The ROYAL MARSDEN
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Optimisation and standardisation of CT imaging post microwave liver ablation

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The Royal Marsden Hospital, London

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NHS

Context: Microwave liver ablation

- Thermal ablation has become an accepted treatment strategy for primary and oligometastatic secondary liver cancer.

Needles are placed from the skin directly into a target liver tumour

Lethal microwave energy deposited

Tumour must be fully heated with a margin of normal tissue (safety margin)

Advantages:

Lower cost

Shorter hospital stays

Lower morbidity and mortality than surgery

Disadvantages:

High recurrence rate

Often only used for inoperable tumours

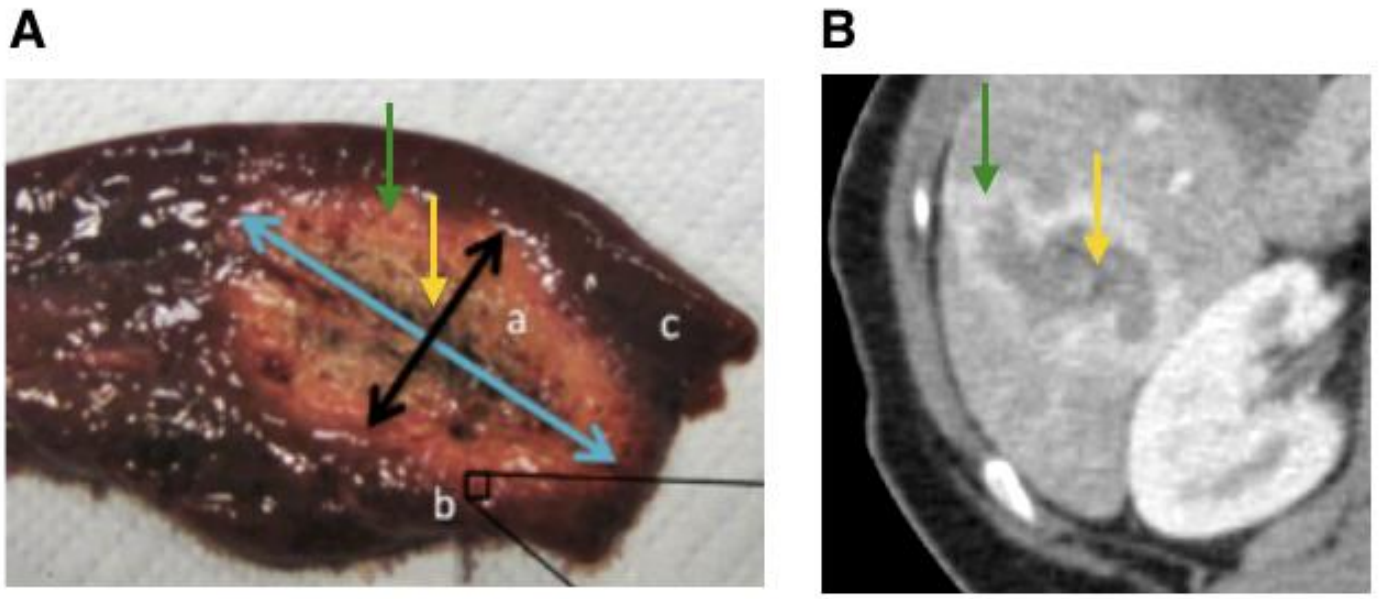
Context: Microwave liver ablation

Reference: The Royal Marsden Cancer Charity (https://twitter.com/royalmarsden/status/1529387805826334721)

Context: Microwave liver ablation

- Treated region (ablation zone):
  - Inner “white zone”: complete cell death
  - Outer “red zone”: incomplete cell death, hyperaemia, and inflammation
    - ➢ Immunologically active and pro-oncogenic.
- To assess for treatment efficacy: a contrast enhanced CT scan is performed at the end of the procedure.
- New and unique circumstance for which scanning protocols have not been optimised or standardised yet.

Context: Microwave liver ablation



Siriwardana PNPN et al, 2015.

Pathological and CT correlates of a microwave ablation zone.

Green arrows: red zone
Yellow arrows: white zone
A: gross pathology of harvested pig liver demonstrating a microwave ablation zone.
B: Post contrast venous phase CT image following microwave liver ablation.

Materials and methods

Study participants

Retrospective matched **legacy control cohort**	→	Single venous phase CT of the whole liver Prior to optimisation **n = 20**
Prospective **optimisation cohort**	→	Dynamic contrast enhanced monitoring scans Venous phase CT imaging **n = 37**
Optimised cohort	→	Optimised biphasic (late arterial and venous) CT imaging **n = 20**

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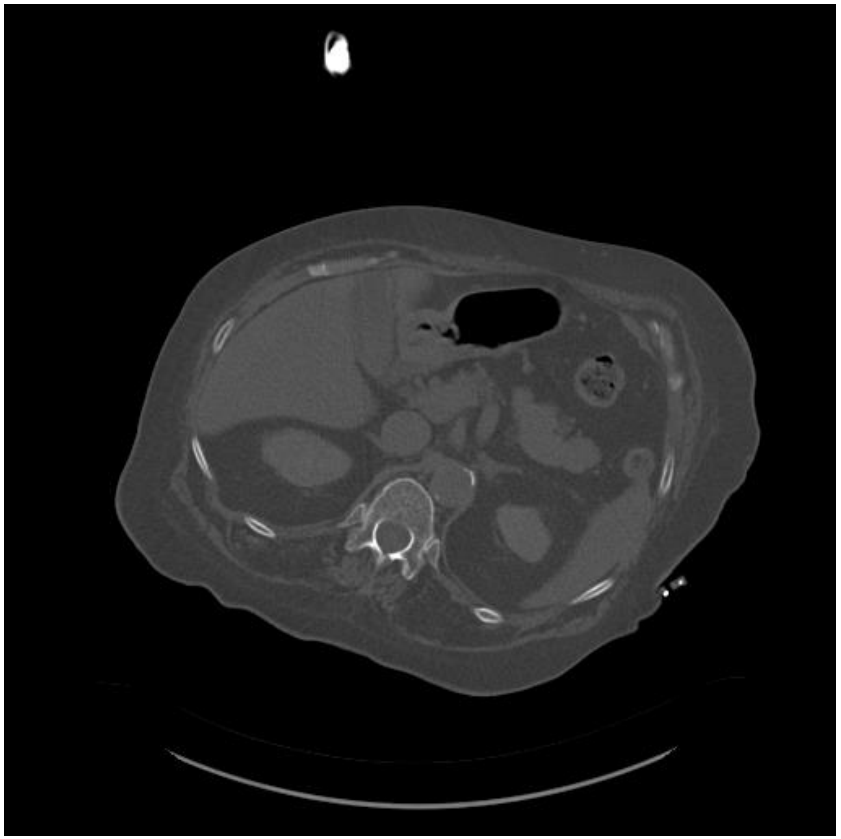
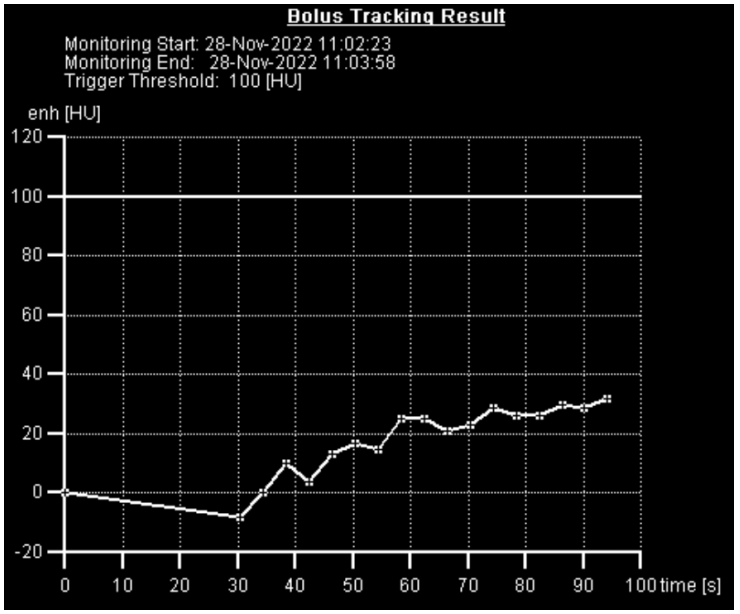
Optimised cohort → Optimised biphasic (late arterial and venous) CT imaging **n = 20**

Study participants – Optimisation cohort

- Main goal: determine optimal contrast resolution/scan timings;
- Single unenhanced pre-monitoring slice;
- Twenty sequential low dose, single 10 mm axial slice monitoring scans
  - 120 kV, 40 mA, 0.5 second rotation time, 10 mm collimation.



Study participants – Optimisation cohort



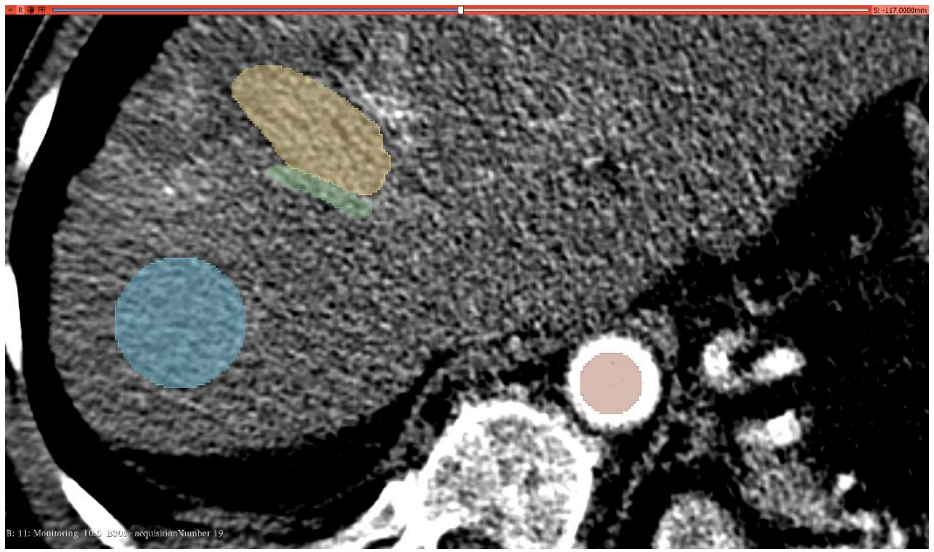
- Enhancement time series through ablation zones (monitoring)
- Pre-contrast slice (pre-monitoring slice)
- Radiation dose increase: about 0.4 mSv (0.02 mSv per monitoring slice)
  - Less than the measured variability in radiation dose (about 1 mSv) resulting from operator choices such as the scan range.
- Helical scan of the whole liver acquired at the end of the dynamic study.

Ablation procedures

- Patients under general anaesthesia;
- High frequency jet ventilation to minimize respiratory excursion;
- CT scanner: Siemens Definition Edge;
- Two microwave generators were used: NeuWave, Johnson & Johnson, WI; Solero, Angiodynamics, NY;
- Antennae were positioned using either freehand or robotic guidance (MAXIO, Perfint PVT, Chennai, In);
- Different numbers of antennae, overlapping ablation zones, and time/power combinations according to operator discretion.

Quantitative image analysis of optimisation cohort and selection of optimised protocol

- Monitoring slices that visually had the greatest contrast between red zone, white zone, and parenchyma were selected for segmentation using 3D Slicer



Quantitative image analysis of optimisation cohort and selection of optimised protocol

- ROIs were labelled, exported as DICTOM RT structure set objects, and analysed using Python:
  - HU values for each ROI along the whole dynamic time series were extracted:
    - ➢ Median and interquartile range of each ROI histogram were plotted versus time;
  - Contrast-to-noise ratio (CNR) between red zone and parenchyma and white zone and parenchyma
  - Pre-monitoring slice: establish if aorta enhancement could be used to trigger helical scan

Qualitative image analysis in legacy control and optimised cohorts

- Post ablation DICOM images from optimised and legacy cohorts
  - Images were anonymised and transferred to a PACS workstation for visual assessment of IQ;
  - Random order;
  - Assessed independently by two attending radiologists;
    - Unaware of the study purpose and blinded to all clinical information.

1. Very poor quality: cannot see the ablation zone. Non diagnostic.

2. Poor quality/visualization of ablation zone. Somewhat helpful.

3. Satisfactory quality/visualization of ablation zone. Helpful.

4. Good quality/visualization of ablation zone. Very clear.

5. Excellent quality/ visualization of ablation zone. Exemplary.

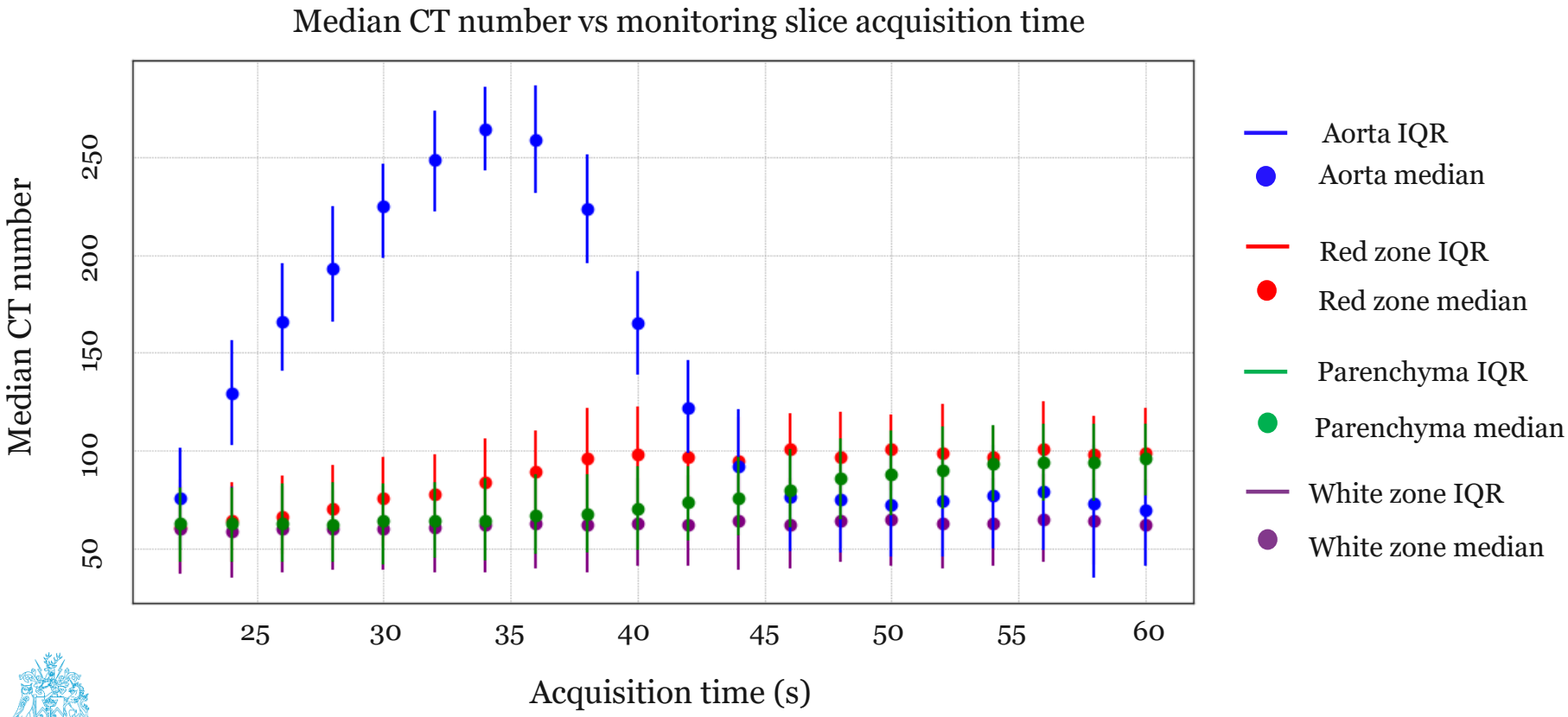
Results

Study participants

- Seventy-seven participants across three cohorts;
- Median age: 63 years (IQR 50 – 71 years);
- 58% men;
- 140 target liver tumours;
- 78% colorectal cancer metastases;
- 87% performed with robotic guidance;

Analysis of dynamic contrast enhancement curves

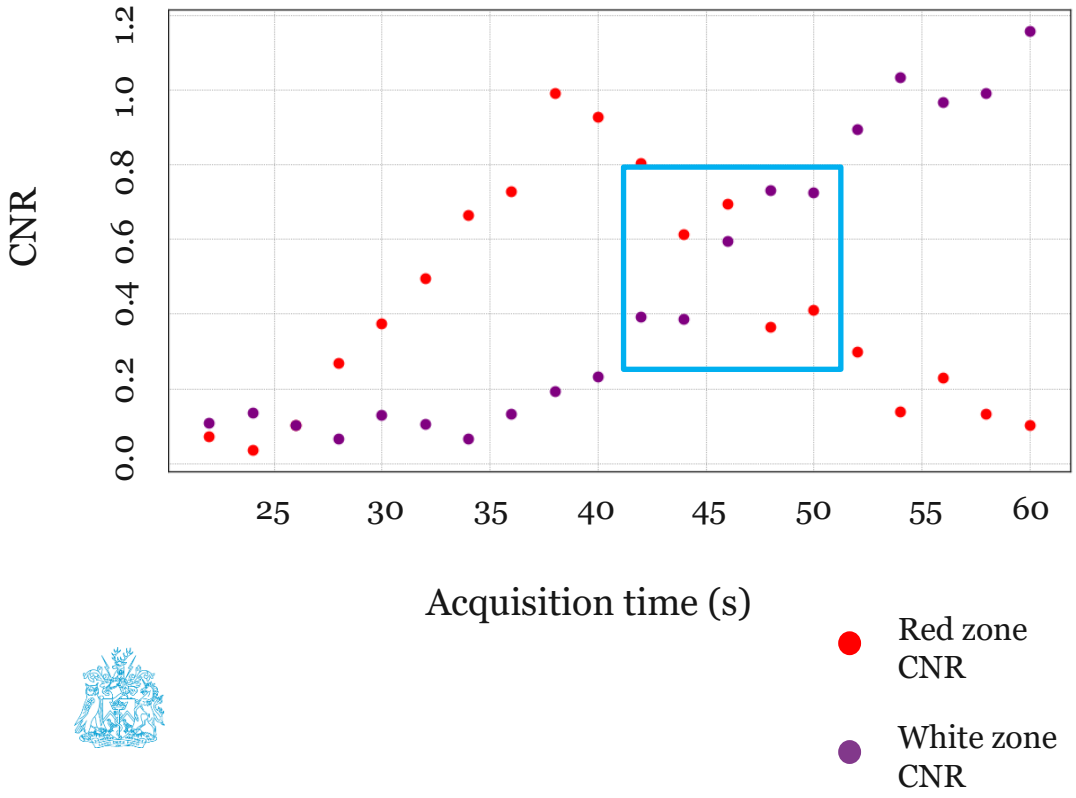
Typical enhancement curve



Analysis of CNR

CNR between red zone and parenchyma and white zone and parenchyma

CNR red zone/parenchyma and CNR white zone/parenchyma

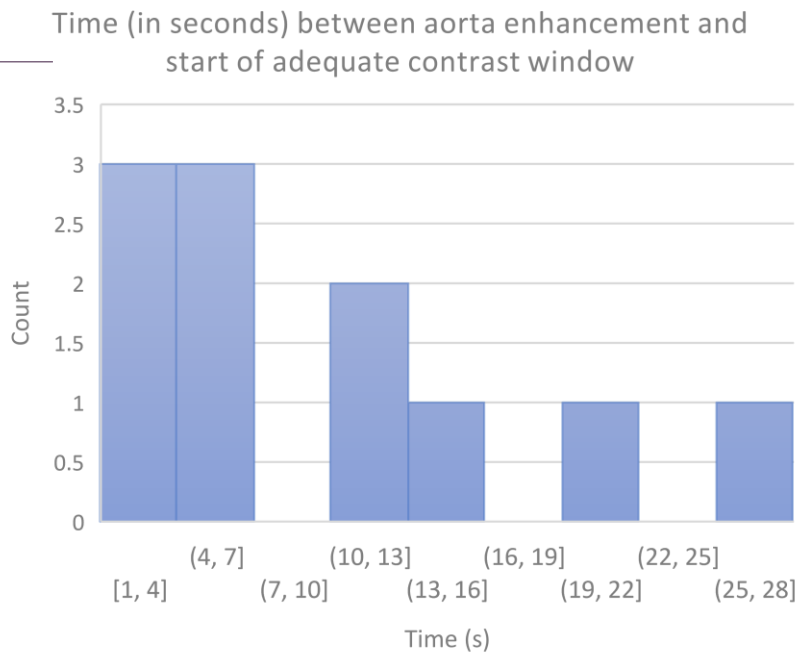


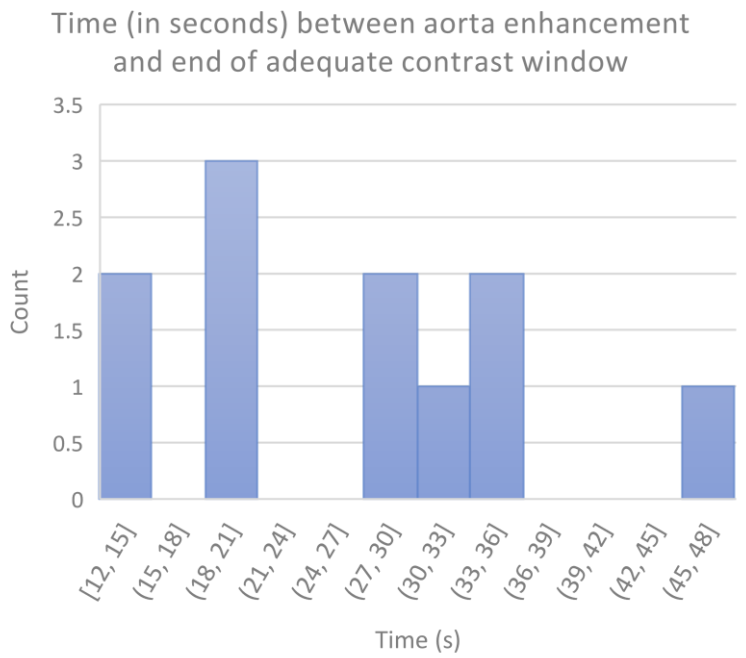
- Start and end time after contrast injection for both CNR values being above 0.4 was highly variable;
- Fixed delay protocol was not considered further.

Analysis of CNR

- Bolus tracking technique: use abdominal aorta enhancement as trigger;
- Most studies: peak aorta was at least 200 HU;
- “Adequate contrast window”:
  - Start: difference between time of peak aorta and **minimum** time where both CNRs > 0.4;
  - End: difference between time of peak aorta and **maximum** time where both CNRs > 0.4.

Analysis of CNR





- High variability:
- Some patients presented adequate contrast 1-4 seconds after peak aorta enhancement;
- Others had adequate contrast 26 seconds after the aorta had peaked.

Optimised protocol

- Based on what was observed for most patients:
  - Monitoring scan starting at 20 seconds post contrast initiation.
  - Arterial phase: delay of 12 seconds from 200 HU enhancement in the aorta or from peak aorta if 200 HU wasn't reached;
  - Venous phase: maximum discrimination between white zone and parenchyma (delay of 29 seconds).

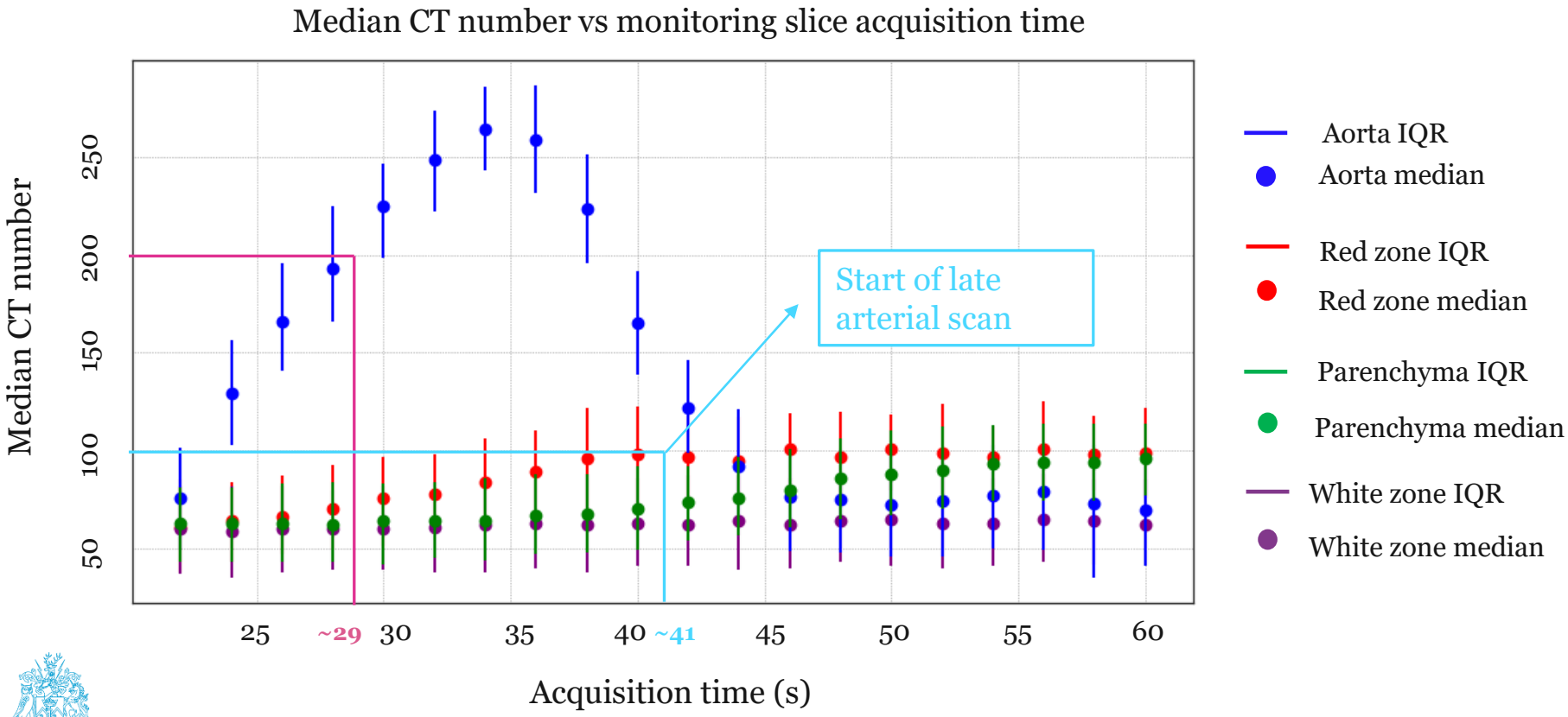
Optimised protocol

Current protocol used for the liver microwave ablation of patients in the optimised cohort

Parameter	Probe placement phase	Late arterial phase	Portal venous phase
Mode	i-Spiral	Spiral	Spiral
kV	120	120	120
Qref mAs†	170	170	170
Rotation time	0.5 s	0.5 s	0.5 s
Pitch	0.8	0.6	0.6
Detector configuration	32 x 1.2 mm	128 x 0.6 mm	128 x 0.6 mm
Delay	n/a	12 seconds from peak aorta	29 seconds from peak aorta
Reconstruction kernel	B30f	B20f and I30f I30f for the robot software	B20f and I30 f
Slice thickness	3 mm	3 mm	3 mm
Slice interval	3 mm	3 mm 1 mm for the robot software	3 mm
Contrast volume	n/a	100 ml Omni 350, 5 ml/s	n/a

Analysis of dynamic contrast enhancement curves

Typical enhancement curve



Qualitative image analysis in legacy control and optimised cohorts

Median visual IQ Likert score (mean of both readers)

Optimised arterial phase studies vs **legacy** control cohort

4.75 vs 2.75 for most recently ablated tumours, P < 0.0001

4.75 vs 2.75 for all tumours, P < 0.001

Optimised venous phase studies vs **legacy** control cohort

4.25 vs 2.75 for most recently ablated tumours, P < 0.001

4.00 vs 2.75 for all tumours, P < 0.0001

Conclusions, limitations, and next steps

Summary: conclusions, limitations, and next steps

Conclusions

- New protocol can assist radiologists in judging the efficacy of ablation procedures;
- Decisions regarding repeat ablation can be made with patient still on the table whilst under anaesthesia
  - ➢ Increase quality of ablations;
  - ➢ Reduce local recurrence;
  - ➢ Ultimately: improve survival.

Summary: conclusions, limitations, and next steps

Limitations

- High anatomic variability;
- Wrong timing for monitoring scans: missed peak aorta enhancement;
- Motion artefact;
- Needle artefact;
- No red zone visible.

Next steps

- Image segmentation: comparison between pre-ablation and post-ablation scans
- Assess the impact of the optimised protocol on survival

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