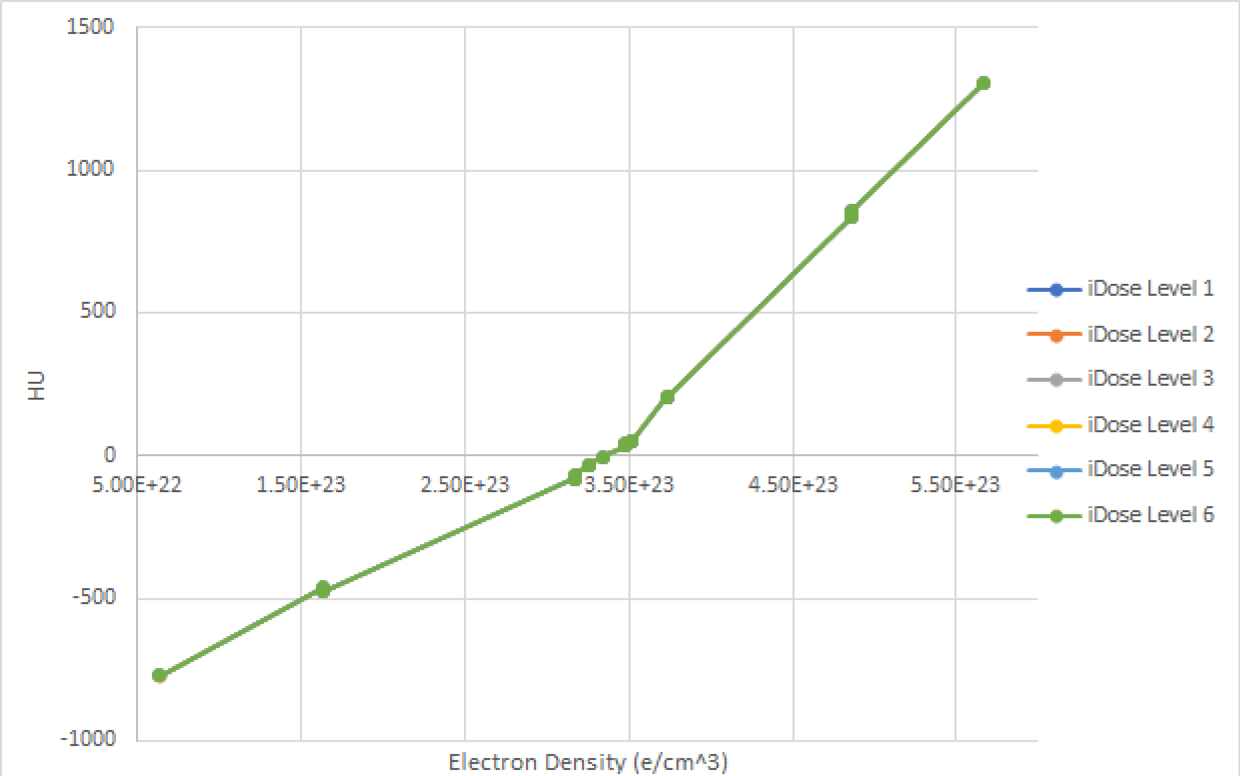


Image Quality (CIRS)



- HU variation from changing iDose recon level was up to 100× smaller than the difference from rescanning the phantom with the **same protocol settings**.



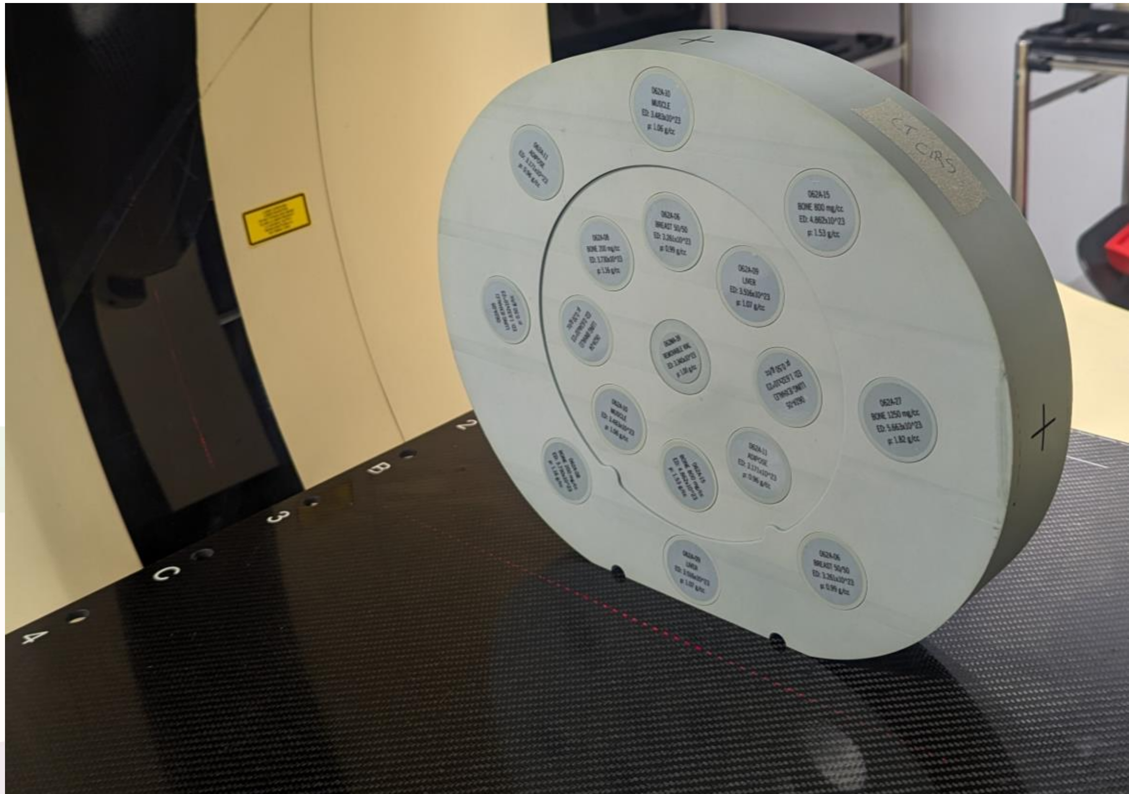
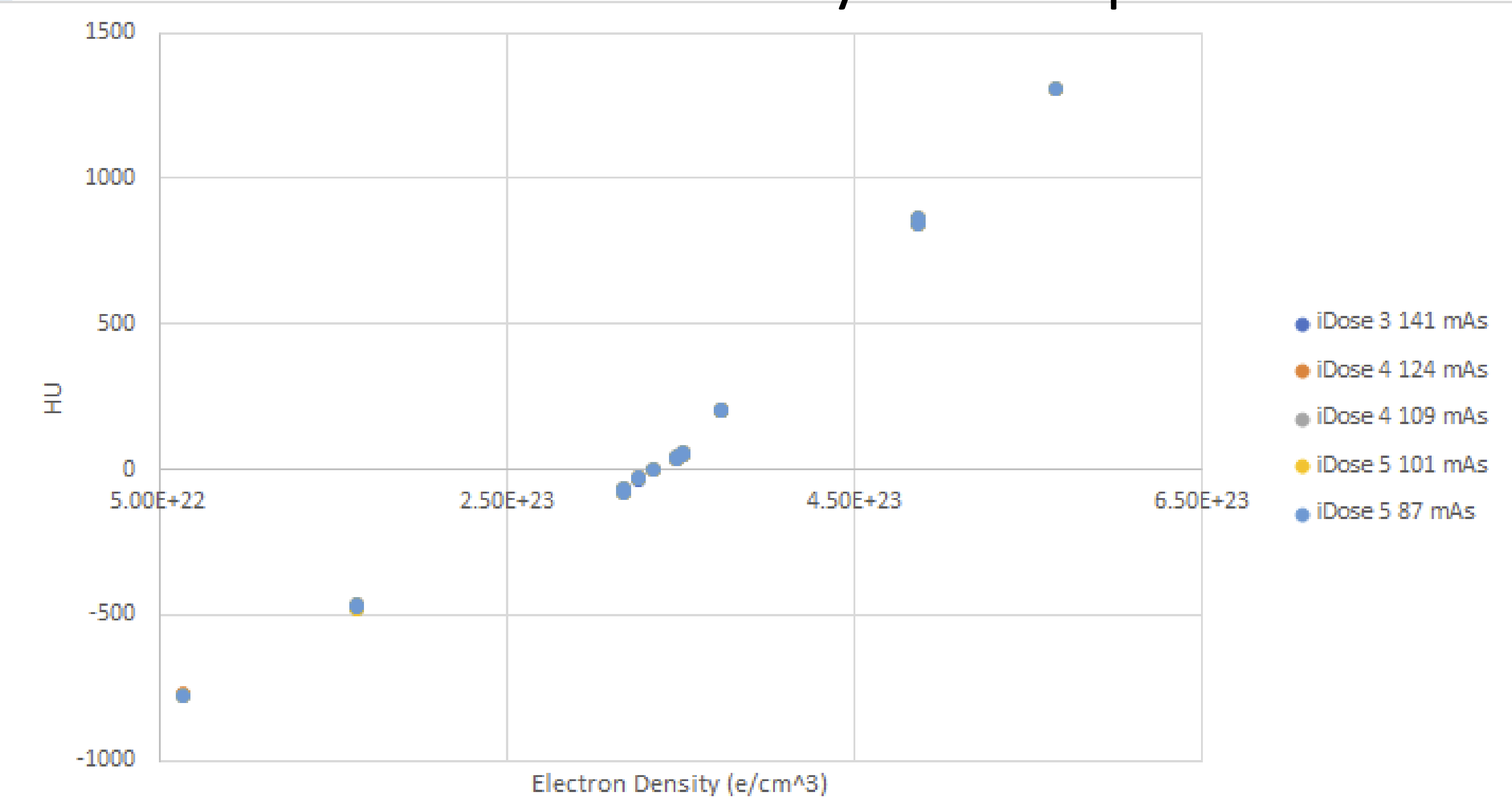


Image Quality (CIRS)

- Max observed HU difference for any insert was ± 6 HU for different test protocols
  - Within ± 10 HU for water and ± 20 HU for other materials tolerance recommended by IPEM Report 81



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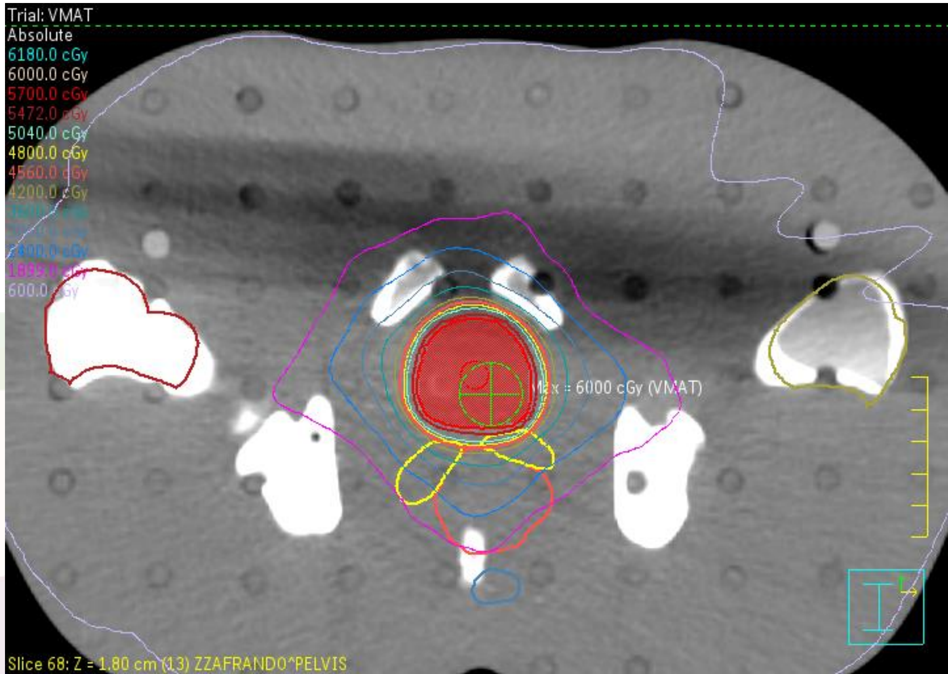
Phantom plan dose measurements

- Scanned the head and neck, chest and pelvis regions of the Alderson RANDO phantom
- Calculated the monitor units and norm point dose for single beams
- Max variation was ± 0.6 MU and ± 8 cGy (0.1% of prescribed dose)
- Created a VMAT pelvis plan on phantom
  - Max difference in min PTV dose: 20 cGy
  - All objectives met on all plans

Copy_All_Beams_From_Trial

Load_All_Beams_From_Copy



Phantom plan dose measurements

Scan protocol	Monitor units (MU)	NORM dose (cGy)	Dose at fixed MU (428.1 MU)
iDose 3, DRI 17	428.1	5999.4	5999.4
iDose 4, DRI 17	428.2	5999.8	5998.4
iDose 5, DRI 17	428.2	6000.6	5999.2
iDose 6, DRI 17	428.1	6000.0	6000.0
iDose 4, DRI 16	427.9	6000.2	6003.0
iDose 4, DRI 15	428.1	5999.4	5999.4
iDose 5, DRI 14	428.1	6000.5	6000.5
iDose 5, DRI 13	428.3	6000.4	5997.6
iDose 6, DRI 12	428.2	6000.2	5998.8
iDose 6, DRI 11	427.7	5999.6	6005.2

Table 6: Variation in planned monitor units and point doses for a single lateral beam pelvis plan calculated on each RANDO pelvis image set.

Scan protocol	Monitor units (MU)	NORM dose (cGy)	Dose at fixed MU (268.5 MU)
iDose 3, DRI 18	268.5	6500.9	6500.9
iDose 4, DRI 18	268.5	6500.9	6500.9
iDose 5, DRI 18	268.5	6501.2	6501.2
iDose 6, DRI 18	268.4	6498.9	6501.4
iDose 4, DRI 17	268.2	6500.2	6507.5
iDose 5, DRI 15	268.2	6500.4	6507.7
iDose 6, DRI 13	268.3	6500.2	6505.1

Table 8: Variation in planned monitor units and point doses for a single anterior beam plan calculated on each RANDO head and neck image set.

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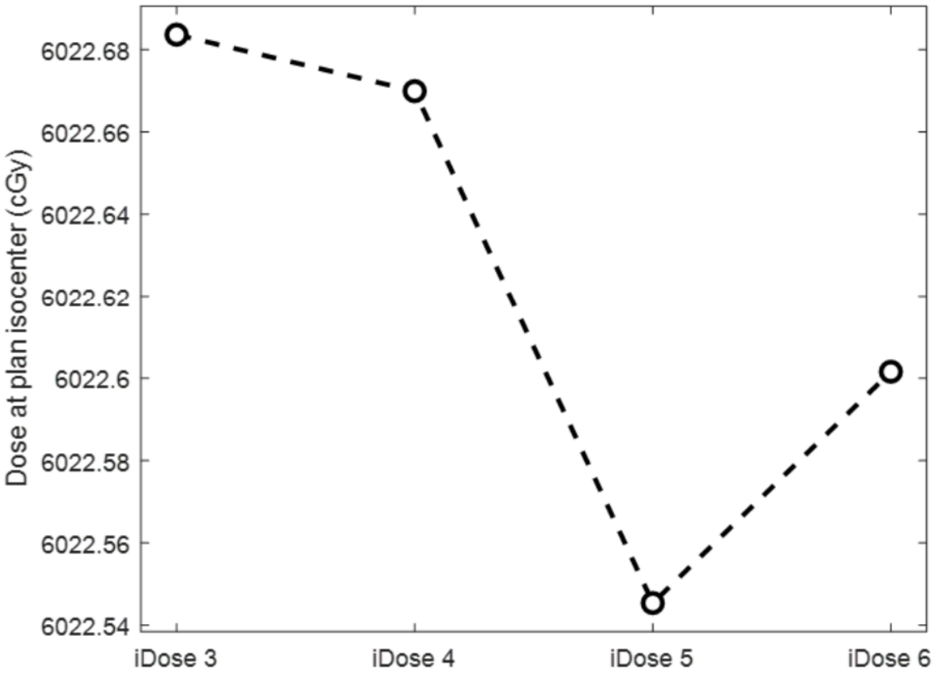
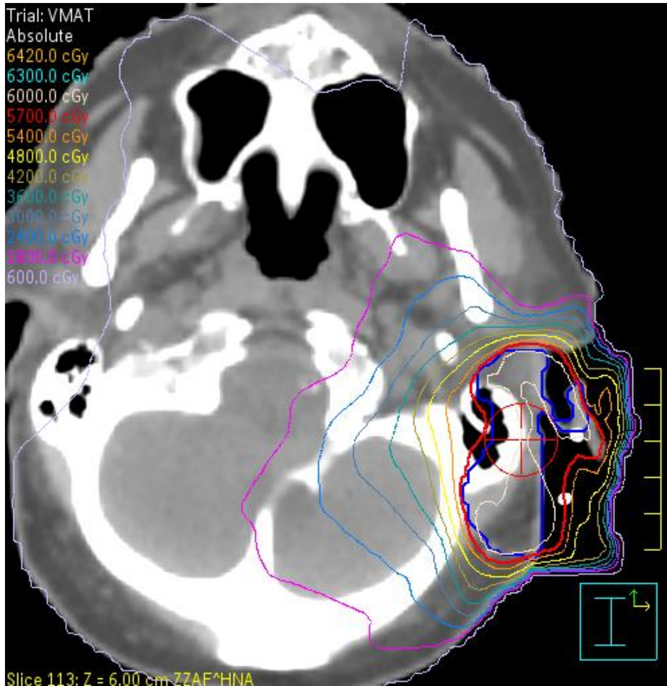
Anonymised patient plans

- Reconstructed planning CT images for patients who completed treatment
- Copied treatment fields from the approved plan onto iDose 4, 5 & 6 recons and calculated dose
- Plans had essentially identical PTV coverage
- Max dose to organs at risk were within 1 cGy





- iDose Level 3

- iDose Level 6

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Autocontouring

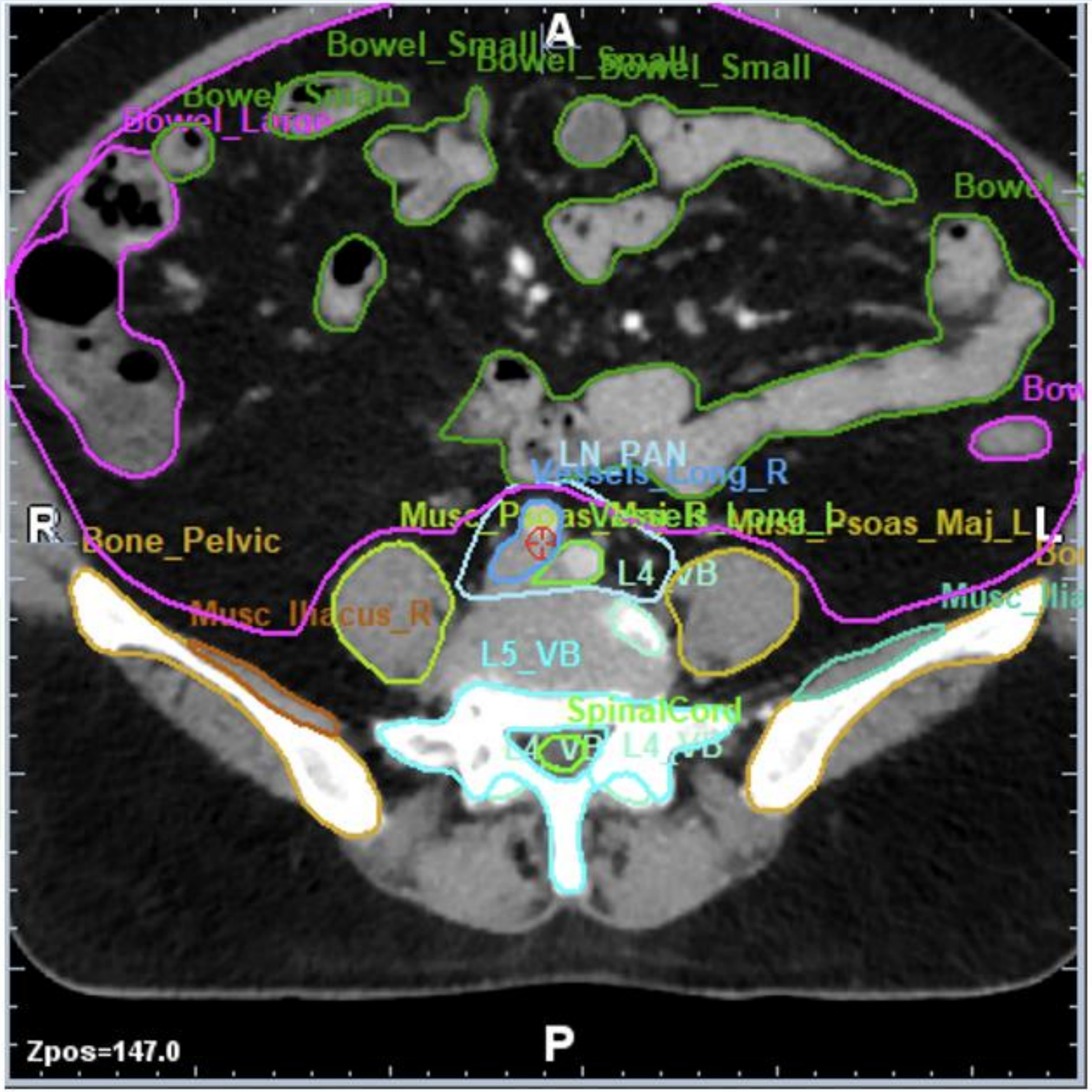
- Assessed MVision AI contouring for different iDose level recons for anonymised head and neck and gynae scans
- Largest contour change was < 2%

Mvision contours for cervix planning

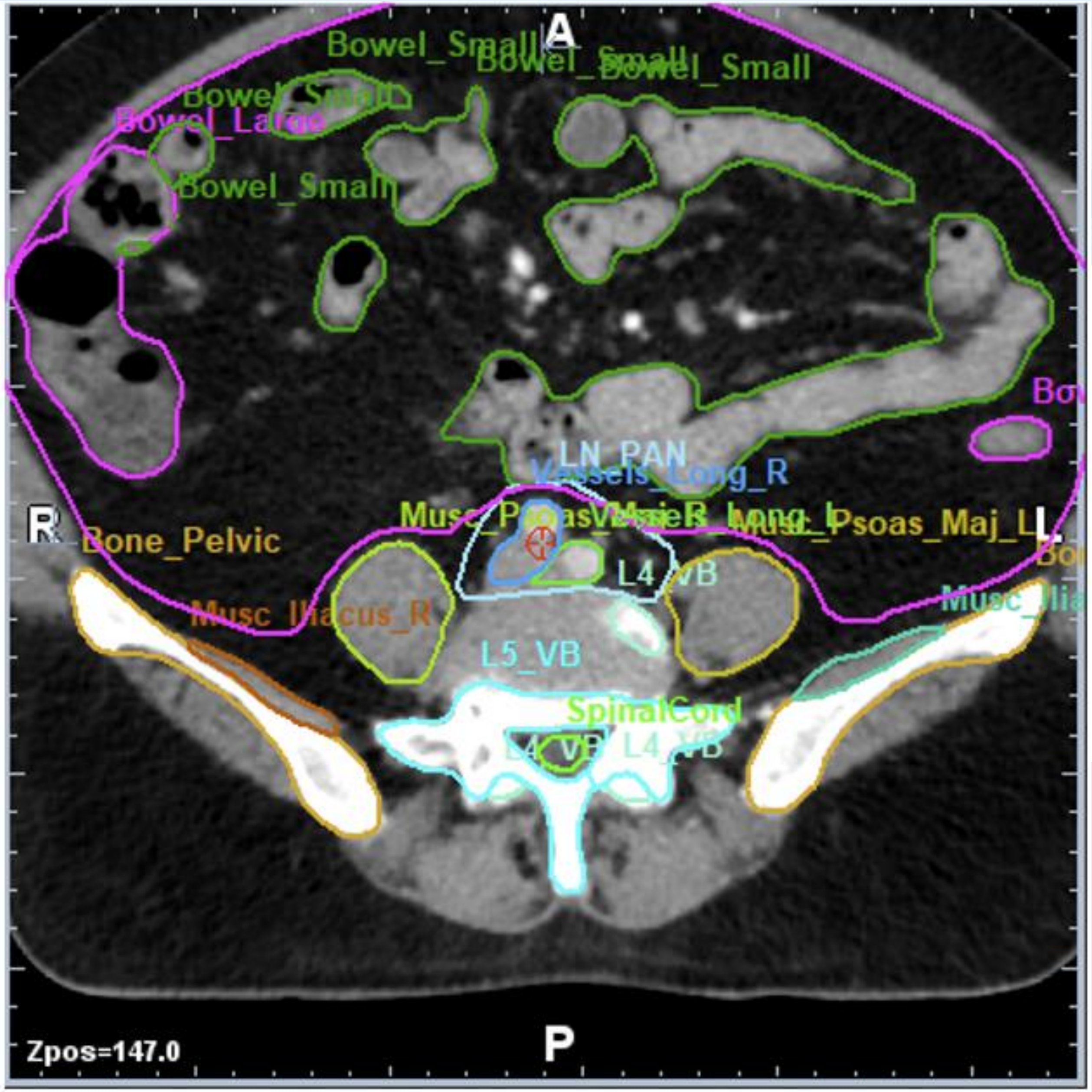
VOI	iDose 3 Vol. (ml)	VOI surface (cm*cm)	iDose 4 Vol. (ml)	VOI surface (cm*cm)	iDose 5 Vol. (ml)	VOI surface (cm*cm)	iDose 6 Vol. (ml)	VOI surface (cm*cm)
Bladder	371.5	280.6	371.3	278.8	371.1	279.1	370.9	277.6
Bowel_Large	415.1	791.1	416.5	787.3	418	787.2	419.8	789.8
Bowel_Small	712.6	1370.4	707.3	1349.6	705.1	1350.2	702.3	1355.1
Colon_Sigmoid	17.1	53.5	17.2	54	17.3	54.1	17.4	54.3
FemurHeadNeck_L	104.4	145.9	104.4	145.9	104.4	146.1	104.4	146.6
FemurheadNeck_R	108.5	151.5	108.5	151.1	108.5	150.9	108.5	151.4
Kidney_L	114.5	148.7	114.5	148.4	114.4	148.5	114.4	148.7
Kidney_R	141.7	244.5	141.3	246.2	140.8	245.6	140.2	243.6
Rectum	77.7	125.5	77.8	126.6	77.9	126.9	77.9	127.4
Spc_Bowel	4,900	2125.7	4,900	2127	4,900	2141.9	4,900	2136.1
SpinalCord	9.8	43.5	9.7	43.6	9.7	43.5	9.8	43.6

MVision contours for head and neck planning

VOI	iDose 3 Vol. (ml)	VOI surface (cm*cm)	iDose 4 Vol. (ml)	VOI surface (cm*cm)	iDose 5 Vol. (ml)	VOI surface (cm*cm)	iDose 6 Vol. (ml)	VOI surface (cm*cm)
Brainstem	30	62.6	30	62.4	30	63.2	30	62.5
Cavity_Oral	94	105.3	94	105	94	104.7	94	103.7
Eye_L	8.2	22.7	8.2	22.8	8.2	22.8	8.2	22.8
Eye_R	8.4	23	8.4	23.2	8.4	23.6	8.4	23.6
Lens_L	0.2	1.9	0.2	1.9	0.2	1.9	0.2	2
Lens_R	0.2	1.5	0.2	1.5	0.2	1.5	0.2	1.6
OpticChiasm	0.5	4.9	0.5	4.9	0.5	4.9	0.5	4.9
Parotid_L	38.8	71.6	38.9	71	38.9	70.5	38.9	70.4
Parotid_R	37.7	65	37.7	65.1	37.7	64.8	37.7	64.5
SpinalCord	21.3	101.9	21.2	101.9	21.2	101.8	21.2	101.8



iDose Level 6



iDose Level 3

Conclusions

- Propose new head and neck, pelvis and thorax CT protocols that provide a 10% reduction in dose with non-inferior image quality
- Changing iDose level and mAs does not result in plan dose variations greater than 1% → no changes to CT-density table in TPS required
- iDose reconstruction level impacts autocontours (slightly)
- Research used to implement new CT protocol for HDR brachytherapy
- Next steps:
  - Enlist clinicians to analyse patient scans on new settings
  - Investigate other sites, 4DCT, etc.

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Special thanks

- Project supervisors – Davinder Gardner (RWT), Doug Northover (RWT), Tom Roberts (RWT), Colin Lee (Clatterbridge Cancer Centre)
- Jonathan Allred – methodology used from “*Introducing AiCE Deep-Learning Reconstruction Algorithm into a Radiotherapy Workflow*”
- David Platten – NPS ImageJ plugin

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Thanks for listening.

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