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San Raffaele

Spatial resolution characteristics of a clinical Photon-Counting Computed Tomography scanner

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26th International Workshop on **Radiation Imaging Detectors**



Bratislava, Slovakia

Aim of this work



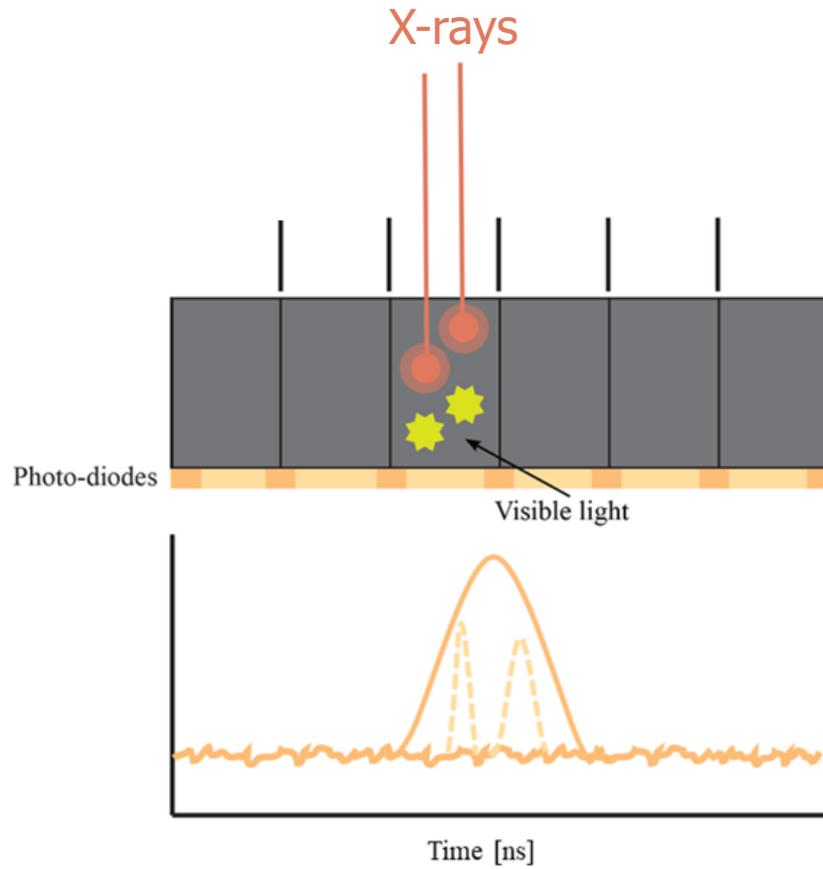
To provide an assessment of the in-plane spatial resolution of a clinical PCCT using previously validated methods

Introduction - PCCT

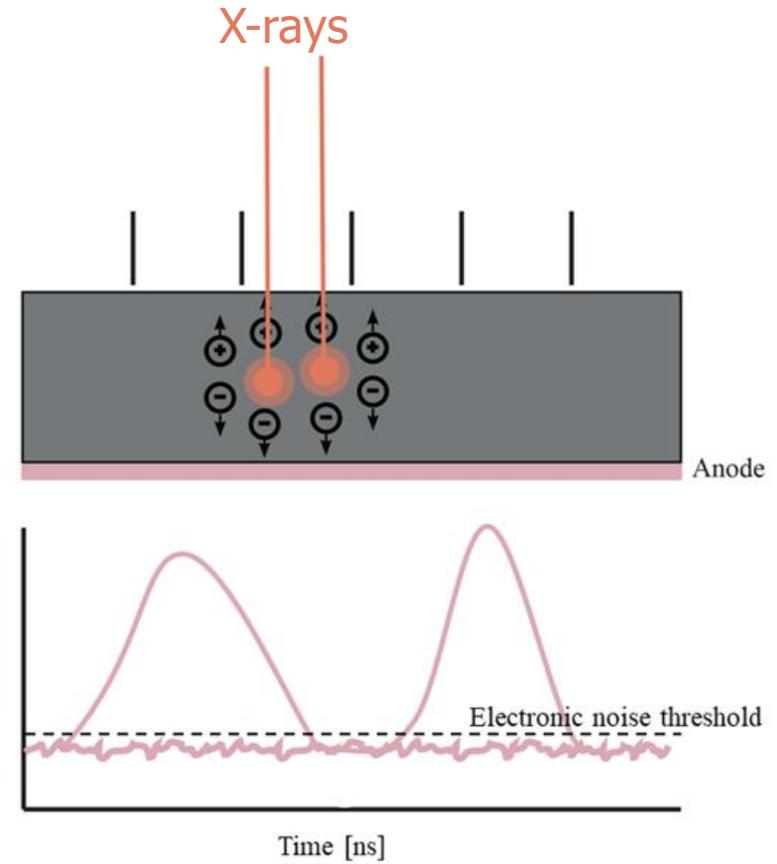


- Photon Counting Computed Tomography (PCCT) is a new technique that have the potential to overcome energy integrating detectors (EIDs) CT.
- This work was conducted using the Siemens Naeotom Alpha® PCCT installed at IRCCS San Raffaele Scientific Institute (Milan, Italy)

Introduction – Photon Counting Detectors



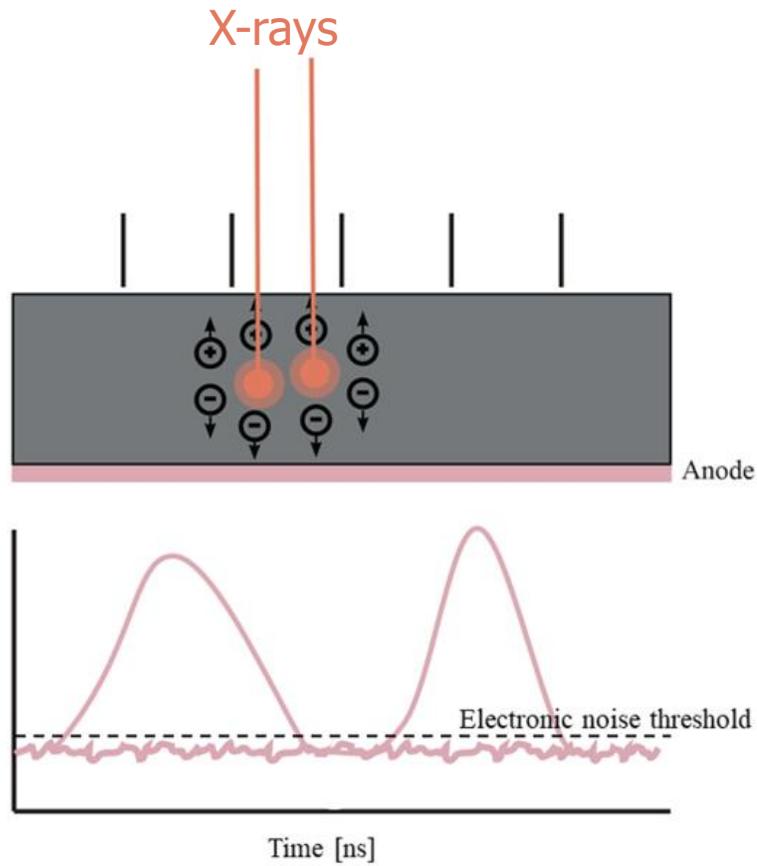
Energy Integrating Detectors



Photon Counting Detectors

van der Bie et al., *Eur J Radiol* (2023)

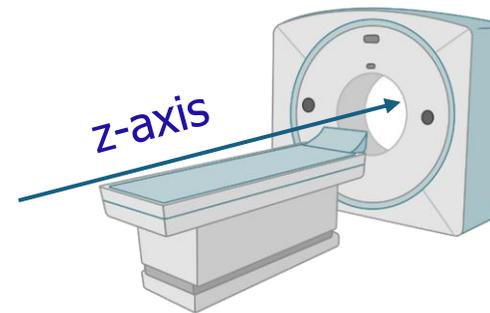
Introduction – Photon Counting Detectors



Photon Counting Detectors

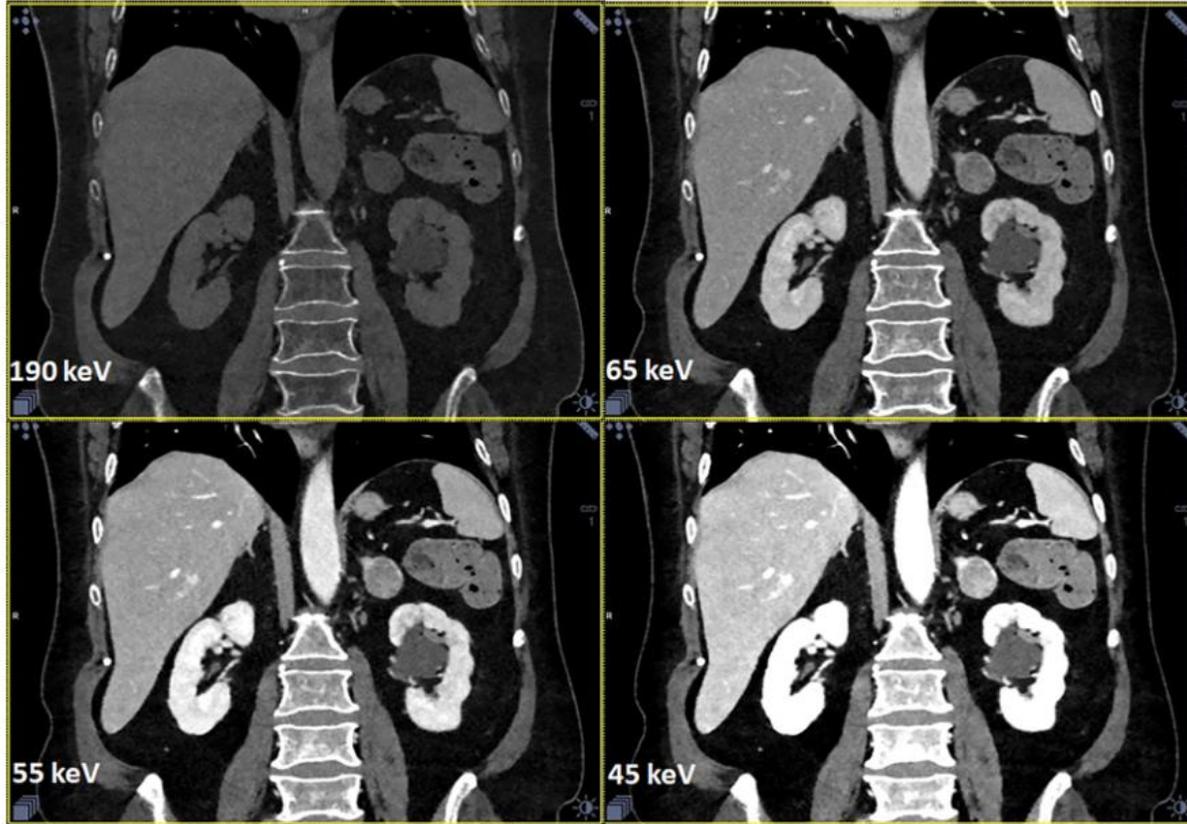
PCCT is provided with QuantaMax detectors:

- CdTe (Cadmium Telluride);
- Pixel size at the isocenter: 0.15 x 0.27 mm
- Longitudinal z-coverage: 144x0.4 mm and 120x0.2 mm



Flohr et al., *Phys Med* (2020)
van der Bie et al., *Eur J Radiol* (2023)

Introduction - PCCT



Flohr et al., *Phys Med* (2020)

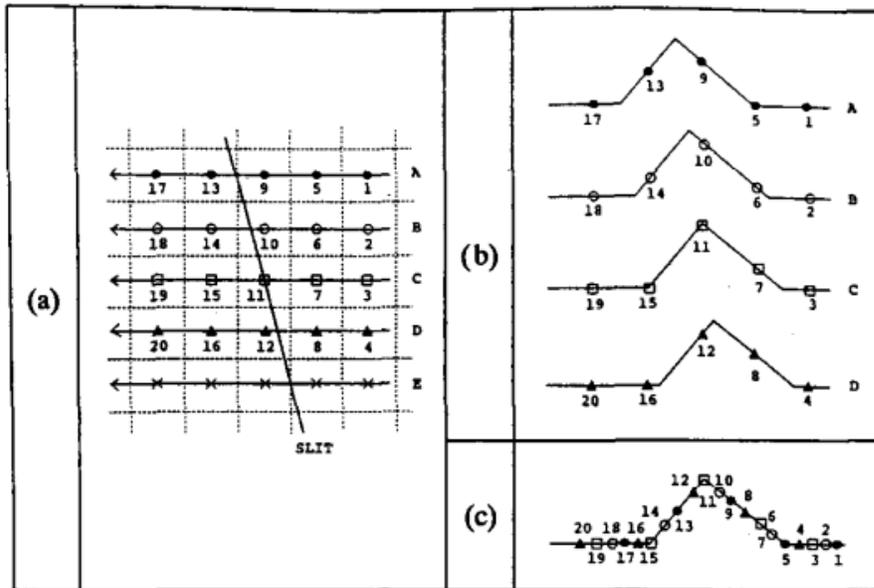
Advantages of PCDs for CT applications:

- Reduced electronic noise (energy threshold);
- Improved spatial resolution;
- Low-dose imaging (e.g. lung screening);
- Multi-material decomposition through spectral analysis (VMIs, VNCs...)

Theoretical background

- The Modulation Transfer Function (MTF) provides a detailed description of the spatial resolution of a CT system.
- MTF can be measured from the Point Spread Function (PSF) using an object which is thinner than the resolution of the scanner

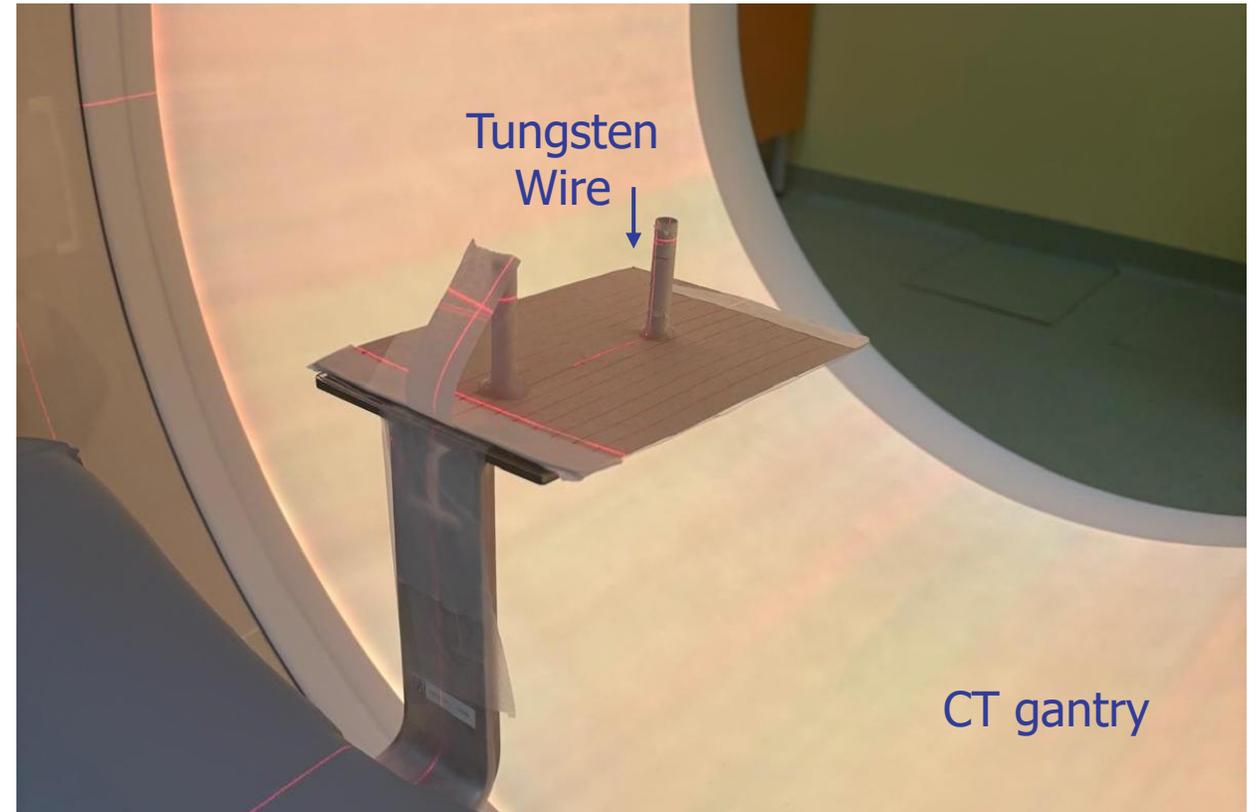
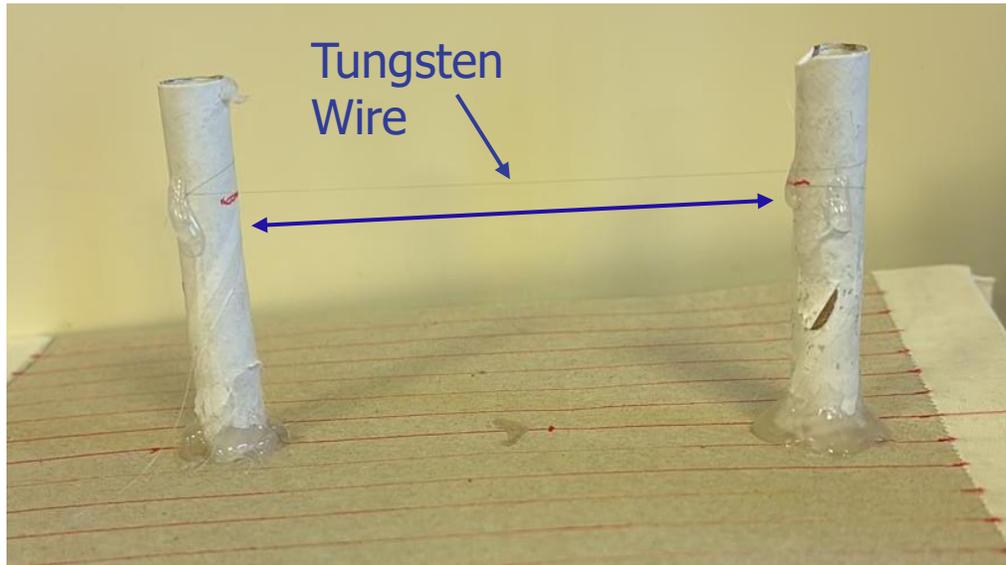
We used a 99.95% pure tungsten (W) wire (diameter of 0.0125 mm)



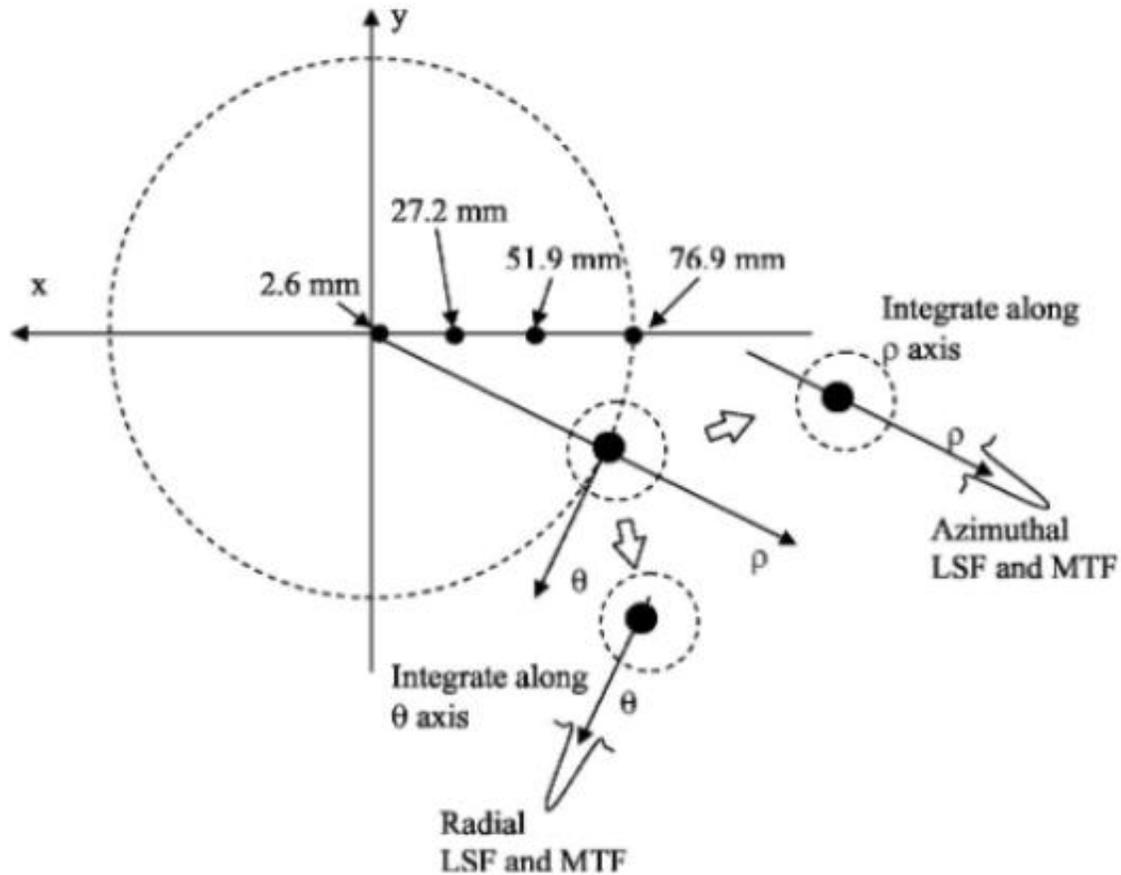
The wire was tilted of about 3° in the coronal plane to obtain the pre-sampled MTF

Boone J. M. et al., *Med Phys* (2001)
Fujita H. et al., *IEEE Trans on Med Im* (1992)

Materials and Methods: Experimental Setup - 1

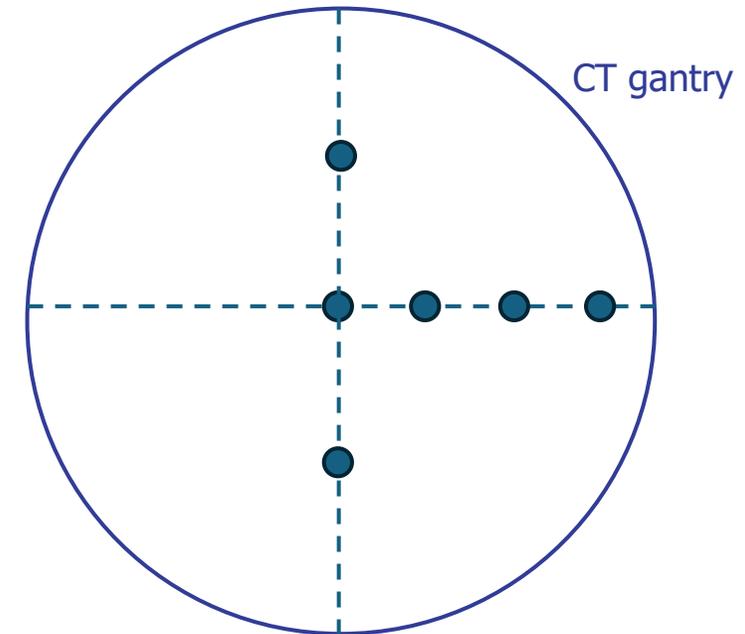


Materials and Methods: Experimental Setup - 2



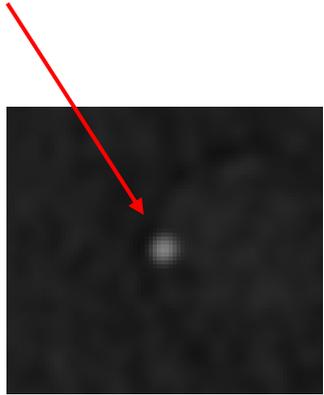
Yang et al., *Med Phys* (2007)

- The wire was positioned at the isocenter of the gantry ($x = 0, y = 0$), and at $x = +2, +4, +6$ cm $y = \pm 5$ cm respect to the isocenter

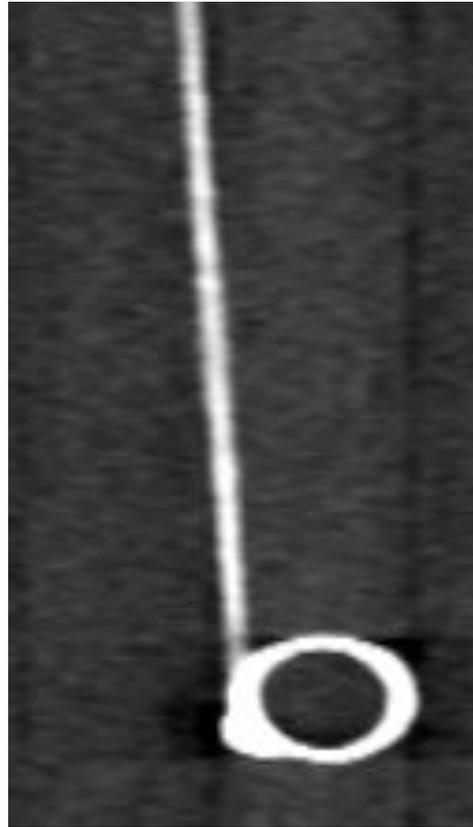


Acquisition positions of the wire in the CT gantry

Materials and Methods: Acquisition Protocols



Axial view



Coronal view

We focused on three acquisition protocols:

- Head;
- Abdomen/Thorax;
- Inner ear (144x0.4 mm and 120x0.2 mm)

Images were reconstructed with iterative algorithms:

- Head: Hr40, Hr60, Hr76, Hv40, Hv60, Hv76
- Abdomen: Br40, Br60, Br76, Bv40, Bv60, Bv76
- Inner Ear: Hr84, Hr89, Hv84, Hv89

Materials and Methods: Software analysis



- We selected ~ 30 slices where the wire was visible and cropped them around it with a 16x16 ROI
- The ROI was integrated along y direction to obtain PSF(x)
- For each slice, a matrix of profiles was built to obtain the pre-sampled PSF
- PSF was normalized to its area
- FFT was performed on PSF to obtain the MTF

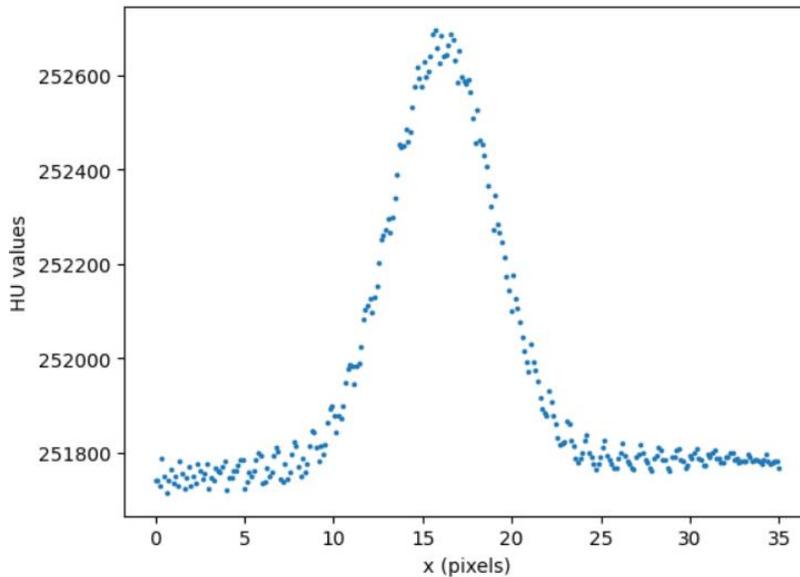
```
LSF_matrix = df.to_numpy()
LSF_matrix = np.flipud(LSF_matrix)
print(range(LSF_matrix.shape[0]))
LSF_campionata = []
for col in range(LSF_matrix.shape[1]):
    for row in range(LSF_matrix.shape[0]):
        LSF_campionata.append(LSF_matrix[row, col])
df_campionato = pd.DataFrame(LSF_campionata, columns=["Valori"])
```

Pre-sampling
process

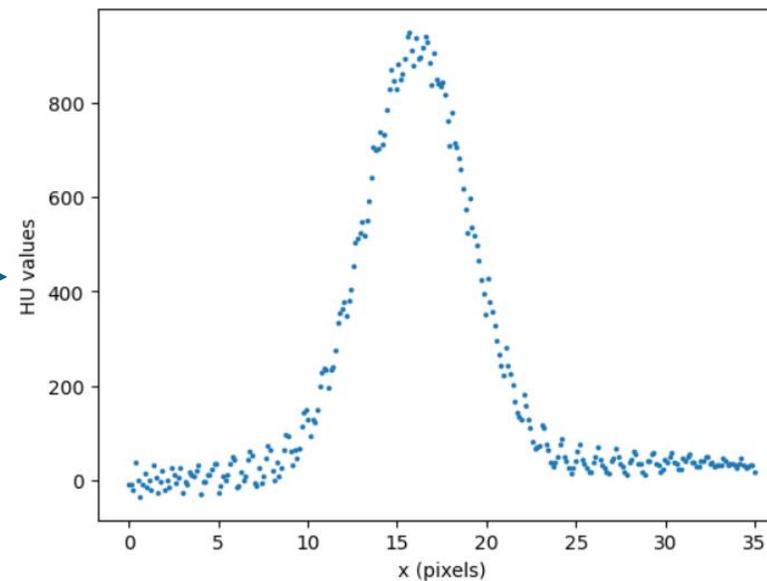
Materials and Methods: Software analysis



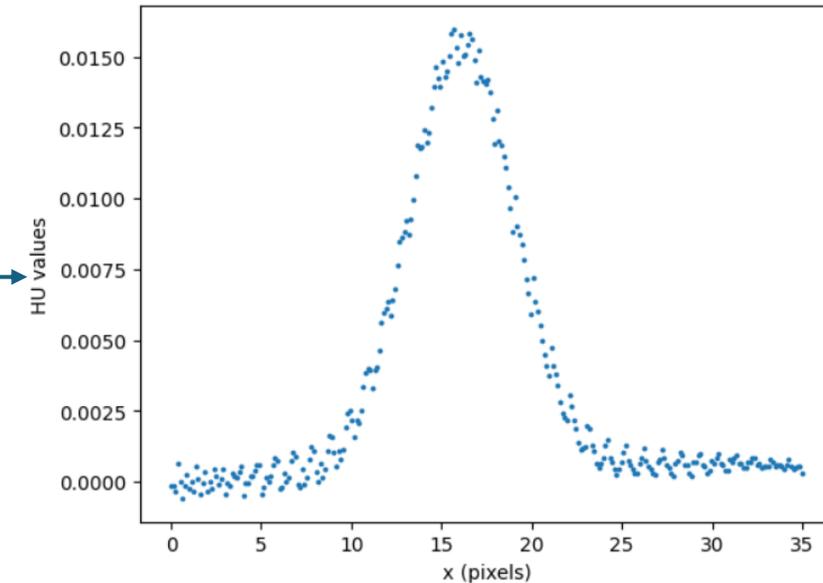
Processing of the measured PSF to obtain the MTF



Integrated pre-sampled PSF



Tails are subtracted to have zero average



The curve is normalized to its area

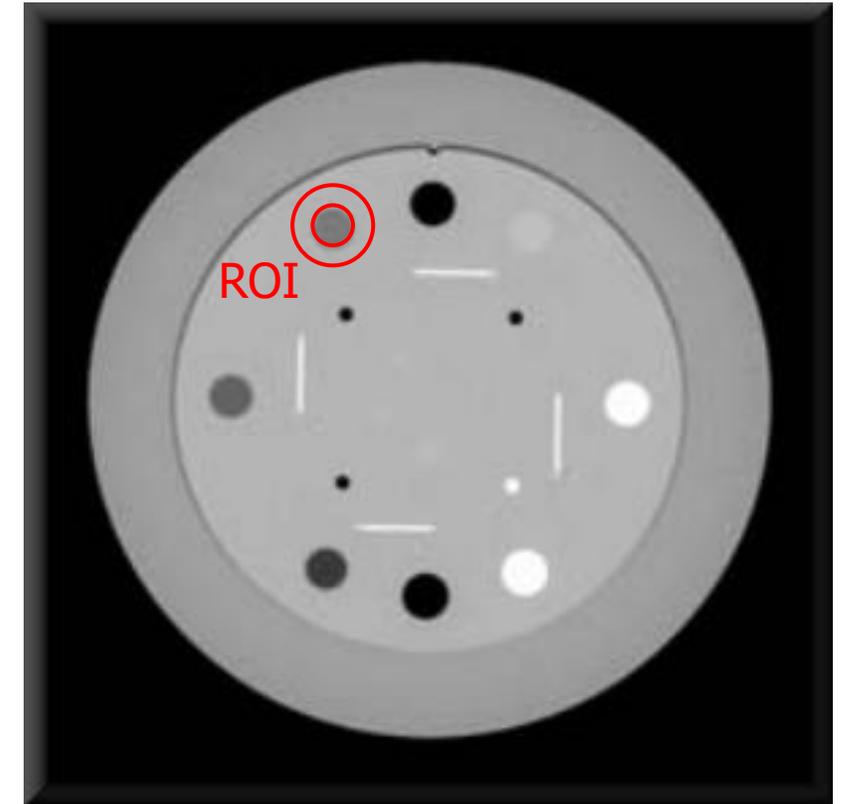
Materials and Methods: TTF

Iterative Reconstruction algorithms are non-linear:

- MTF measured with the tungsten wire is not sufficient when dealing with non-linear reconstructions;
- Target Transfer Function provides a more accurate description of the spatial resolution related to a specific contrast object

Analysis was performed via ImQuest software (Duke University)

<https://gitlab.oit.duke.edu/railabs/SameiResearchGroup/imquest>



Catphan600 Phantom

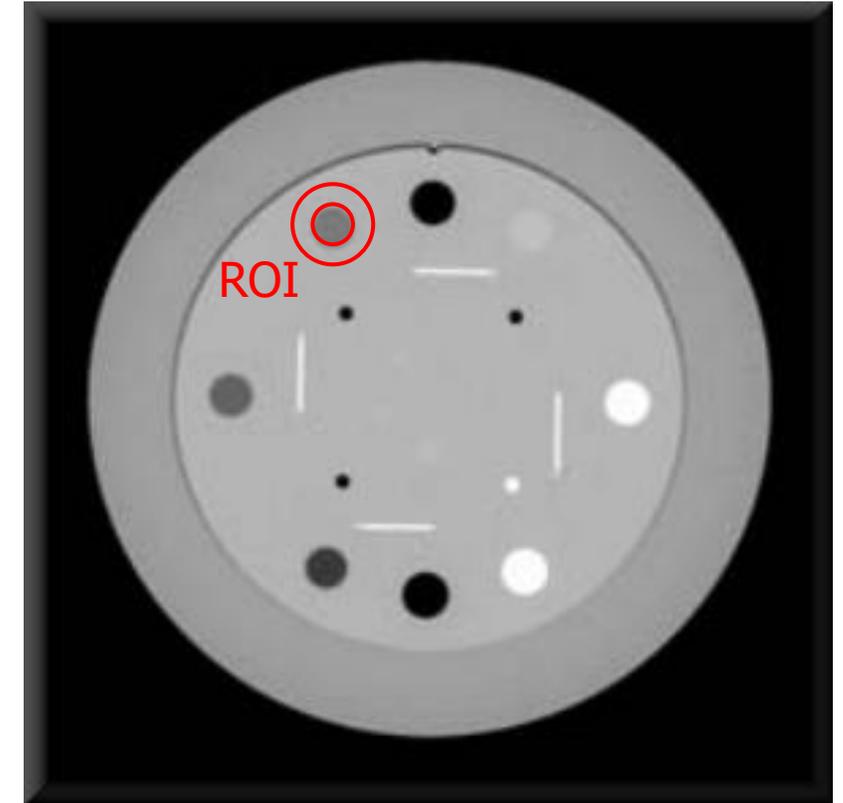
Materials and Methods: TTF

The phantom was acquired with three clinical protocols:

- Abdomen/Thorax (Standard vs Flash; Standard vs UHR);
- Head;
- Inner Ear (Standard vs UHR)

Analysis was performed via ImQuest software (Duke University)

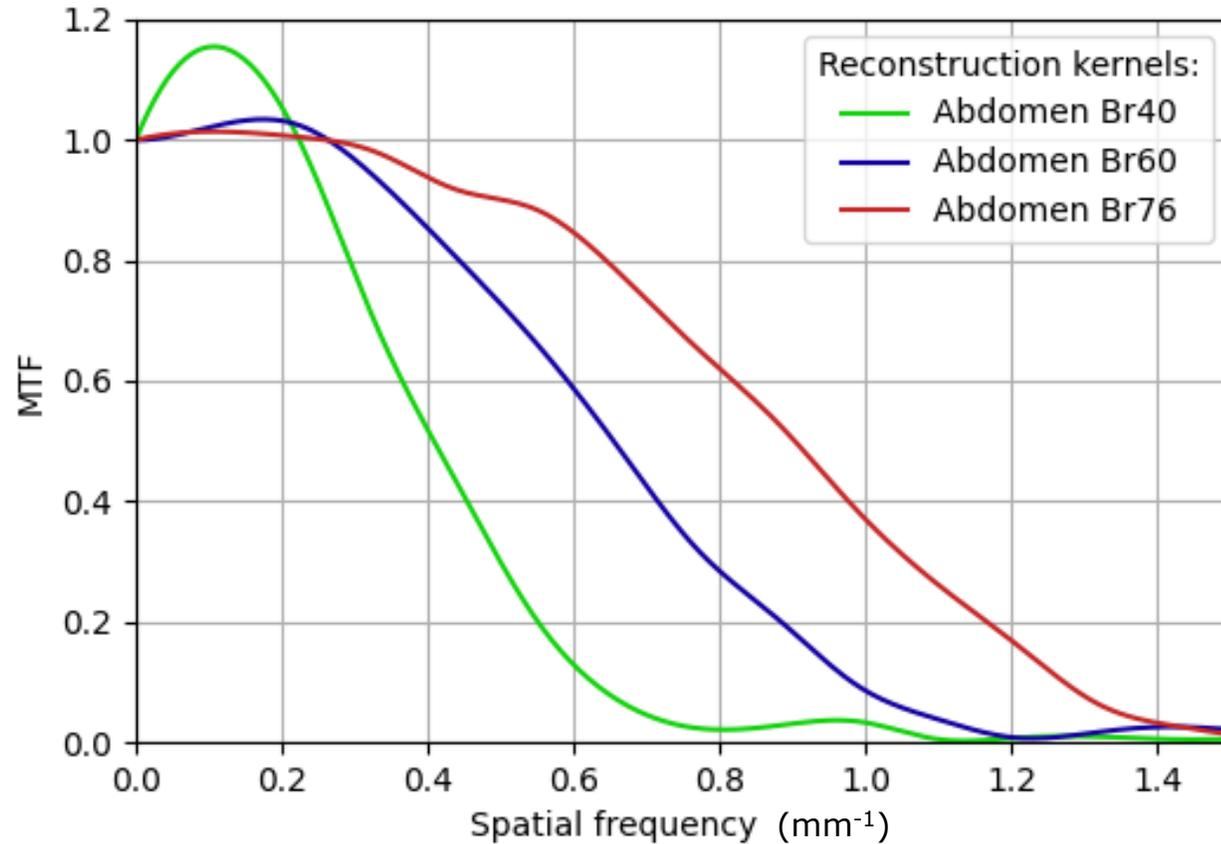
<https://gitlab.oit.duke.edu/railabs/SameiResearchGroup/imquest>



Catphan600 Phantom

Results - 1

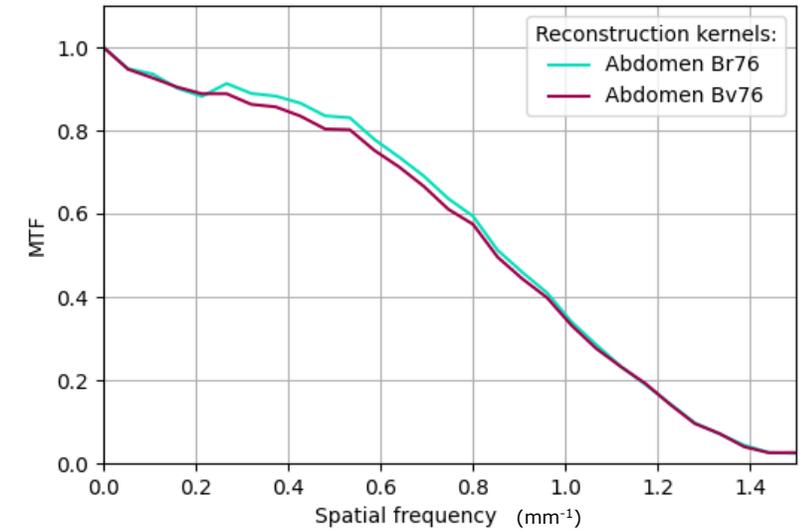
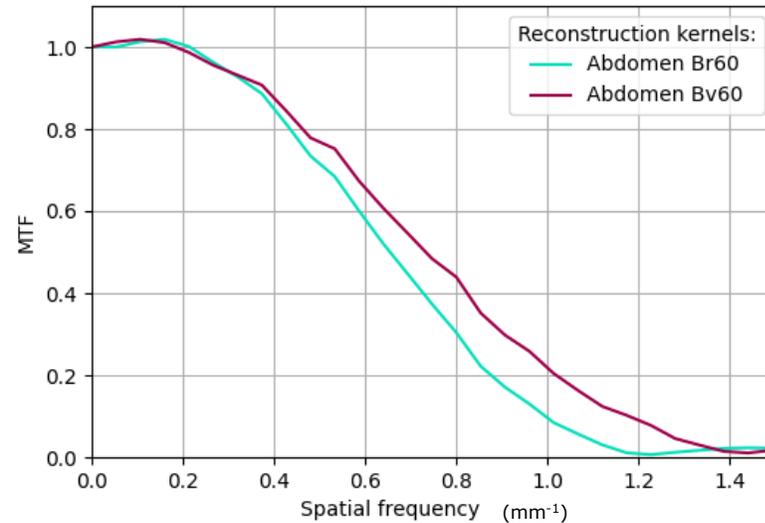
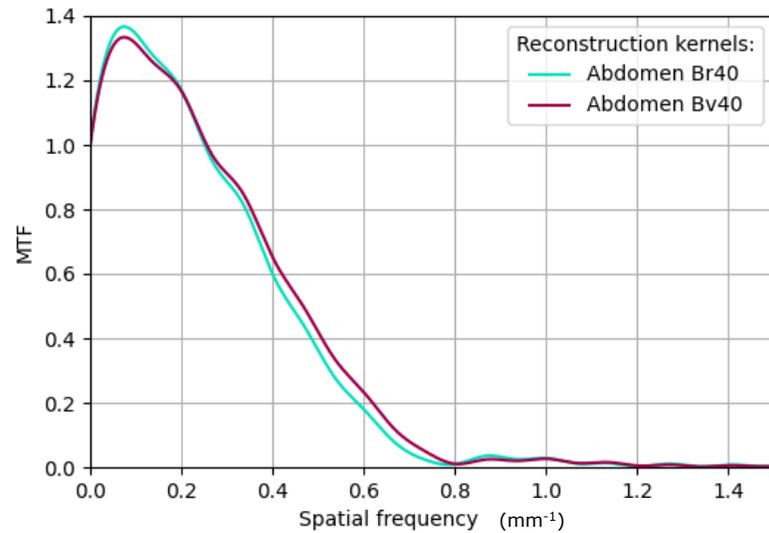
MTF for abdomen/thorax protocol at increasing sharpness of the reconstruction kernel



	Br40	Br60	Br76
$f_{50\%}$ (mm ⁻¹)	0.40	0.65	0.90
$f_{10\%}$ (mm ⁻¹)	0.62	0.98	1.27

Results - 1

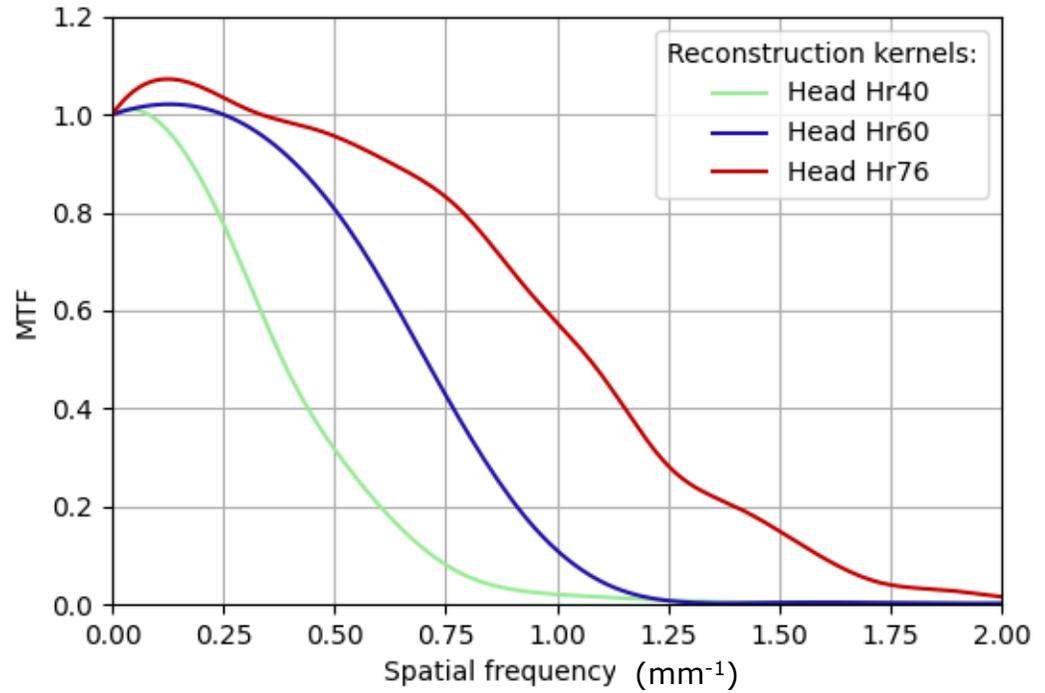
MTF for abdomen/thorax protocol: comparison of standard and vascular kernels



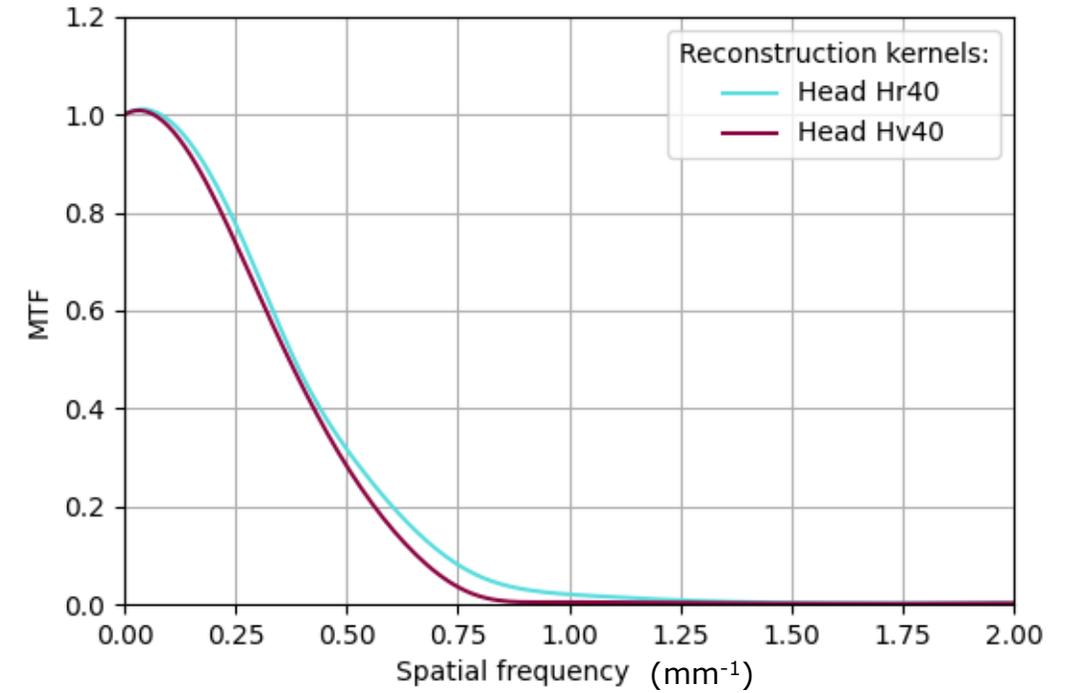
	Br40	Bv40	Br60	Bv60	Br76	Bv76
$f_{50\%}$ (mm ⁻¹)	0.40	0.47	0.65	0.74	0.90	0.85
$f_{10\%}$ (mm ⁻¹)	0.62	0.67	0.98	1.14	1.27	1.27

Results - 2

MTF for head protocol



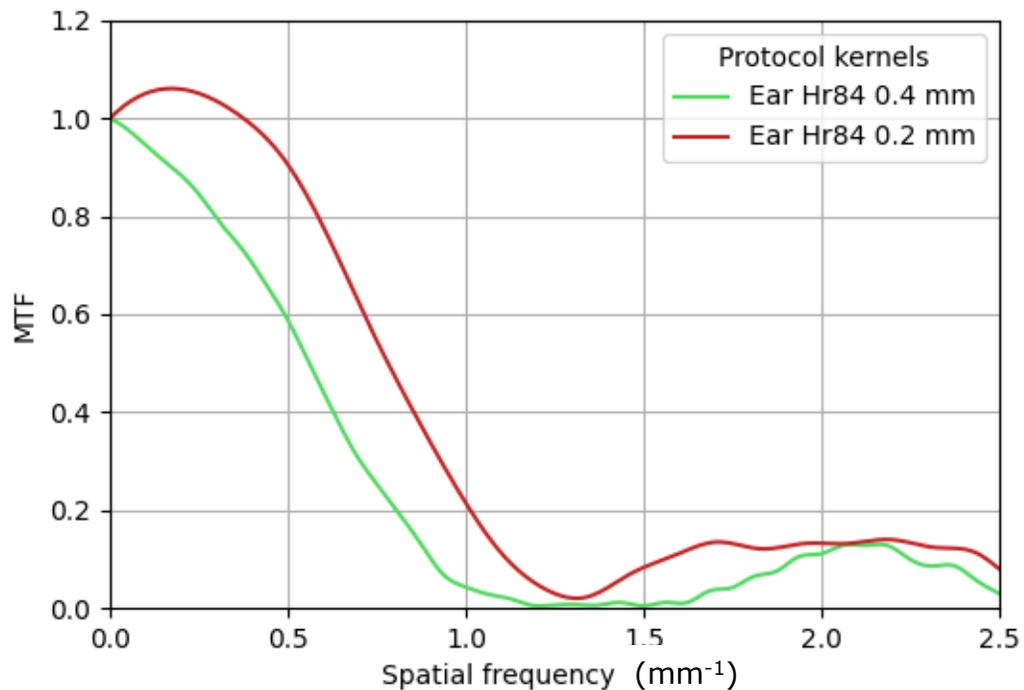
Increasing kernel sharpness



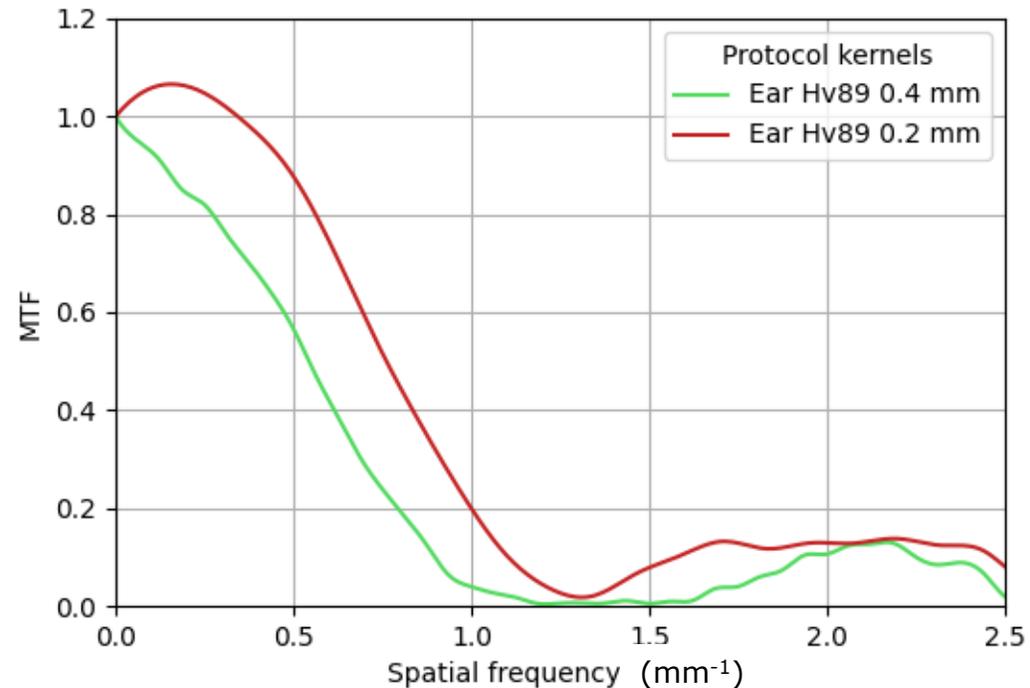
Comparison between standard and vascular kernel

Results - 3

MTF for inner ear protocol

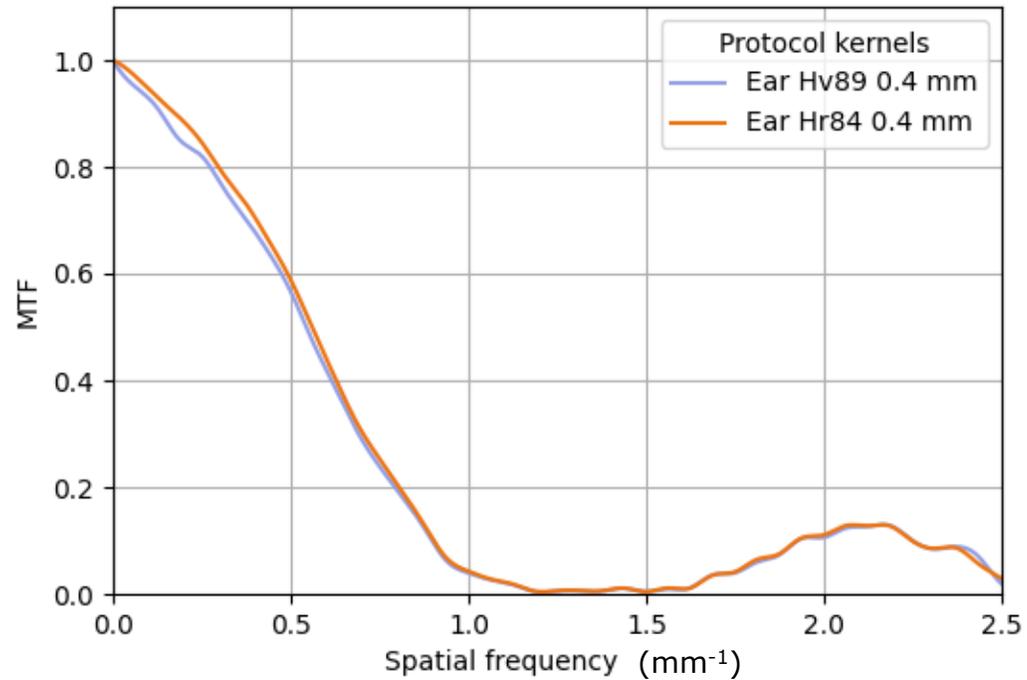


Comparison between standard (144x0.4mm) and UHR (120x0.2mm) slice thickness reconstruction



Comparison between standard (144x0.4mm) and UHR (120x0.2mm) slice thickness reconstruction for vascular algorithms

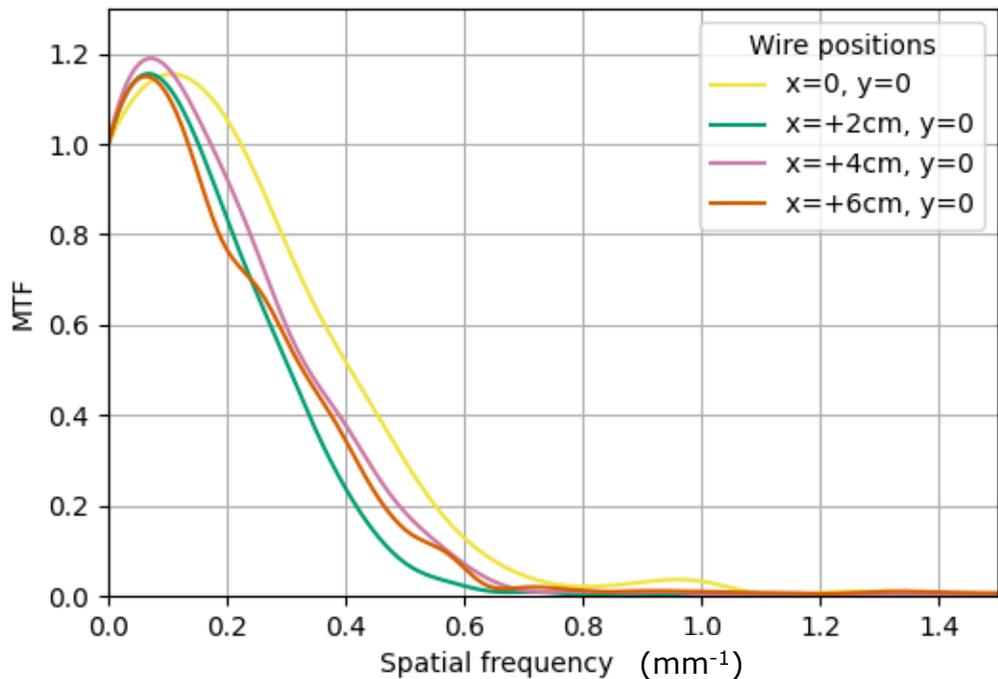
Results - 3



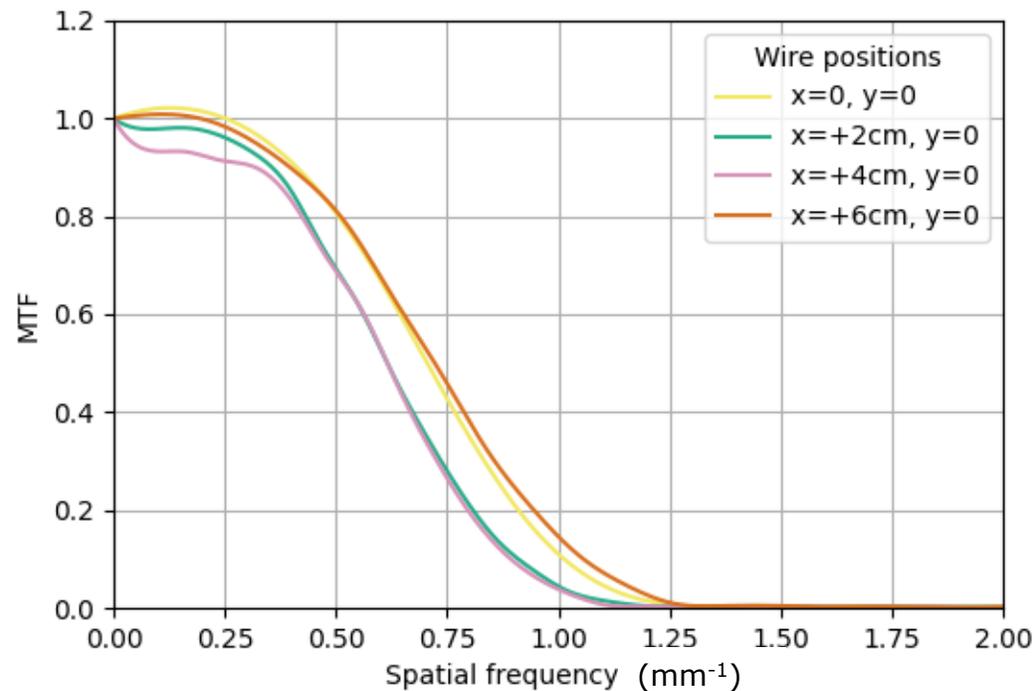
Inner ear protocol comparison between standard and vascular kernels

Results - 4

How does spatial resolution vary in the radial and tangential directions?



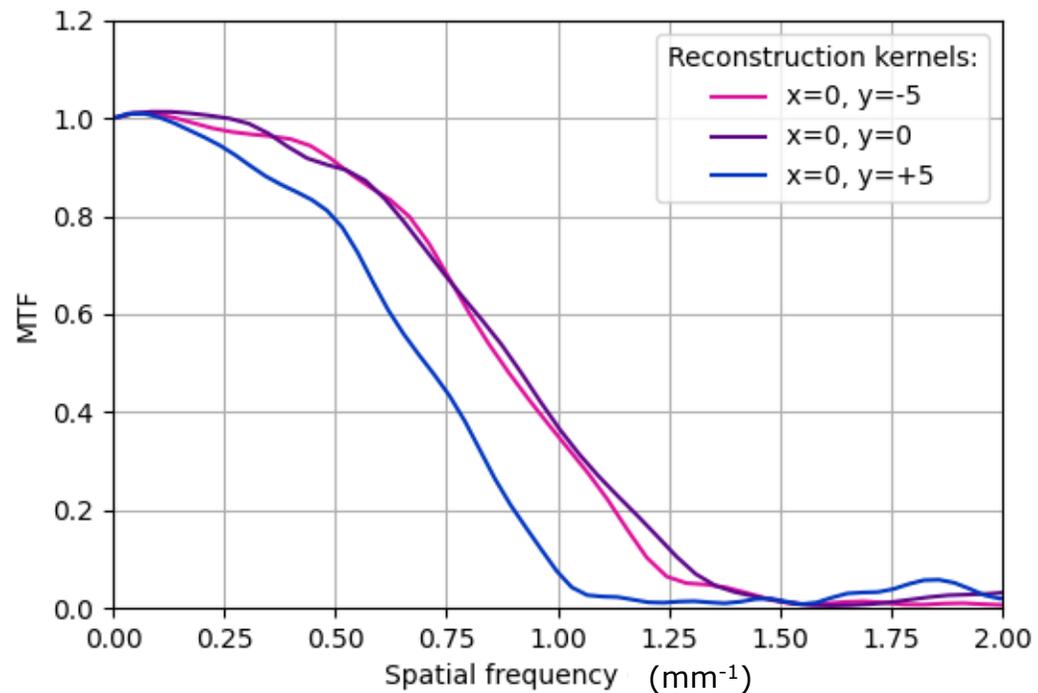
Radial dependence of the MTF for the abdomen protocol (Br40)



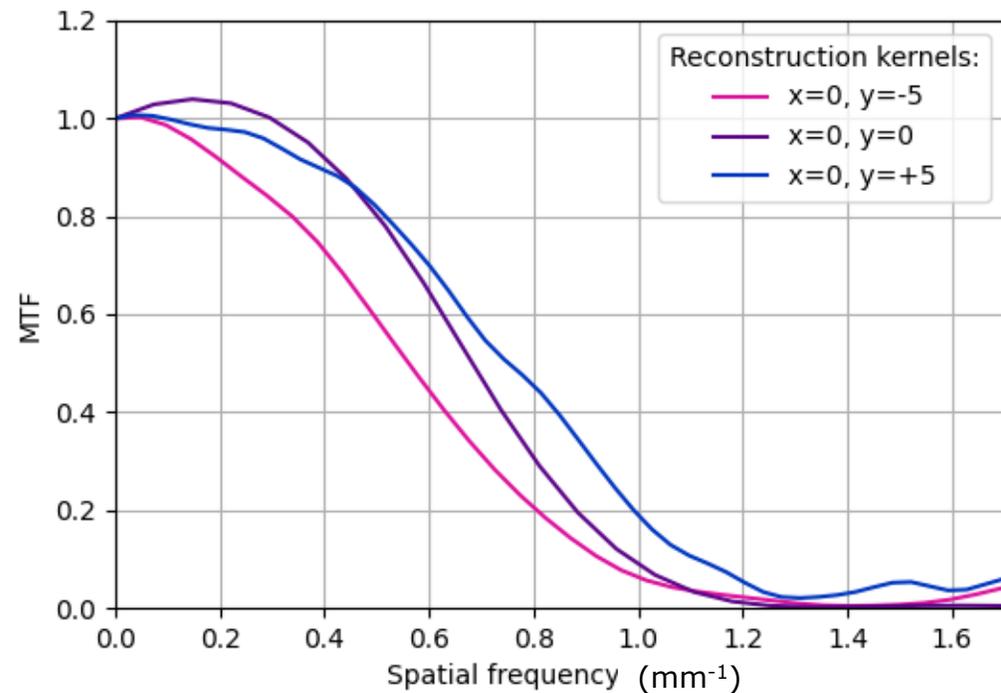
Radial dependence of the MTF for the head protocol (Hr60)

Results - 5

How does spatial resolution vary in the radial and tangential directions?



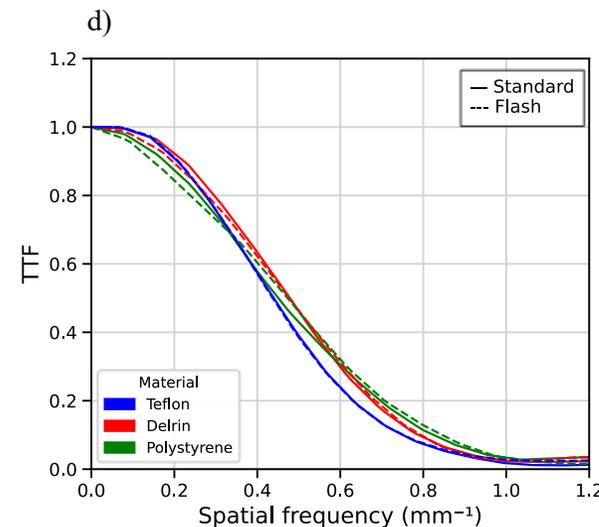
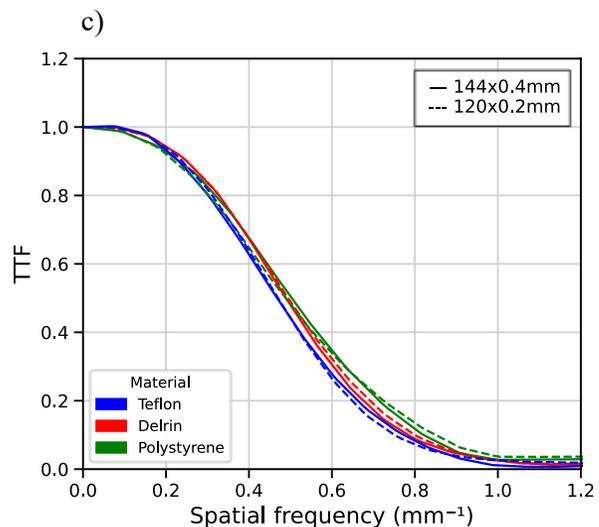
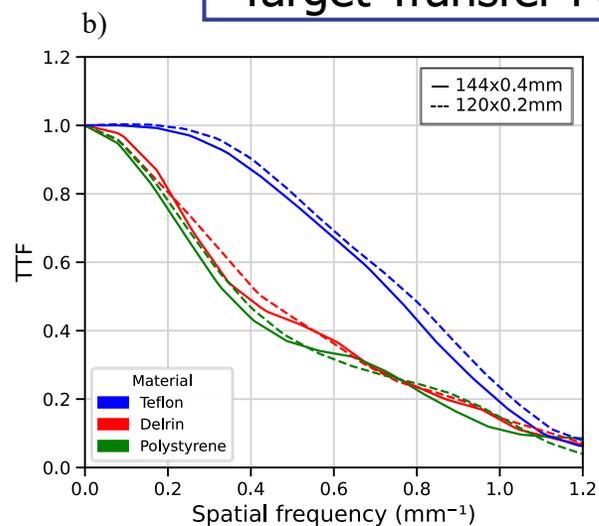
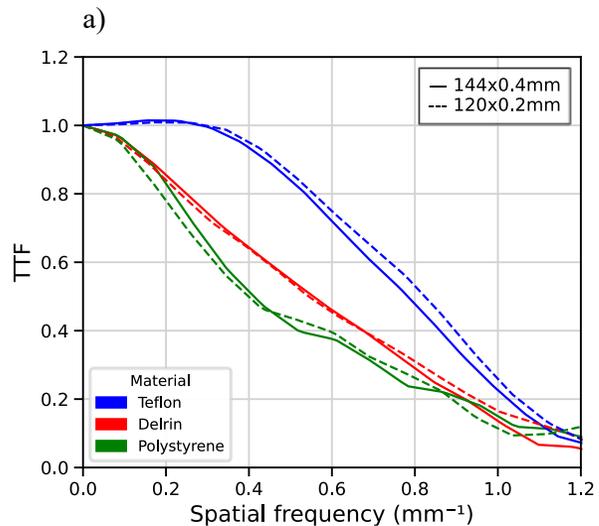
Tangential dependence of the MTF for the abdomen protocol (**Bv76**)



Tangential dependence of the MTF for the head protocol (**Hv60**)

Results - 6

Target Transfer Function results



a) Inner Ear protocol (@140 kV, 200 mAs) – Standard vs UHR

b) Inner Ear protocol (@100 kV, 300 mAs) – Standard vs UHR

c) Abdomen protocol – Standard vs UHR

d) Abdomen protocol – Standard vs Flash

Discussion and conclusion

- First clinical PCCT was characterized in terms of spatial resolution: MTF and TTF were measured;
- Spatial Resolution increased with increasing kernel sharpness (from 0.62 to 1.27 mm⁻¹ for the abdominal reconstruction algorithm);
- UHR was also assessed in the case of IE protocol: $f_{10\%}$ went from 0.87 to 1.58 mm⁻¹;
- TTF did not show a strong dependence on the reconstructed slice thickness, but the Teflon parameters in the case of Inner Ear were greater than low contrast objects;

Discussion and conclusion

Limitations and future perspectives:

- We used an 'home-made' phantom for the wire acquisitions. Measurements should be repeated using more suitable phantoms;
- The same characterization will be performed on the equivalent previous technology (Dual Energy CT) to be compared with PCCT

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Thank you for your kind attention!



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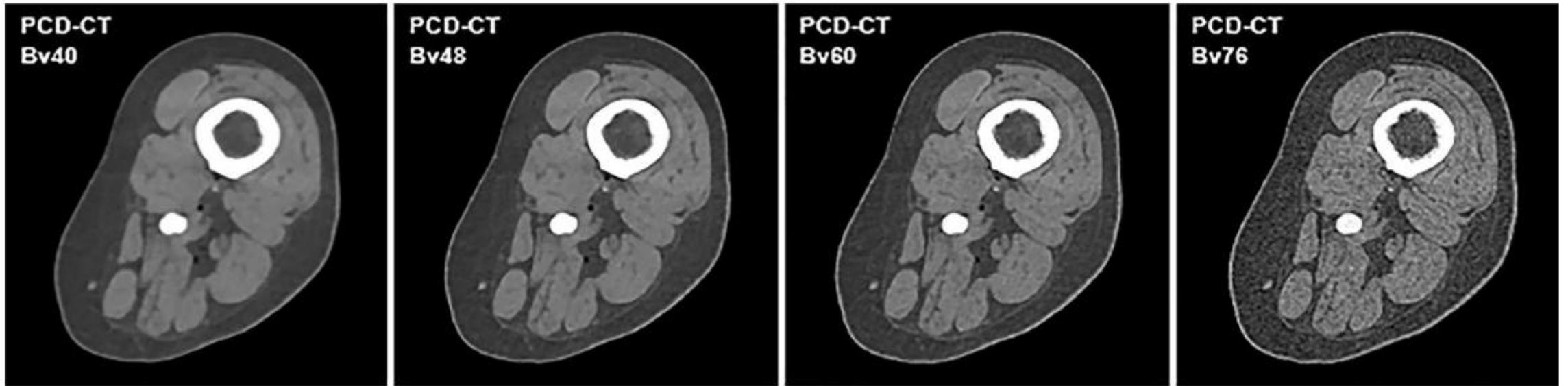


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IWORID, 6-10 July 2025

Additive slides

Application of vascular kernels of PCD-CT to the leg district for CTCA characterization



Gruschwitz et al., *Sci Rep* (2023)