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# Can CT reconstruction algorithms be changed to improve image quality in radiotherapy CT planning scans?

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# 1. Background

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## Portsmouth RT CT scanner – Toshiba Aquilion LB (2009)

| Protocol name | kV | Rotn time | mA mod | FOV | Pitch | Thickness | Recon | | Boost | Recon mm | Recon interval |
|---|---|---|---|---|---|---|---|---|---|---|---|
| RTP Head 2mm | 120 | 1 | Fixed mA | 320 M | HP15 | 0.5x16 | FC13 | QDS+ | ON | 2 | 2 |
| RTP Abdomen Supine 2mm | 120 | 1 | ON - STD | 400 L | HP15 | 1 x 16 | FC13 | QDS+ | ON | 2 | 2 |
| RTP Abdomen Pelvis 2mm | 120 | 1 | ON - STD | 400 L | HP15 | 1 x 16 | FC13 | QDS+ | ON | 2 | 2 |
| RTP Prostate 2 mm + single slice | 120 | 1 | ON - STD | 550 LL | HP15 | 1 x 16 | FC13 | QDS+ | ON | 2 | 2 |
| RTP Prostate Brachy 2mm | 120 | 1 | ON - STD | 150 LL | HP15 | 1 x 16 | FC13 | QDS+ | ON | 2 | 2 |
| RTP Rectum (Supine) 2 mm | 120 | 1 | ON - STD | 550 LL | HP15 | 1 x 16 | FC13 | QDS+ | ON | 2 | 2 |
| RTP Gynae 2mm Supine | 120 | 1 | ON - STD | 550 LL | HP15 | 1 x 16 | FC13 | QDS+ | ON | 2 | 2 |
| RTP Chest 2mm | 120 | 1 | ON - STD | 550 LL | HP15 | 1 x 16 | FC13 | QDS+ | ON | 2 | 2 |
| RTP Breast 2mm | 120 | 1 | ON - STD | 550LL | HP15 | 1 x 16 | FC13 | QDS+ | ON | 2 | 2 |

- Radiotherapy CT scan protocols often limit the reconstruction kernels used.

# 1. Background

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PAPER

**IPEM topical report: the first UK survey of dose indices from radiotherapy treatment planning computed tomography scans for adult patients**

Tim J Wood[1,2,3], Anne T Davis[1,4,5], James Earley[1,6], Sue Edyvean[7], Una Findlay[8], Rebecca Lindsay[1,9], Andrew Nisbet[1,5,6], Antony L Palmer[1,4,5], Rosaleen Plaistow[1,10] and Matthew Williams[1,11]

Published 10 September 2018 • © 2018 Institute of Physics and Engineering in Medicine
Physics in Medicine & Biology, Volume 63, Number 18

- From national RT CT dose audit, more than half of centres used the same reconstruction kernel for lung, brain, prostate & head/neck [30 of 53 centres]

- Intention – match clinical scan protocols to those used when treatment planning system (TPS) was commissioned.

# Reconstruction kernels affect image quality

Siemens
H10
(smooth)


Siemens
H70
(sharp)


- In diagnostic imaging CT kernels vary for different body region and imaging tasks. Lots to choose from.
- Radiotherapy guidance [AAPM] says scan protocols should be optimised. Are they?

TOSHIBA

# Aquilion series

V4.63 software or above

## Scanograms

Smoother → Sharper

- FL 1
- FL 2
- FL 3
- FL 4

**Notes**

BHC: Beam hardening correction reduces artifacts from bones. EG. Streak artifact from temporal bones, between shoulders and hips.

Filters are used to fine tune image sharpness and smoothing. Commonly FC 30 used for bone imaging is combined with an edge enhancement filter.

### Color Key

- Available Options
- Recommended for Anatomical Region
- Recommended for Thick Axial
- Recommended for Volume
- Recommended for Scanogram

## Body Algorithms with BHC

| Smoother → Sharper | Increased Contrast |
|---|---|
| FC 1 | |
| FC 2 | FC 7 |
| FC 3 | FC 8 |
| FC 4 | FC 9 |
| FC 5 | |

## Body Algorithms without BHC

| Smoother → Sharper | Increased Contrast |
|---|---|
| FC 11 | |
| FC 12 | FC 17 |
| FC 13 | FC 18 |
| FC 14 | FC 19 |
| FC 15 | |

## High Resolution Lung Algorithms

| Smoother → Sharper | |
|---|---|
| FC 83 | |
| FC 84 | FC 55 |
| FC 85 | FC 56 |
| FC 86 | |

## Standard Lung Algorithms

| Smoother → Sharper | Decreased Noise |
|---|---|
| FC 50 | |
| FC 51 | |
| FC 52 | FC 55 |
| FC 53 | FC 56 |



# Aquilion™

### Color Key

- Available Options
- Recommended for Anatomical Region

## Temporal bone Algorithms

Smoother → Sharper

- FC 80
- FC 81

## Bone Algorithms

Smoother → Sharper

- FC 30
- FC 35
- FC 81

Note: FC 30 + an edge enhancement filter may also be used to provide images with the desired amount of sharpness

## Head Algorithms with BHC Fine Grain Size

| Smoother → Sharper | Increased Contrast |
|---|---|
| FC 20 | |
| FC 21 | FC 26 |
| FC 22 | |
| FC 23 | |
| FC 24 | |
| FC 25 | |

## Head Algorithms with BHC Coarse Grain Size

| Smoother → Sharper | Increased Contrast |
|---|---|
| FC 62 | |
| FC 63 | FC 68 |
| FC 64 | |
| FC 65 | |
| FC 66 | |
| FC 67 | |

## Head Algorithms without BHC

Smoother → Sharper

- FC 41
- FC 42
- FC 43
- FC 44

## Head Algorithms without BHC Pediatric

| Smoother → Sharper | Increased Contrast |
|---|---|
| FC 46 | |
| FC 47 | FC 49 |
| FC 48 | |

# Calibration curve for a treatment planning system

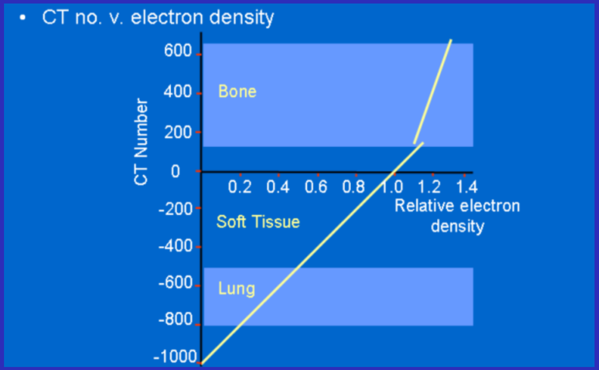
- Calibration curve in TPS converts HU for different

Set CT scan protocol (s)

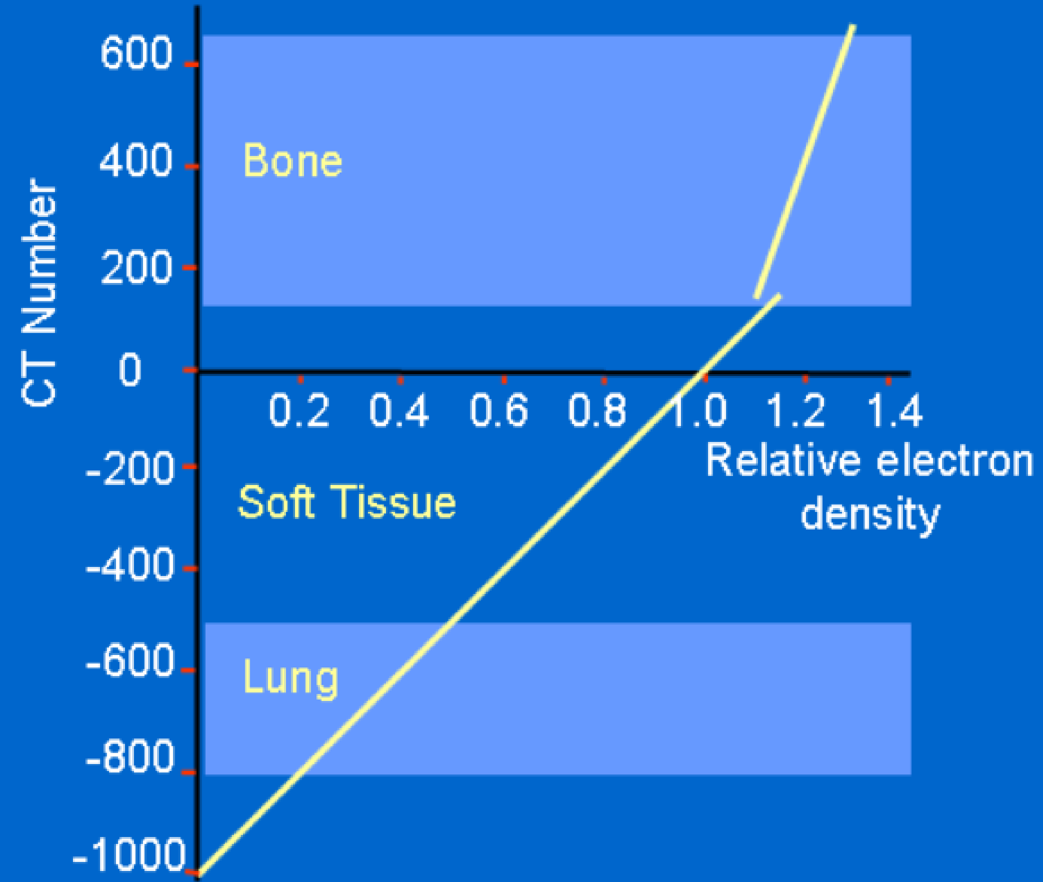
Slice width
FOV
Recon kernel
mA etc

Scan phantom

Produce calibration curve(s)



- CT no. v. electron density




Slide courtesy of Impact
[ww.impactscan.org]

For TPS calibration:

Need to consider how HU values might change if scan parameters vary for different protocols

Options:

- average data to produce a single calibration curve and be aware of inaccuracies this introduces
- have several calibration curves to match different scan protocols
- limit the changes in different CT scan protocols

# 2. Objectives

If scan parameters are changed to improve clinical image quality, how much HU change is ‘too much’ if not changing the TPS calibration curve?

Can tolerances be set for HU change which clearly link to dose change in the RT treatment plan?

# 3. From literature review

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Dosimetry in the treatment plan depends on:

- The dose calculation algorithm used in the TPS
- The energy of the treatment beam (change in HU has less impact for higher energy treatment beams)
- Body composition eg amount of bone/soft tissue/lung
- Volume of tissue that treatment beams pass through eg deep or superficial tumour
- The HU of the various tissues
- The calibration curve (RED vs HU) of the TPS

| Tissue | RED value | Defined tolerance (RED or HU) | Reference |
|---|---|---|---|
| Lung | 0.2 | +/- 0.05 (+/- 25%) [+/- 50HU] | ESTRO Booklet No 7 (2004) |
| | 0.21 | +/- 0.02 (+/- 10%) or +/- 20 HU | IAEA Report series 19 (2012) |
| | 0.2 | +/-0.004 (+/-2% ) [+/- 4 HU] | IPEM Report 88 (1999) |
| | | +/-2% DOSE change or +/- 50 HU | IPEM Report 81 (2018) |
| Soft tissue | 1.0 | +/- 0.05 (+/- 5%) [+/- 50HU] | ESTRO Booklet No 7 (2004) |
| | 1.06 | +/- 0.02 (+/- 2%) or 20 HU | IAEA Report series 19 (2012) |
| | 1.0 | +/- 0.01 (+/-1%) [+/- 10 HU] | IPEM Report 88 (1999) |
| | | +/-1% DOSE change or 30 HU | IPEM Report 81 (2018) |
| Bone | 1.5 | +/- 0.1 (+/- 7%) [+/- 170 HU] | ESTRO Booklet No 7 (2004) |
| | 1.60 | +/- 0.02 (+/- 1%) or 20 HU | IAEA Report series 19 (2012) |
| | 1.3<br>1.8 | +/- 0.03 (+/-2%) [+/- 50 HU]<br>+/-0.04 (+/-2%) [+/- 70 HU] | IPEM Report 88 (1999) |
| | | +/- 2% DOSE change or 150 HU | IPEM Report 81 (2018) |

+ a few papers based on clinical data for old TPSs and treatment techniques

[value] is calculated using a typical calibration curve

# 4. Materials & Methods

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Basic method

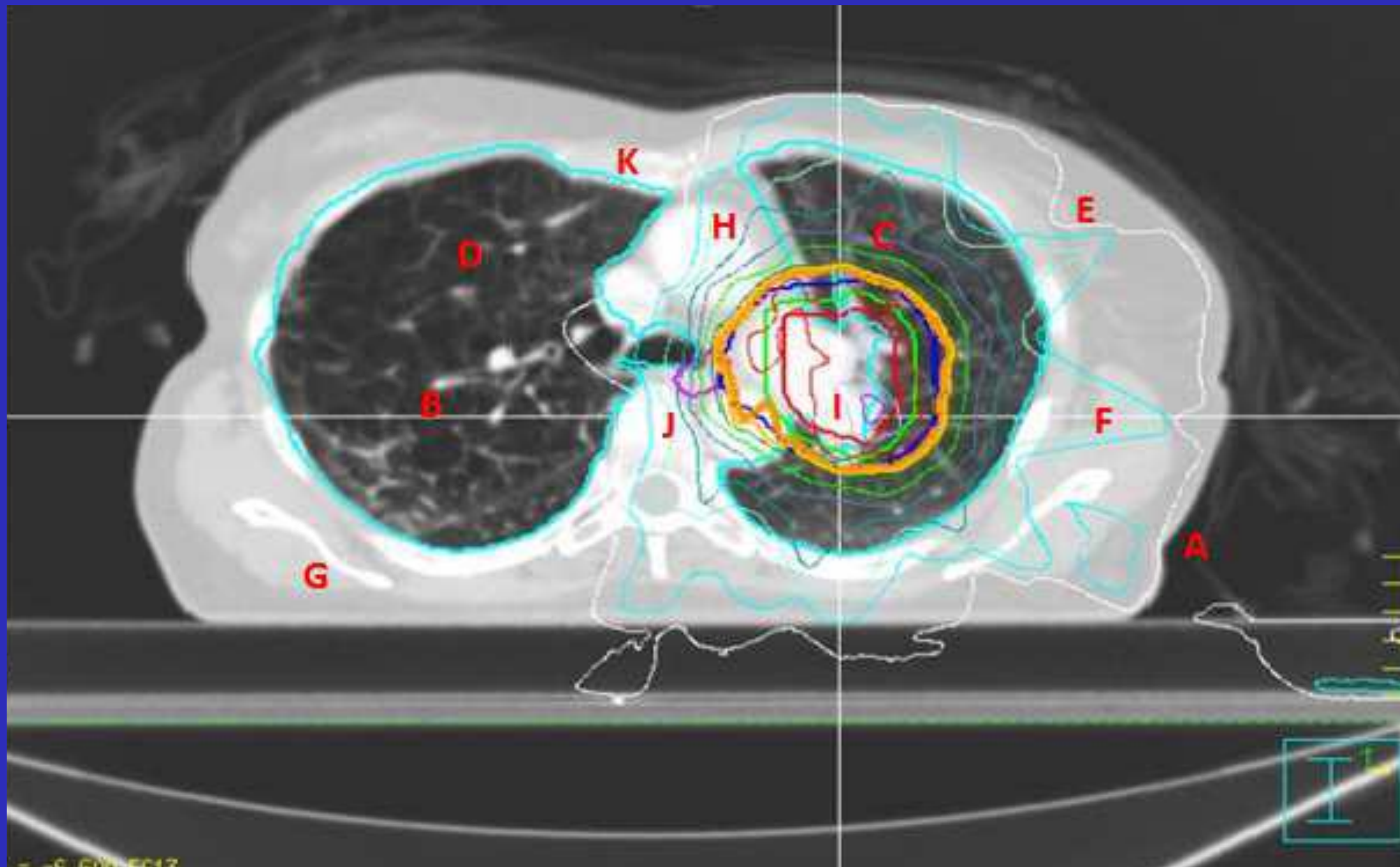
Choose an RT CT image set, reconstruct using several different recon kernels.

Apply standard treatment plan to the different sets of images

Assess HU change for soft tissue, bone and air & compare against dose change in treatment plan.

Repeated for 13 scan sets; 57 images produced in total.

Different body regions: head & neck; prostate; lung


K
H
C
E
D
B
J
I
F
A
G

# 4. Materials & Methods

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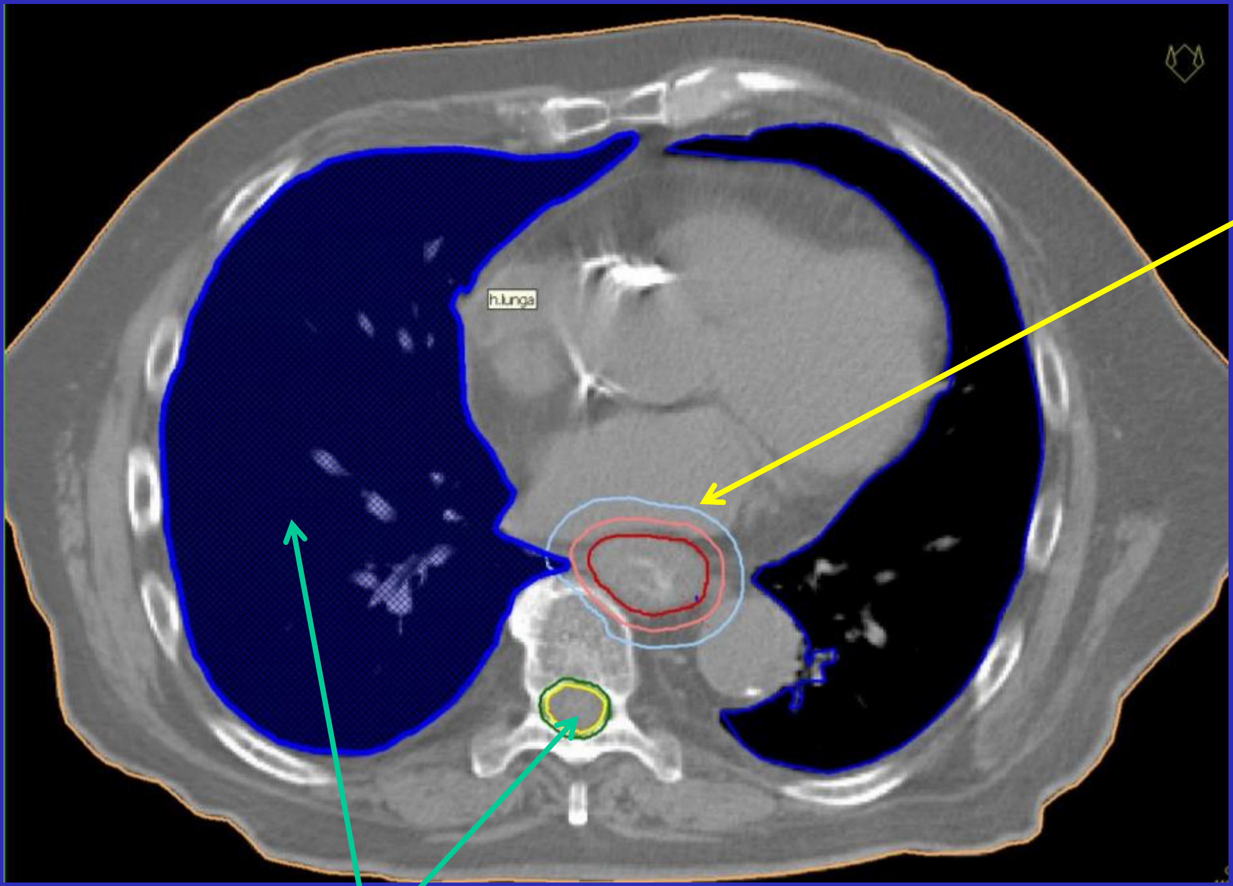
Involved 4 centres, different TPS & CT combination

| Centre | Treatment planning system (software version) | Planning algorithms | CT scanner make and model |
|---|---|---|---|
| P | Pinnacle (9.6) from Philips Healthcare | Collapsed Cone Convolution (CCC); Adaptive Convolve (AC) | Toshiba Medical System Ltd Aquilion LB |
| E | Eclipse (11.0.31) from Varian Medical Systems | Analytical Anisotropic *Algorithm* (*AAA*) | GE Healthcare Lightspeed 16 |
| M | Monaco (3.3.30) from Elekta | Monte Carlo Photon (MC) | GE Healthcare Lightspeed RT 16 |
| R | Raystation (v 3.2) from Raystation Laboratories | Collapsed Cone | Siemens Sensation Open |

# Definition of terms




Planning Target Volume (PTV)

used for determining treatment beam positions & sizes and to ensure prescribed dose is appropriately delivered to the tumour & surrounding area

Organs At Risk (OAR) – critical regions of normal tissue of high sensitivity where dose needs to be minimised

Slide courtesy of Per Nilson & Crister Ceberg, Lund University [www.msf.lu.se]

# Definition of terms

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Standard parameters recorded from the treatment plan included:

For the PTV: D99%, D98%, D50%, D2%.

D98% for example means the average dose delivered to 98% of the PTV.

For the OAR: this varied according to organ but was either average dose or % volume of organ at specified dose level.

OAR Head & Neck: parotid, brain, spinal cord
OAR prostate: rectum, bladder, bowel, femoral heads
OAR lung: heart, carina, cord

# 5. Results

Maximum differences between base image and other images with different recon kernels were noted.

Recorded HU differences for bone, soft tissue and air

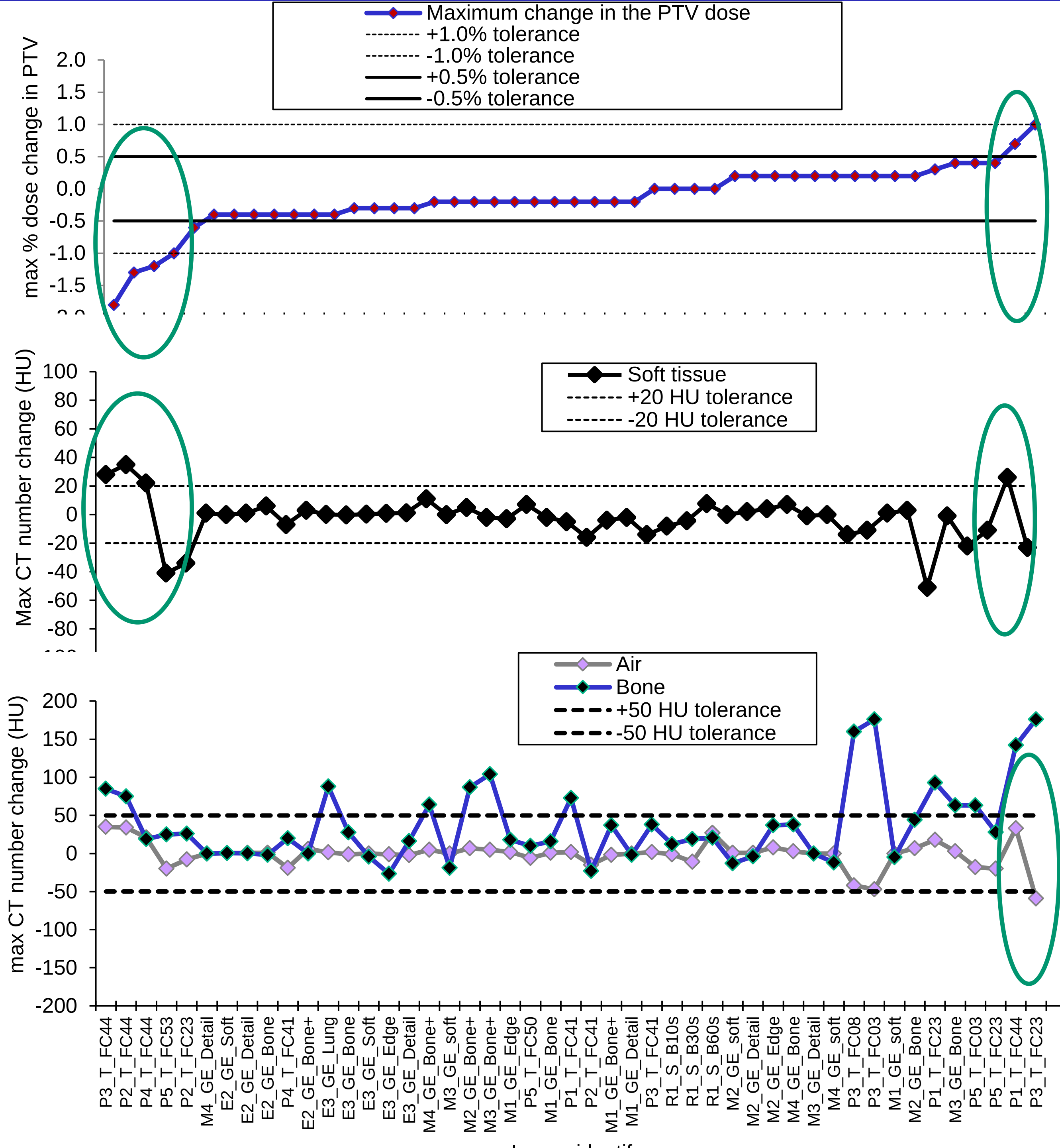
and corresponding (maximum) dose differences in PTV and OARs.

Looking for HU change corresponding to less than +/- 1% dose change in PTV and OAR.

PTV (Tumour)

Soft tissue HU

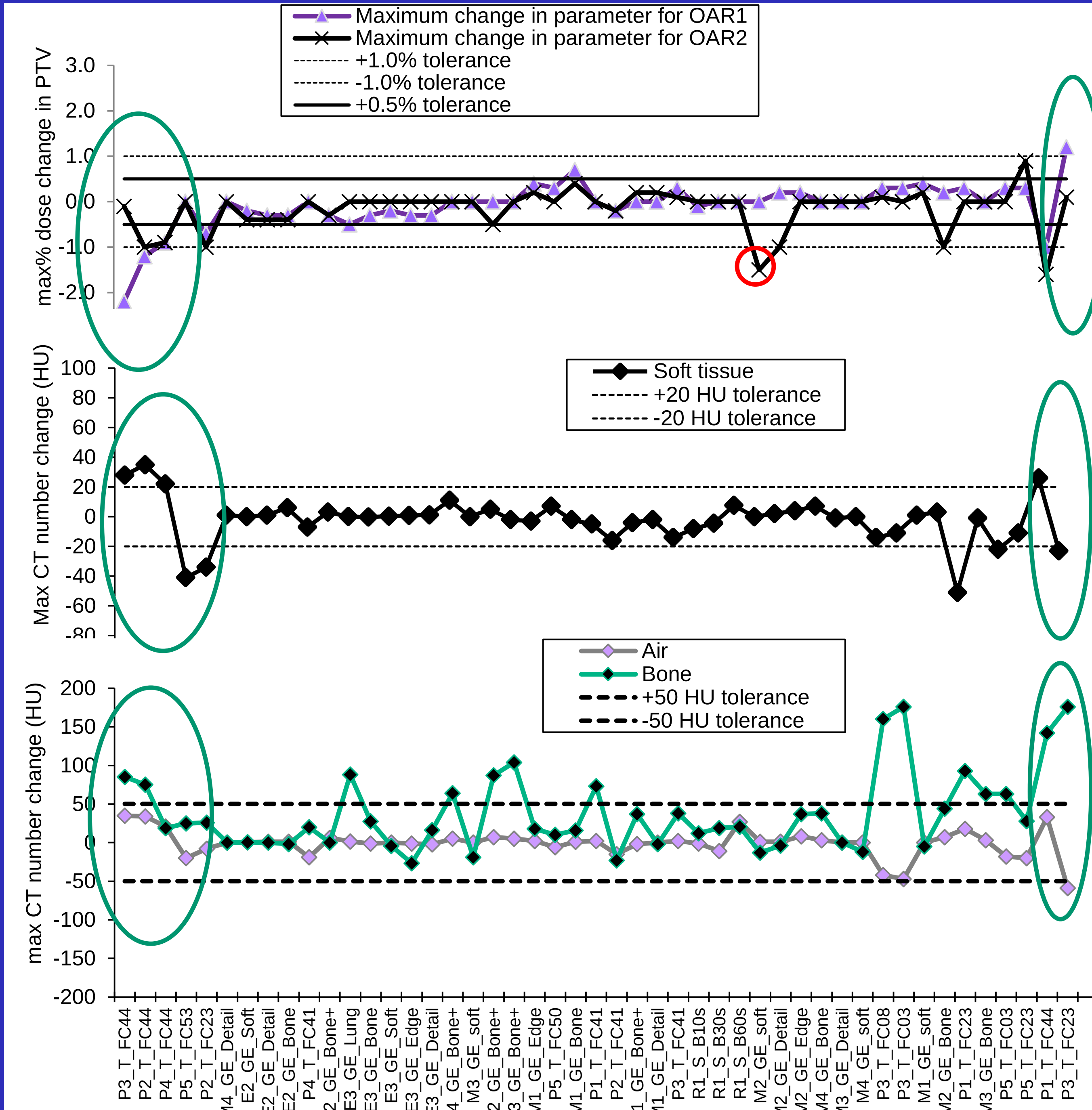
Bone & air HU



OAR

Soft tissue HU

Bone & air HU



# 6. Conclusions

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When using a tolerance of +/- 20 HU for soft tissue and +/- 50 HU for air and bone, dose change in the PTV and OARs was within +/- 1% and in many cases within +/- 0.5%.

HU tolerances can be used as first level check when changing scan parameters before checking in the TPS.

For bone, a tolerance > +/- 50 HU could probably be accepted.

HU change with reconstruction kernel was greatest for GE and Toshiba (Canon) CT scanners.

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Compare with IPEM 81 : Lung +/-2% dose change, +/- 50HU

Soft tissue +/-1% dose change, +/- 30 HU

Bone +/-2% dose change, +/- 150 HU

# Post meeting note

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This work was published in BJR Open

**Radiation dosimetry changes in radiotherapy treatment plans for adult patients arising from the selection of the CT image reconstruction kernel**



https://doi.org/10.1259/bjro.20190023
Received: April 25, 2019
Accepted: June 17, 2019
Published Online: July 25, 2019

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