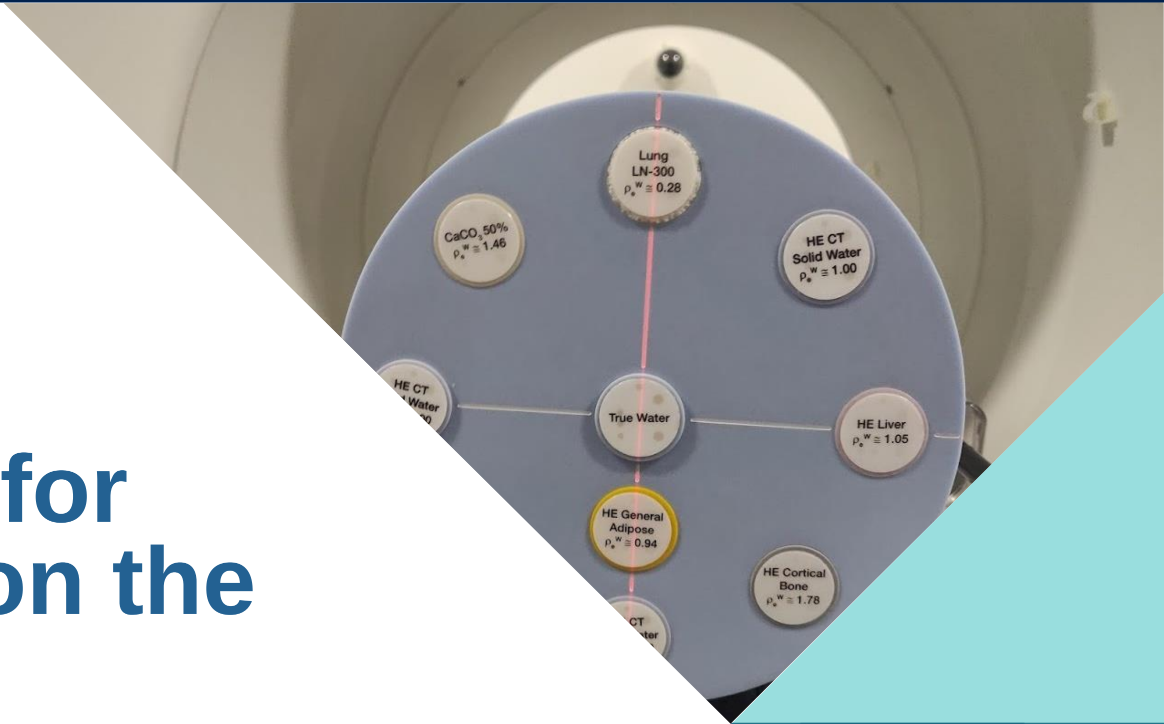

CT-density characterisation for accurate dose calculations on the Accuray Radixact system

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Disclosures

The authors have no financial interests or relationships with any of the manufacturers or vendors of equipment described in this presentation, nor with any of the commercial supporters of the EPSM Conference.

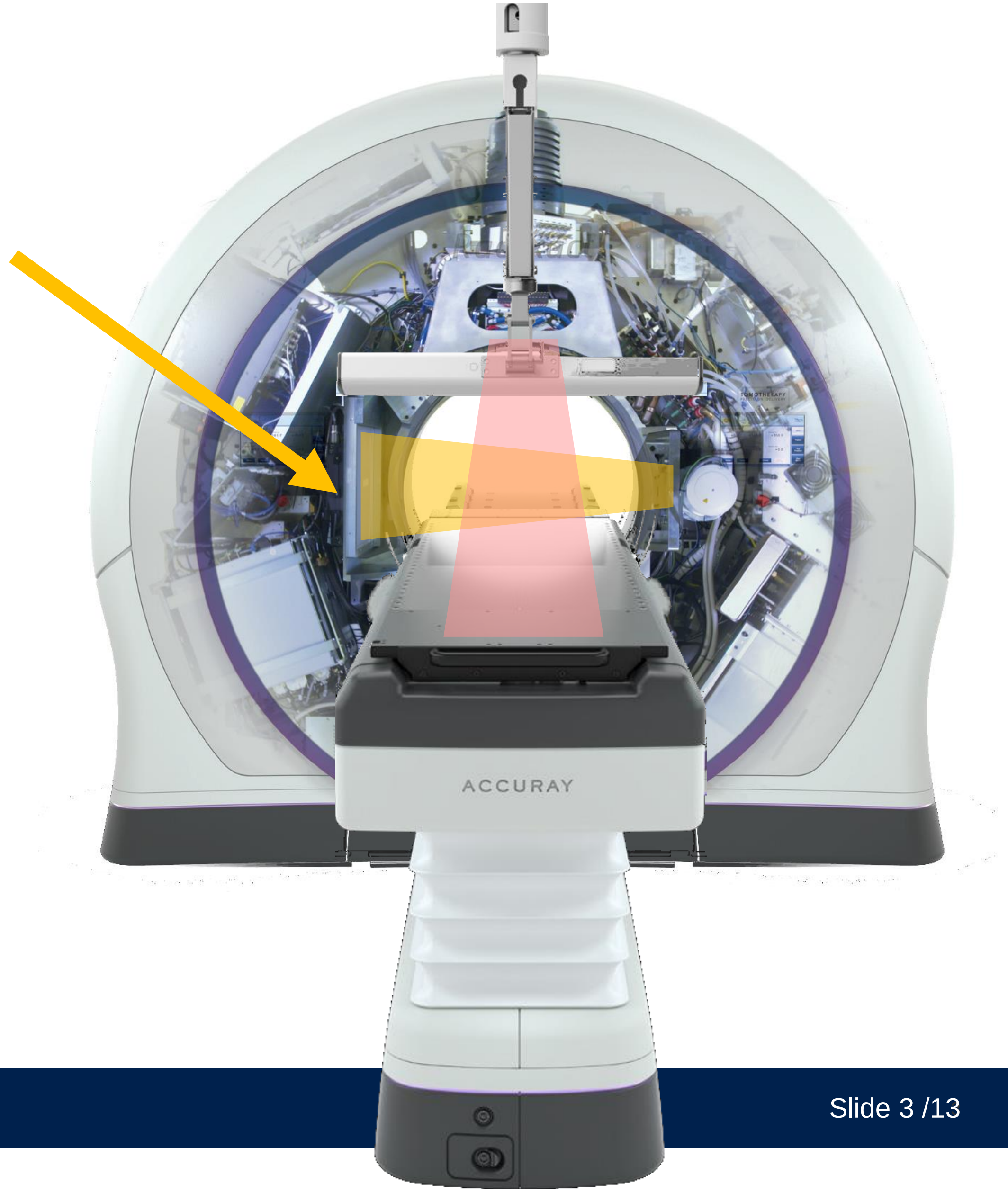
The authors acknowledge the Radiation Oncology Princess Alexandra Ipswich Road physics team for lending the Sun Nuclear Advanced Electron Tissue Density Phantom used in this study.

Accuray Radixact system

The replacement of TomoTherapy Hi-Art systems with the new Radixact system brought with it on-board kV imaging, ClearRT, complementing existing MV imaging.

This has allowed:

- Faster CT image acquisition, providing a significant improvement for e.g. long craniospinal treatments.
- Improved soft tissue contrast from the use of 100-140 kV compared to ~3.5 MV.
- Real-time online adaptation using radiographs acquired during imaging with Synchrony.



Adaptive dose calculations

Another application of this data is for offline adaptive planning using the PreciseART system, allowing fraction dose calculation and summation, and replanning.

An accurate CT-density relationship is critical.

To account for differences in the CT-density relationship, ten “density models” are used for different imaging protocols, i.e., combinations of energies, field of view (determining filter), and “mode” (beam width and pitch).

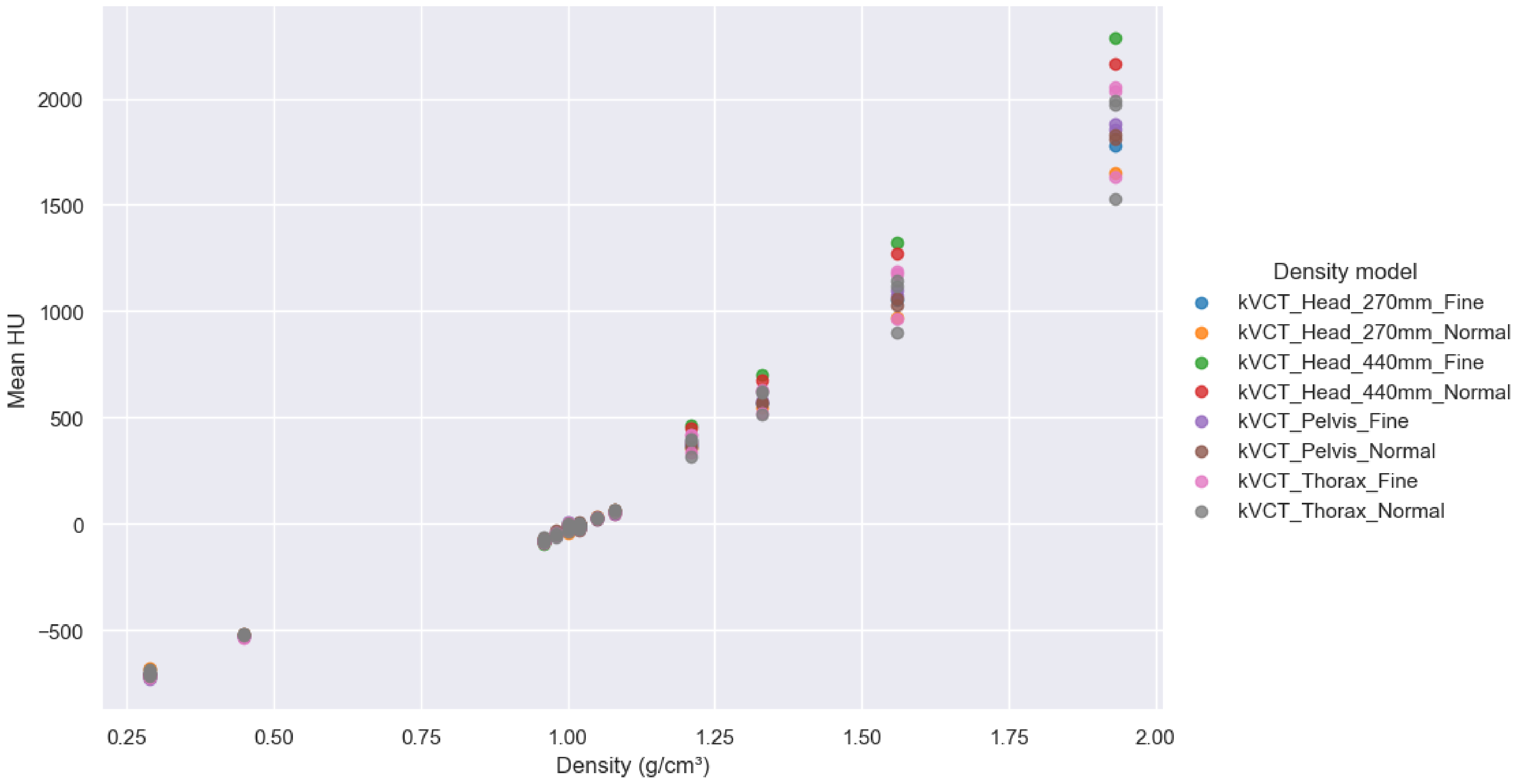
Energy (kVp)	FoV (mm)	Beam width (mm)
100	270	50
100	270	100
100	440	50
100	440	100
120	270	50
120	270	100
120	440, 500	50
120	440, 500	100
140	440, 500	50
140	440, 500	100

Do you need so many density models?

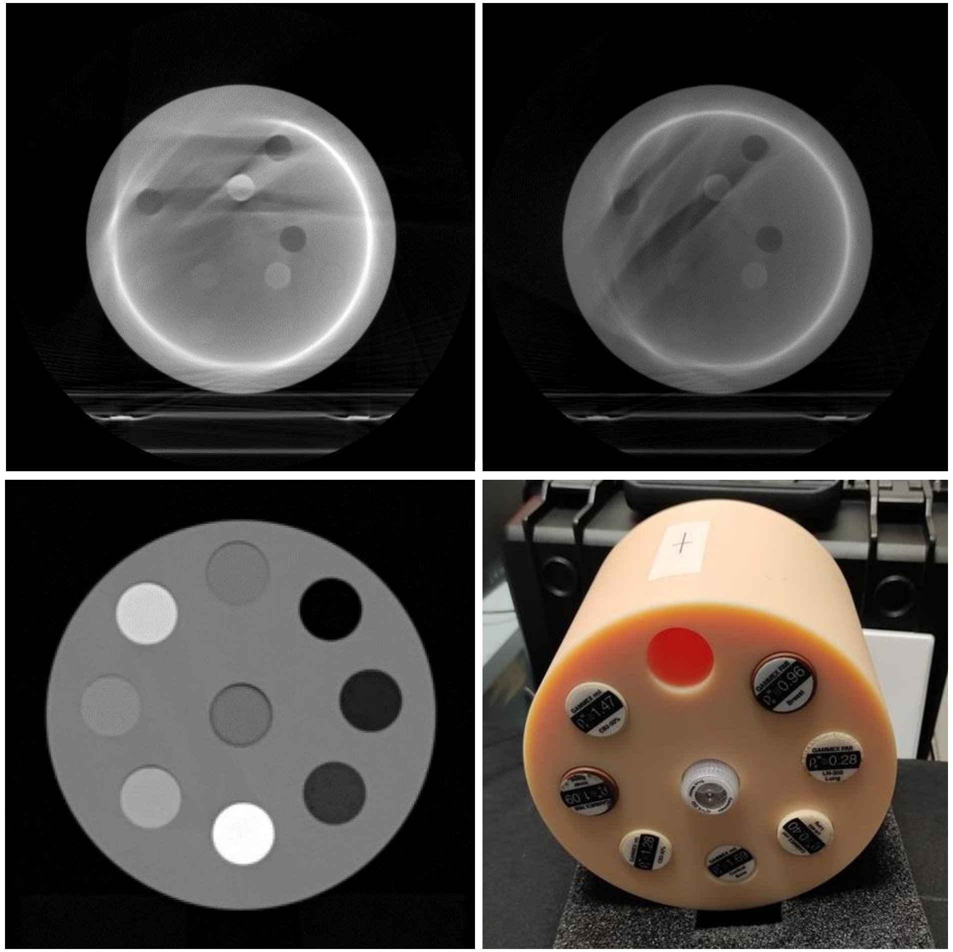
For calculation of dose, yes.

Results shown on right for single phantom scanned with 8 protocols.

HU variations in bone would be large if a single model was used.



Simple, so why present on this?



Our department uses the Gammex Model 472 phantom – 5 cm thick, 33 cm diameter, holes for 16 plugs. However, it doesn’t scan very well, as the reconstruction algorithm uses data 2 cm superior and inferior to the beam as scatter correction.

The ClearRT beam is 5 or 10 cm wide at isocentre.

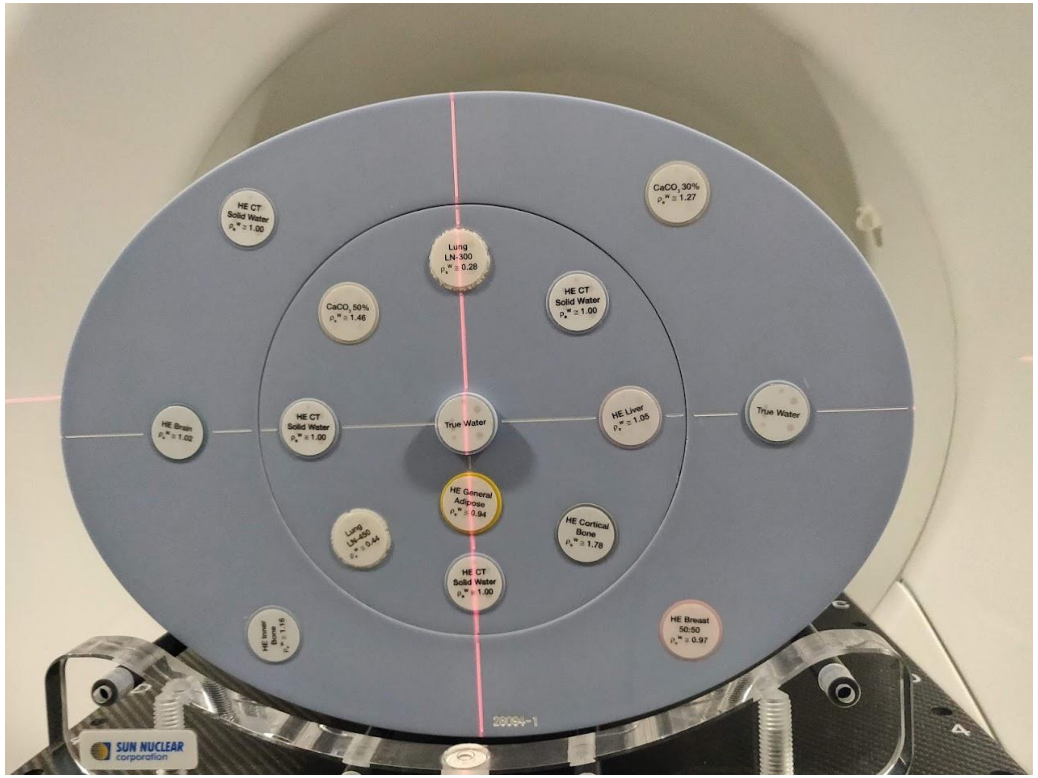
Similar but less significant artefacts occur when using the larger vendor-supplied TomoPhantom, because the inserted length of the Gammex plug is still only 6 cm.

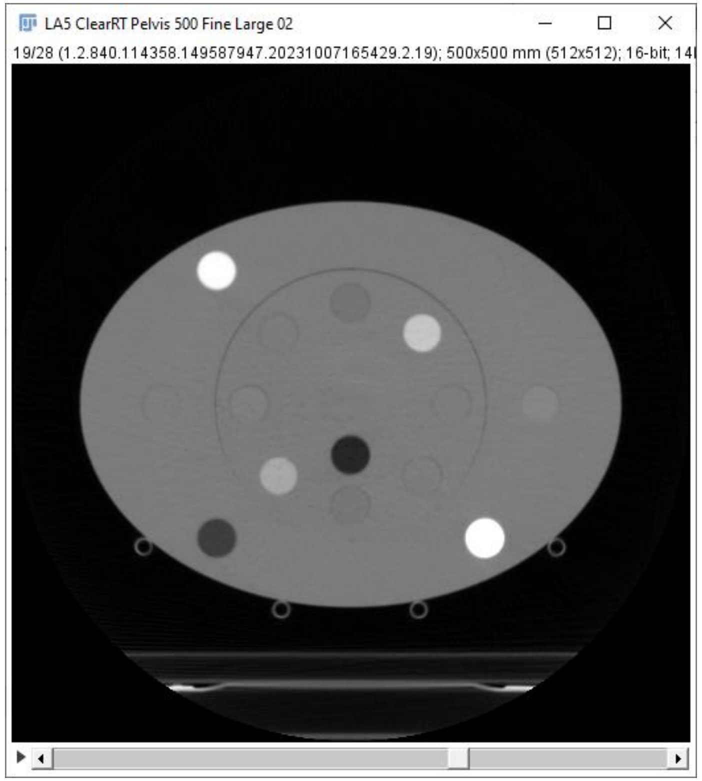
Enter 3D printing. We produce a phantom using resin, able to fit plugs back-to-back, giving us 14 cm.

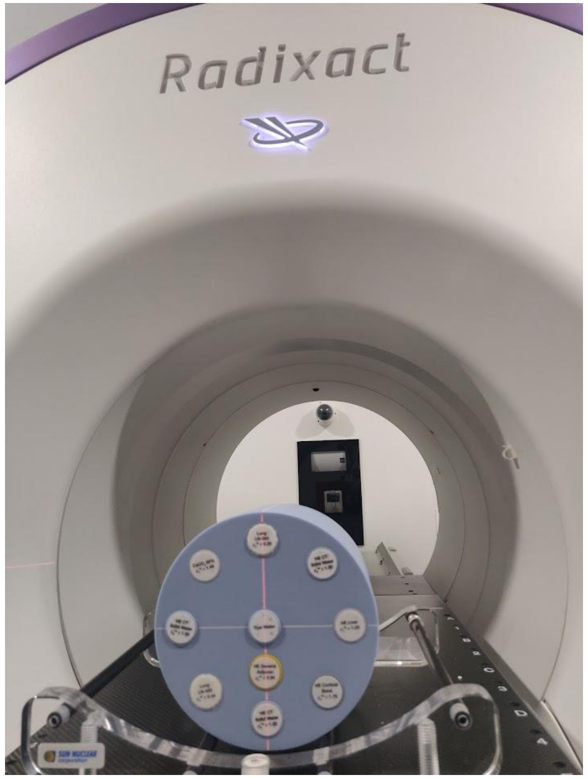
The resin is a bit denser than water, so we decide to compare against a borrowed SNC phantom.

SNC Advanced Electron Density phantom

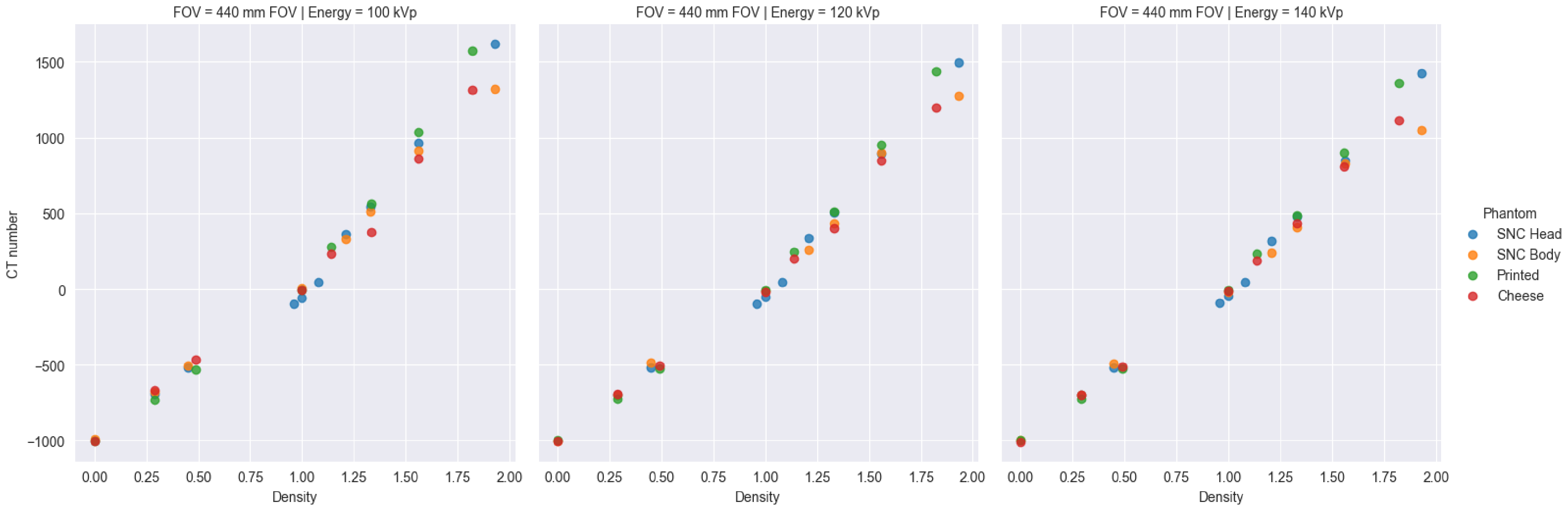
Which is this beautiful one, incidentally also the one that Accuray advise you to use for this. We unfortunately don’t have the budget for one right now. Can we make do with the printed phantom?







Three protocols, four phantoms



Not so simple! We have ~400 HU differences for the bone plugs and ~35 HU differences for water plugs in different phantoms, presumably due to beam hardening effects. Similar, but smaller effects can be seen on CT simulators.

Managing the potential errors

This could be managed, if we are able to ensure the phantom used for calibration is representative of anatomy imaged using a protocol.

For large field of view pelvis/thorax protocols – use the large phantom.

For the small field of view head protocol – use the small phantom.

What about for the large field of view head protocol?

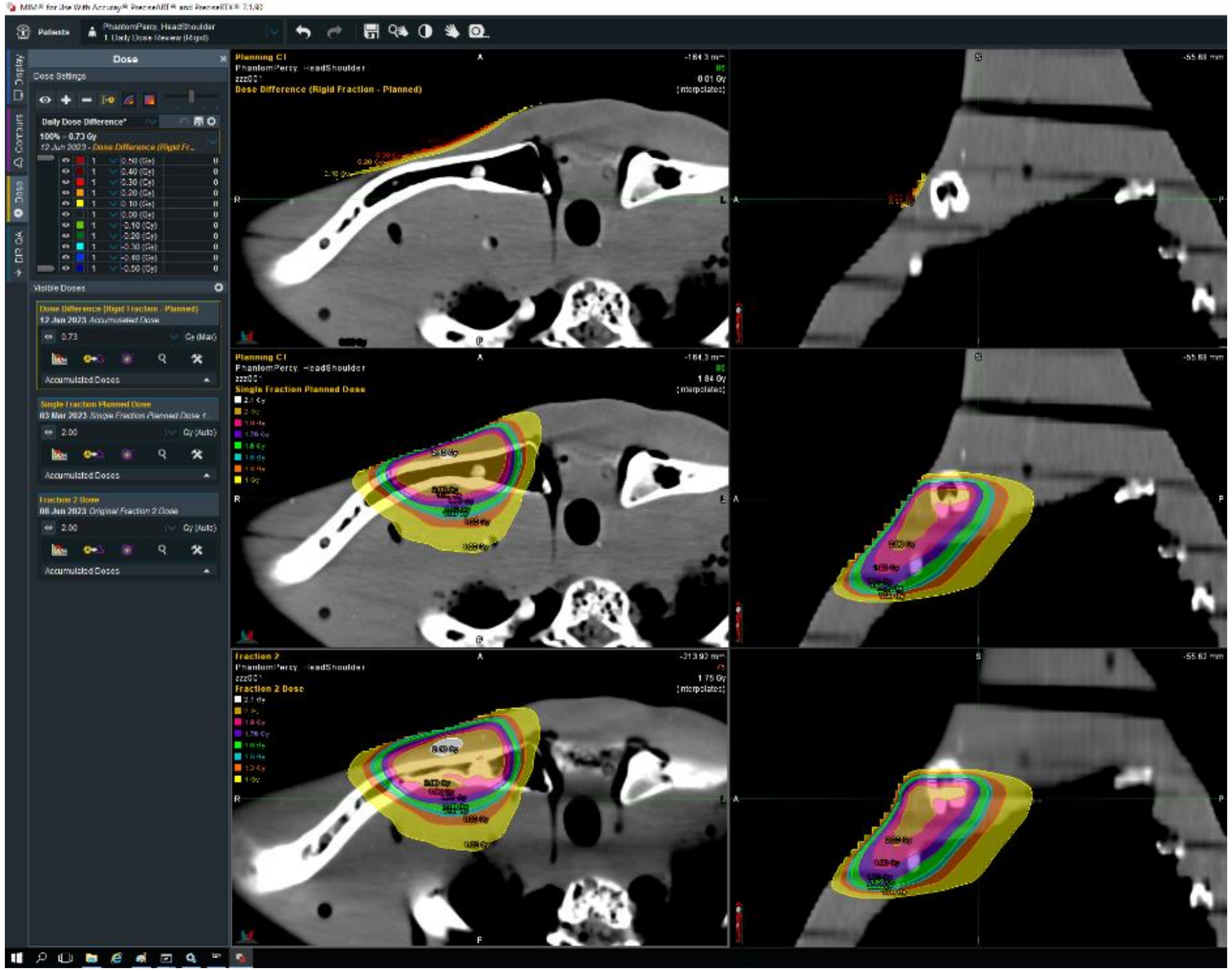
Dosimetry study

Around 40% of our Radixact workload is head and neck, particularly bilateral.

A large field of view is often used if there is a concern about truncation of shoulders for a treatment involving the clavicular region, or due to patient positioning.

We planned and delivered a treatment to the clavicular region of an anthropomorphic RANDO phantom.

Dose differences of up to 15% could be observed due to differences in HU calibration at superior-inferior air-tissue interfaces.



Starting over …

Potential solutions would be use small phantom calibration for 440 mm FOV head protocol.

For H&N treatments extending inferiorly, advise RTs to select head protocol for accurate head calculations, or thorax protocol for accurate shoulder calculations. Or perhaps split the difference in some way.

During these discussions, in great news for Radixact users (albeit frustrating for the project team), Accuray released a software upgrade which improved beam hardening corrections and HU accuracy for high density materials.

We need to borrow equipment again …

ACCURAY

Product Marketing Bulletin

ClearRT™ Enhanced Imaging

Radixact® Treatment Delivery System Software Version 3.0.2

The purpose of this Product Marketing Bulletin is to provide an overview of new software and hardware available for the Radixact® System.

Overview of this release

The primary purpose of this release is to provide enhancements to ClearRT™ helical fan-beam kVCT imaging functionality on the Radixact System, address anomalies from prior versions of the Radixact System and maintain compatibility with the Accuray Precision® Software and iDMS® Data Management System.

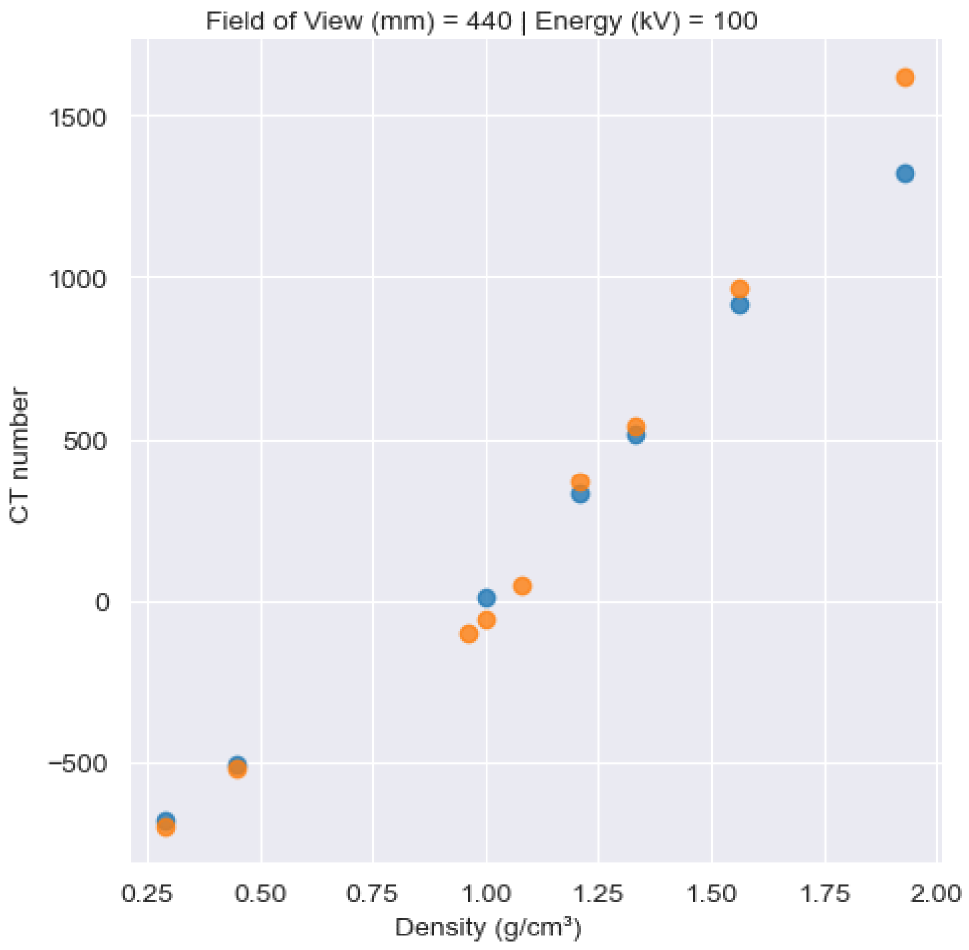
What new functionality has been introduced in this release?

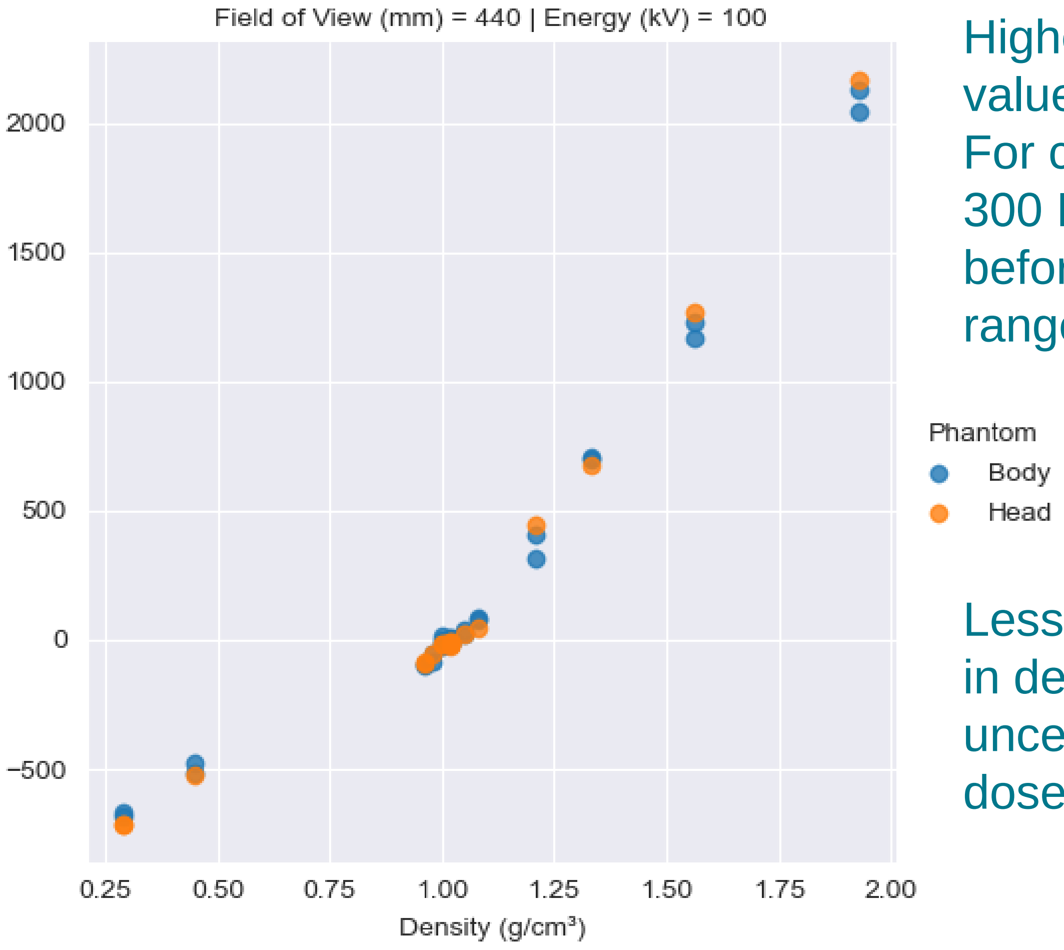
ClearRT Enhanced Imaging

This release supports imaging enhancements for ClearRT helical fan beam kVCT imaging. Enhancements include:

- Bone beam hardening correction to reduce beam hardening artifacts caused by high-density material such as teeth and bones
  - Reduction of dark band artifacts between high-density regions resulting in improved soft-tissue visibility between the regions and improved HU uniformity for dose calculation accuracy
  - Reduction in calcium-blooming artifacts caused by artery calcifications
  - Improved HU accuracy for high density materials for improved density table calibration and dose calculation accuracy

Before and after upgrade





Higher HU values overall. For cortical bone, 300 HU range before, 150 HU range after.

Less uncertainty in density is less uncertainty in dose.

Conclusions

The results of the study highlighted the importance of using protocol specific CT-density calibrations, appropriate phantoms for each protocol, and protocols with appropriate FOVs and scan lengths for patients, to minimise adaptive dose calculation errors.

The software upgrade reduced the potential errors.

This allows greater utilisation of the offline adaptive PreciseART mode, not just as a tool to trigger reimaging and replanning, but as a tool for dose accumulation studies.

We've also ordered an SNC phantom ☺

Bonus photo! Sad attempt to make a phantom using a plant pot, 3D printed negative plugs, and poured epoxy resin.