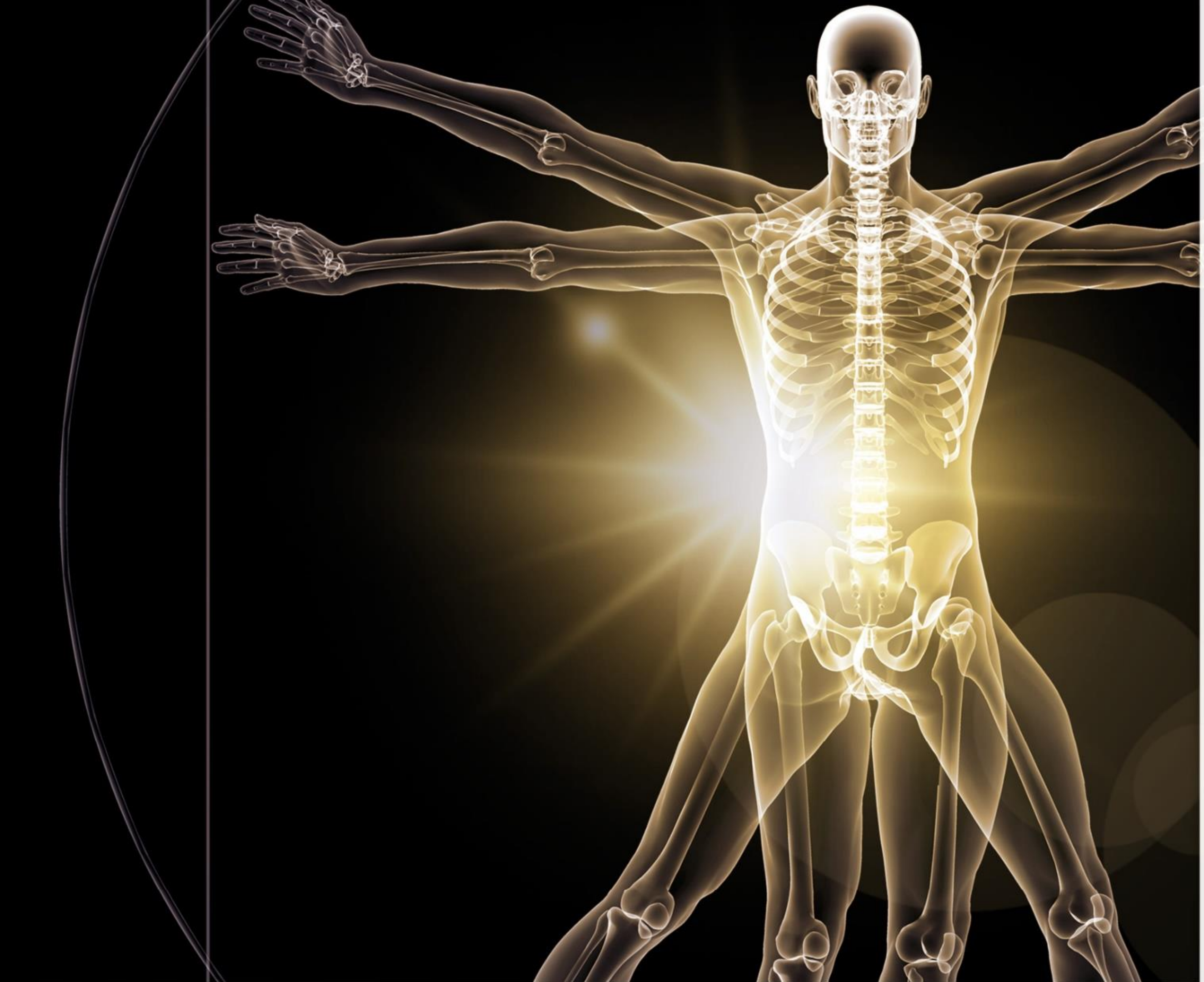


IS3R 2023

Berlin/Germany
August 24–26, 2023

Where do we go from here in CT?

Academic perspective

Mathias Prokop
Radboud UMC, Nijmegen
UMC Groningen
The Netherlands

Disclosures

Research support

- Canon Medical Systems, Siemens Healthineers

Speaker bureau

- Canon Medical Systems, Siemens Healthineers

Department

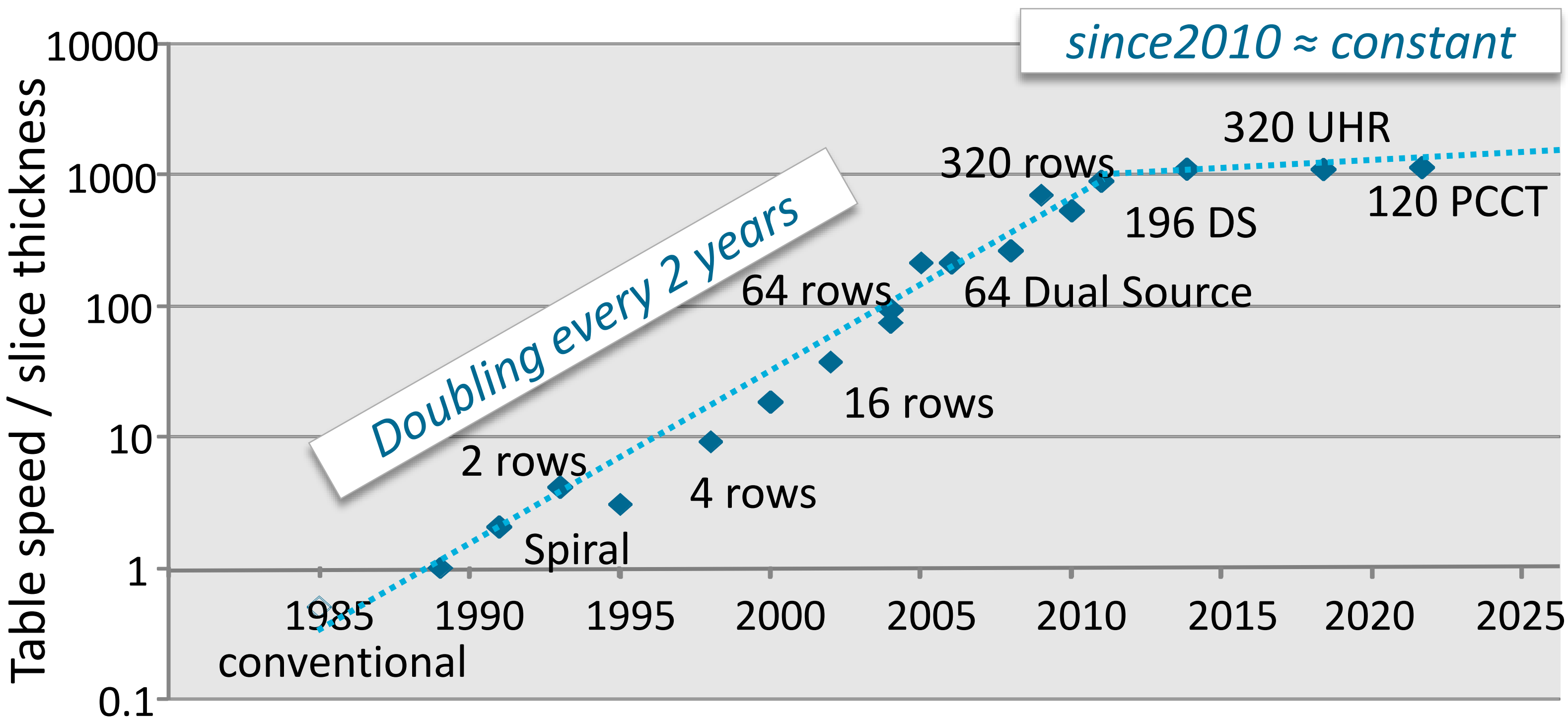
- Thirona (Spinoff; AI for chest imaging)
- Veolity (License; Lung screening software)
- Similarity Filter (License; Noise reduction for 4DCT)

thirona

veolity

Canon

CT used to be an Exponential Technique



Computed Tomography

Hardware

High-end detectors

- 4 cm to 16 cm wide (64 to 320 rows)
- Detector elements 0.5-0.625 mm effective
- Low electronic noise
- Dual layer

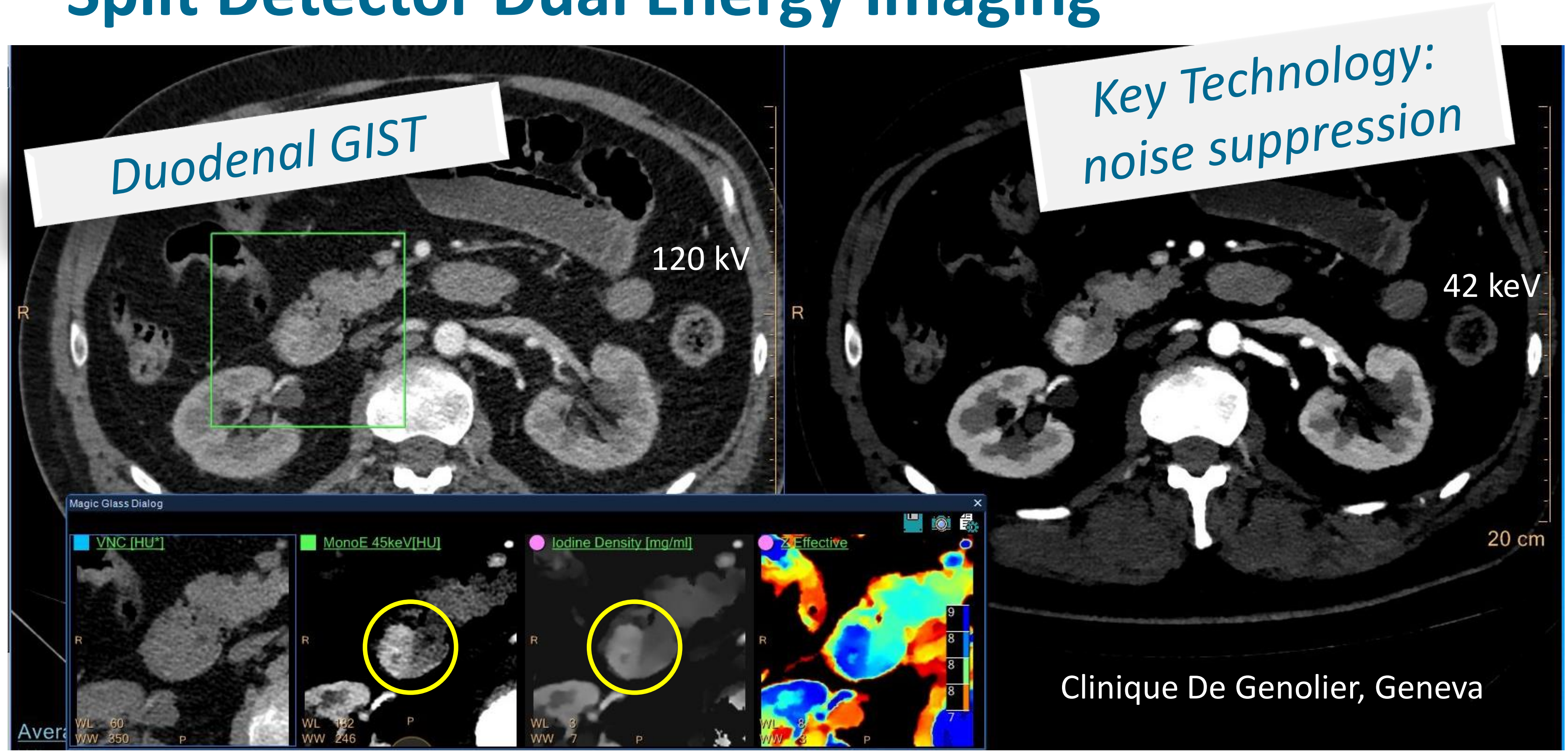
Gantry

- 0.25 s per rotation
- Table speed up to 737 mm/s

Tubes

- High Performance (70-150 kV)
- Dual Source

Split Detector Dual Energy Imaging



Computed Tomography

Future of Hardware Development

1-2 years

High-resolution detectors

- 0.25 mm detector elements
  Low electronic noise

Photon-counting detectors

- Lowest dose
- Dual energy and scatter suppression for

5-10 years

Phase-contrast scanning

- Monoenergetic , phase-coherent radiation

???

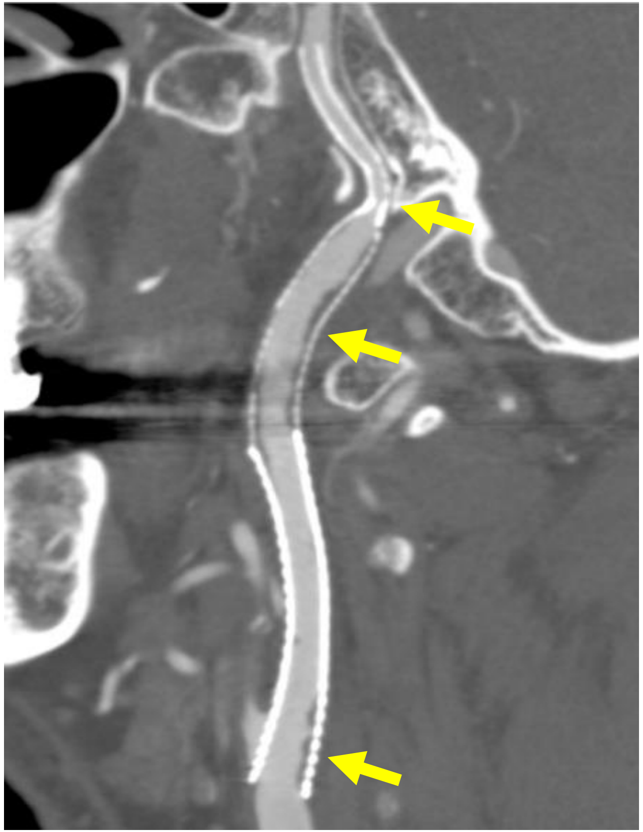
Scanners with inverse Geometry

- Dose painting
- One-shot body scans

???

UHRCT

0.25 mm
UHR detector

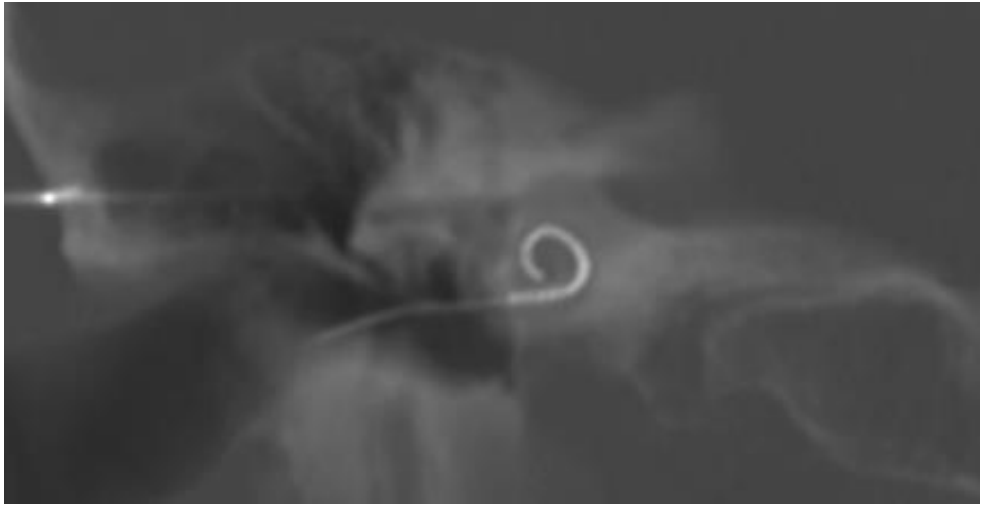


Courtesy Dr. Murayama, Fujita Health University, Japan

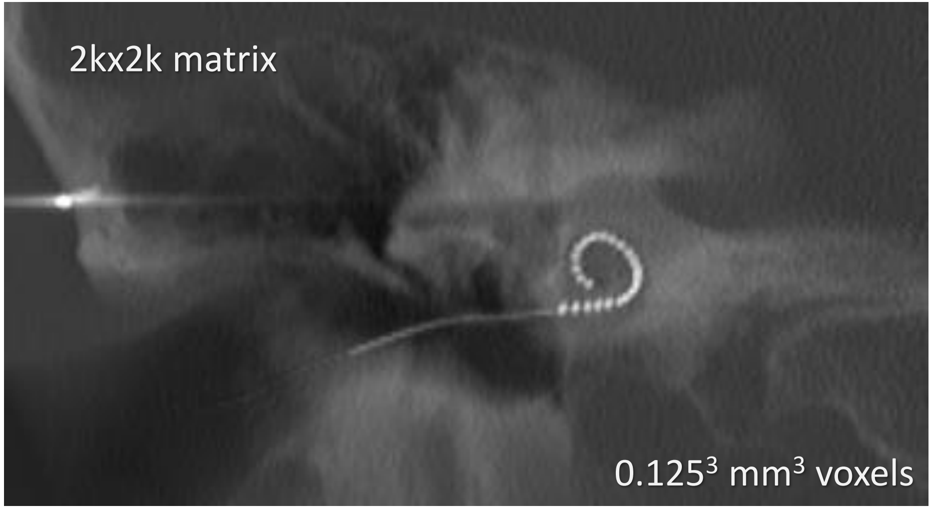
UHRCT

0.25 mm Detectors

Conventional CT



UHR-CT



UHRCT

160 x 0.25 mm
1kx1k matrix

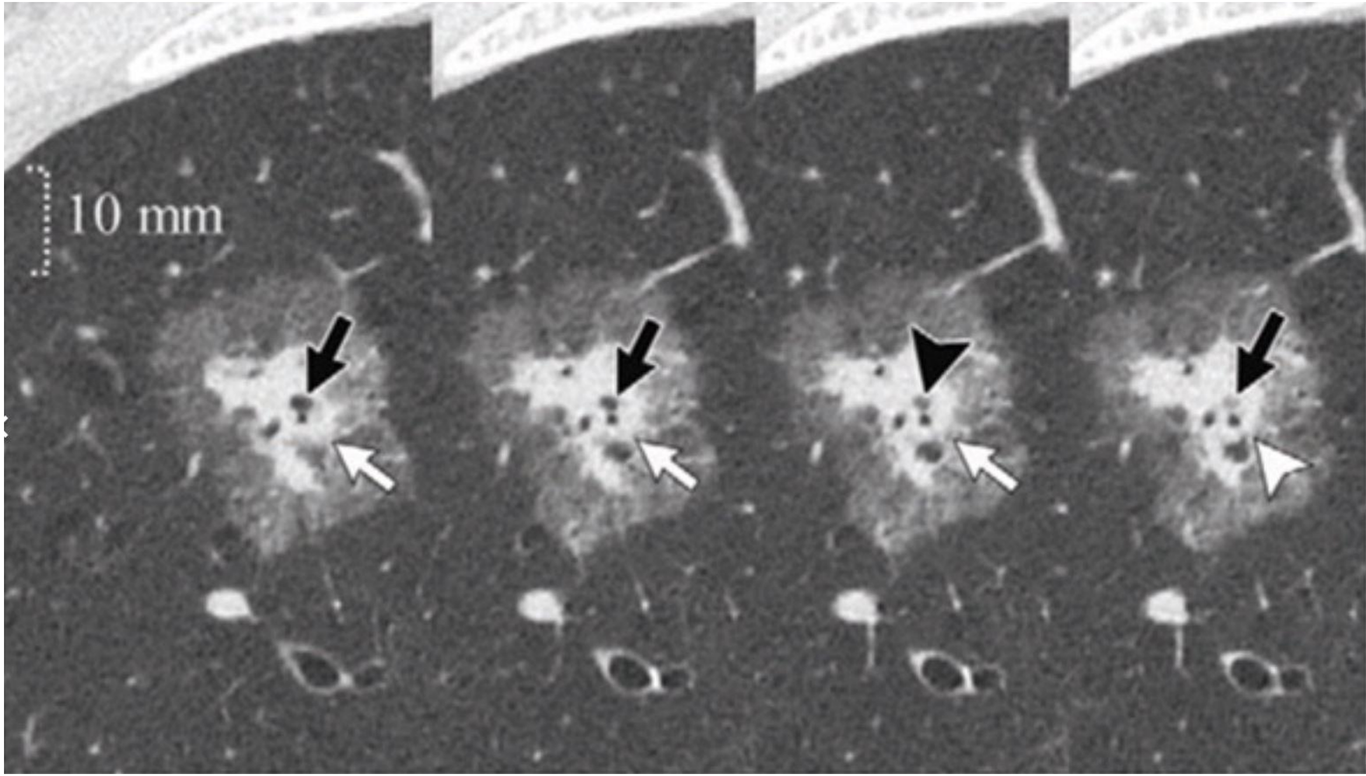
$CTDI_{vol}$ 7.6 mGy
DLP 318 mGy cm
E 4.5 mSv

Aggressiveness Prediction

UHR-CT

Predictors of invasive adenocarcinoma:

- solid core > 8mm
- disruption of air bronchiologram



Iterative Reconstruction

Female 52 years old,
Follow-up imaging for IPMN

Deep Learning Reconstruction

Female 52 years old,
Follow-up imaging for IPMN

Subtraction – Iodine Overlay

Female 52 years old,
Follow-up imaging for IPMN

Computed Tomography

Future of Hardware Development

High-resolution detectors

2018

- 0.25 mm detector elements

  Low electronic noise

Photon-counting detectors

- Lowest dose
- Dual energy and scatter suppression for free

2022

Phase-contrast scanning

- Monoenergetic , phase-coherent radiation

???

Scanners with inverse Geometry

- Dose painting
- One-shot body scans

???

Photon Counting CT

High resolution

- 120 x 0.2 mm detectors

No electronic noise

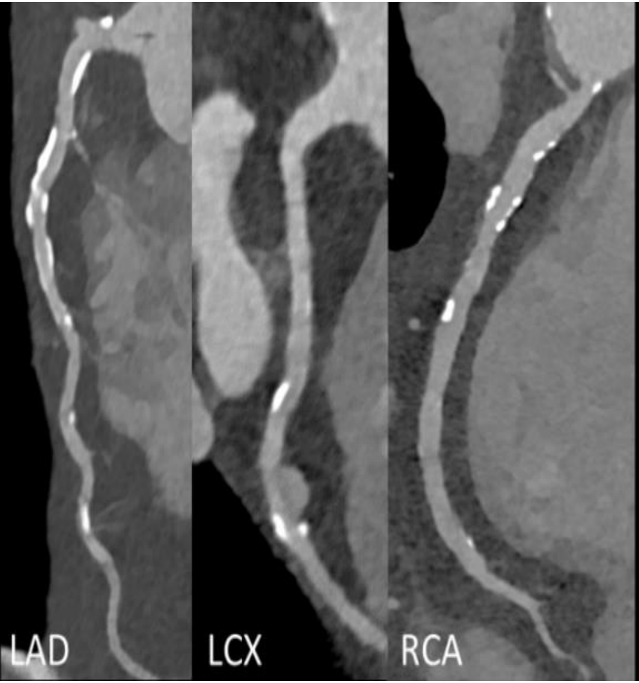
- Ultra-low dose scanning
- Dose accumulation across multiple scans

Multiple energy bins

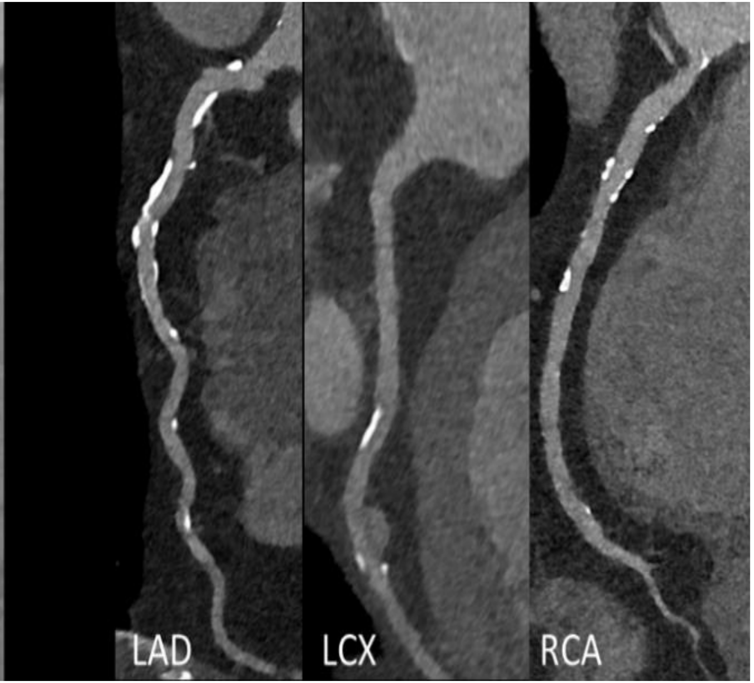
- Dual energy always available
- Optimum spatial alignment

Photon Counting CT

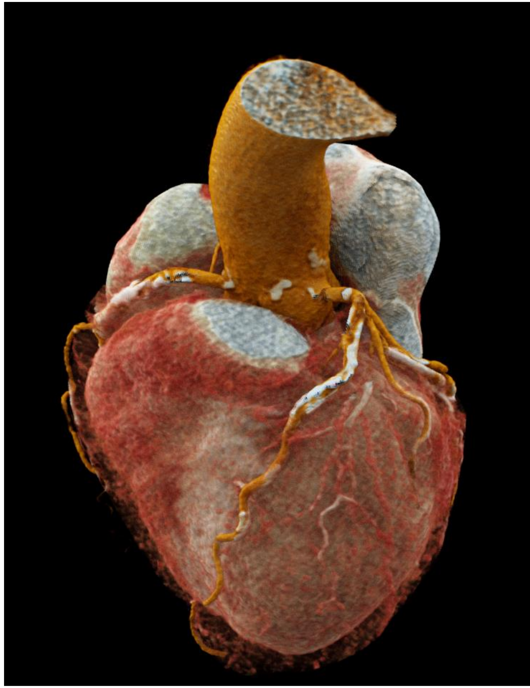
120kVp | DLP 427 mGy*cm



MPR | 0.4 mm | Bv44 | 1024 matrix



MPR | 0.2 mm | Bv56 | 1024 matrix

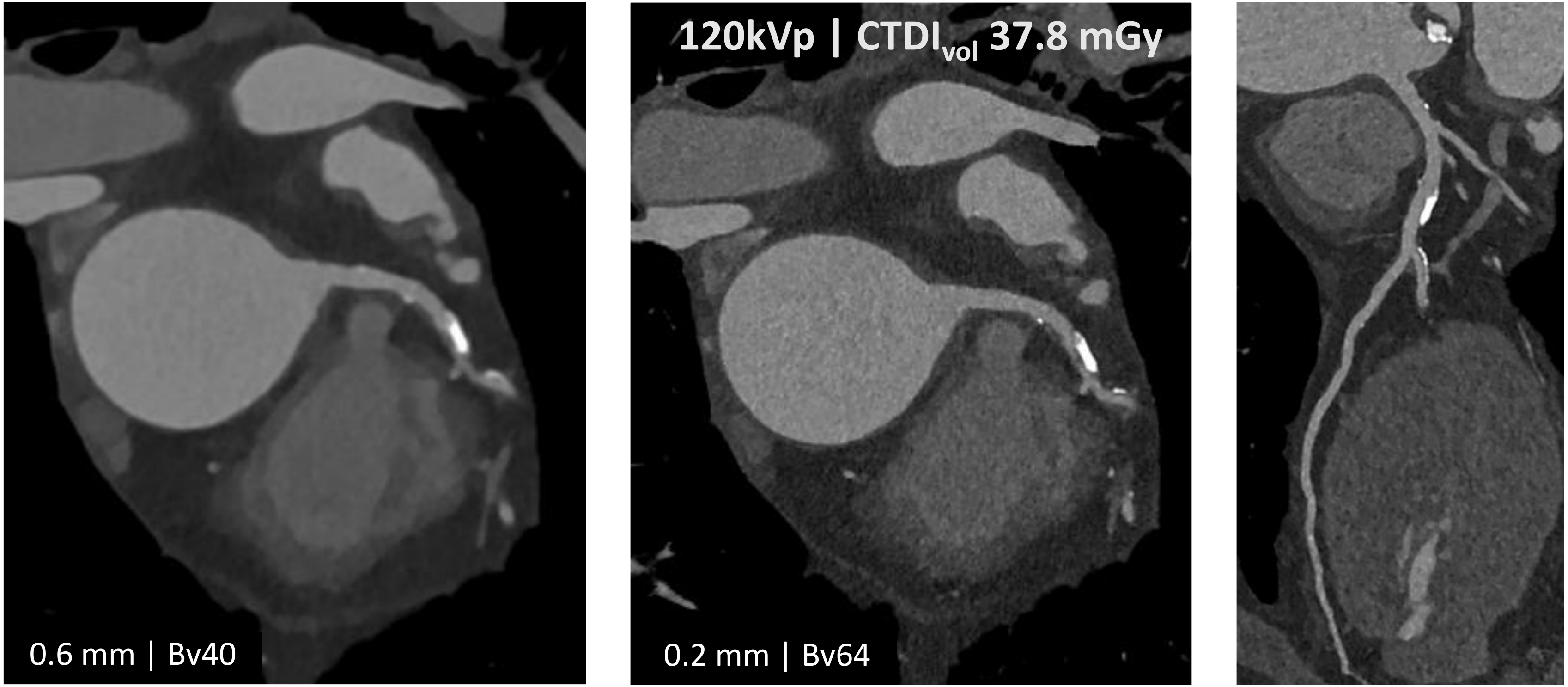


VRT

Courtesy of Semmelweis University, Budapest, Hungary

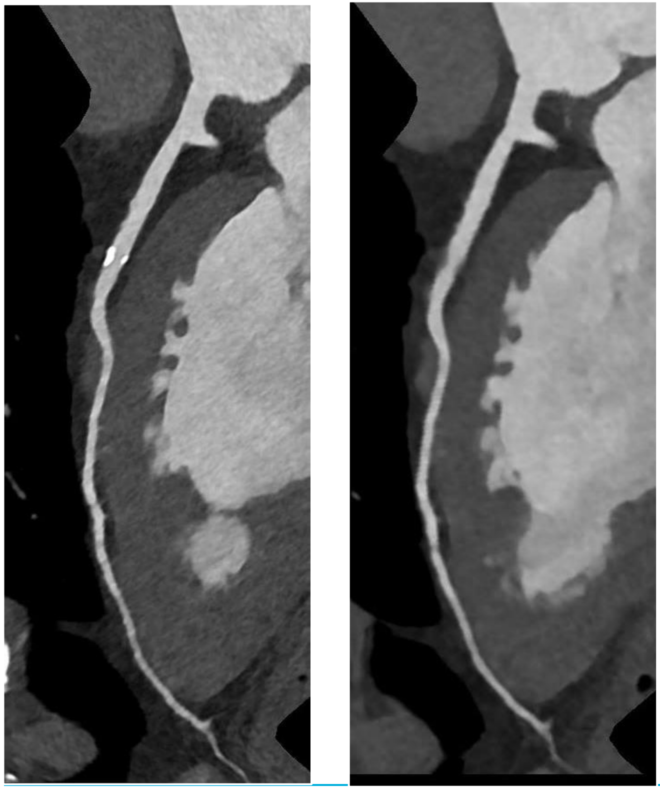
Radboudumc

Photon Counting CT



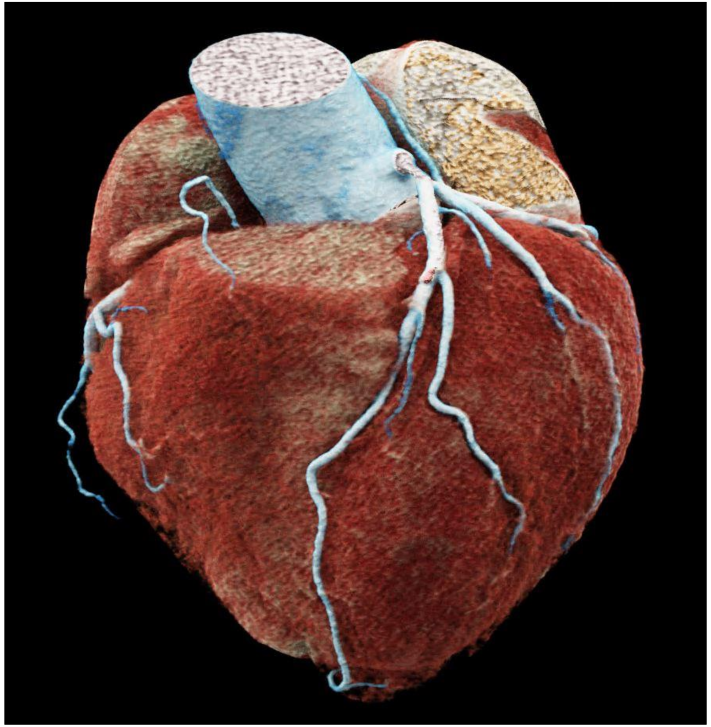
Courtesy of University Hospital Zurich, Zurich, Switzerland

Photon Counting CT



Calcium

removal



140kVp | CTDI$_{vol}$ 16.4 mGy

Courtesy of of Dr. Jones & Partners – SAHMRI, Adelaide, Australia

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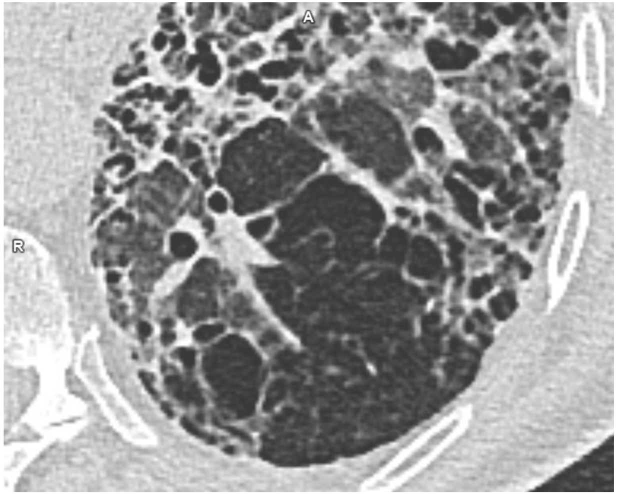
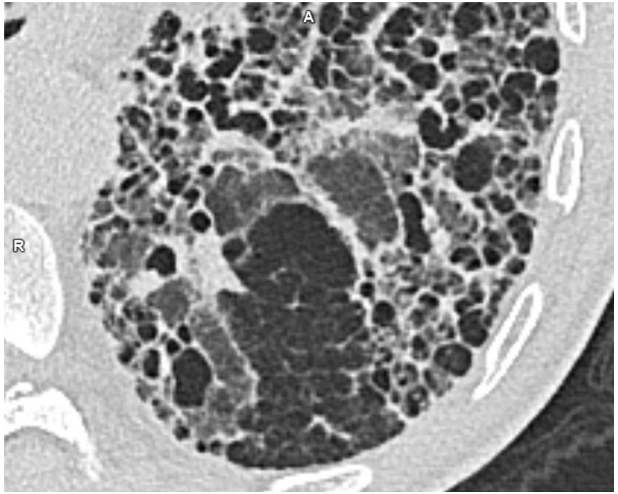
Photon Counting CT

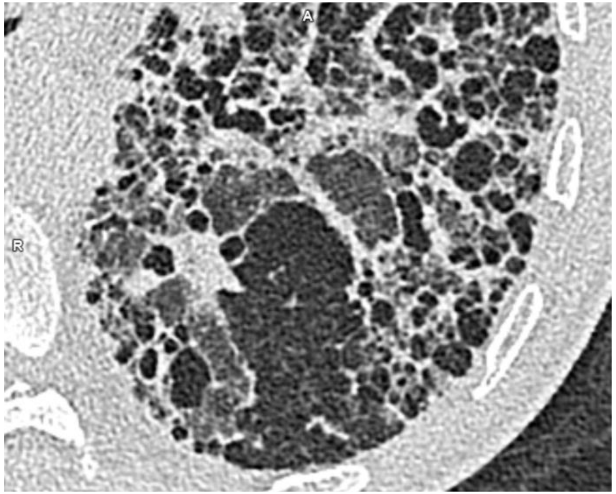
UHR-CT



Standard CT
1 mm | Bl57



PCCT
T3D | 1 mm | Bl60

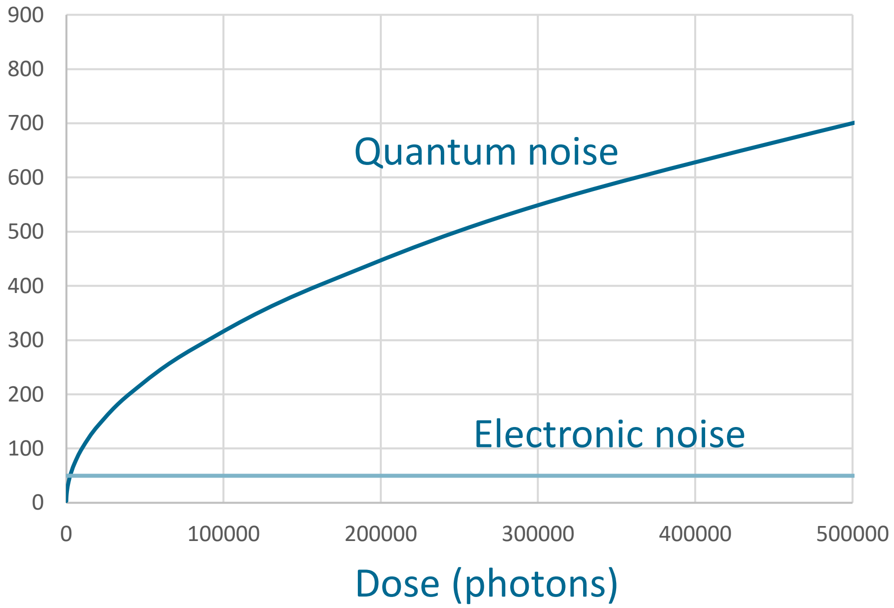


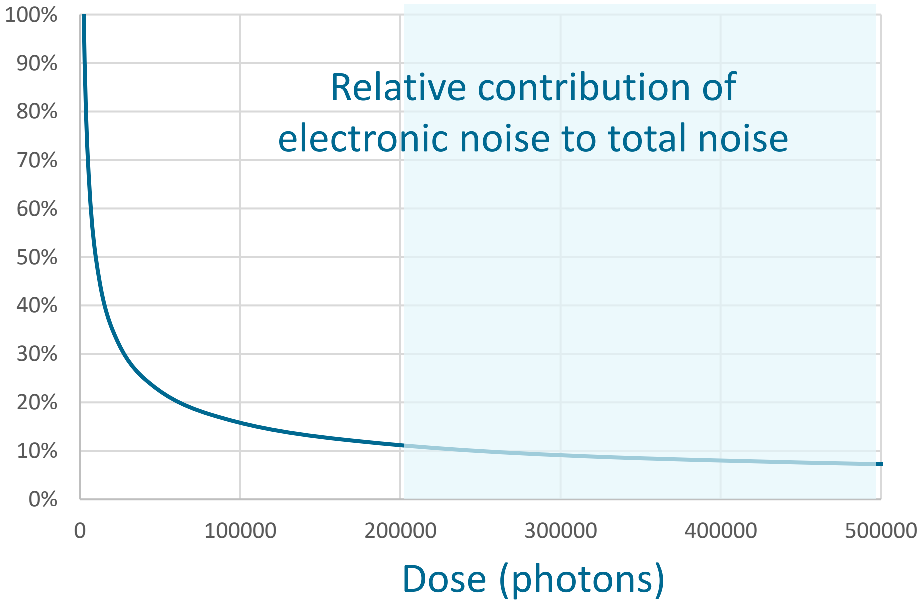
PCCT
T3D | 0.2 mm | Bl60

Courtesy of M. Remy-Jardin, Lille, France

Computed Tomography

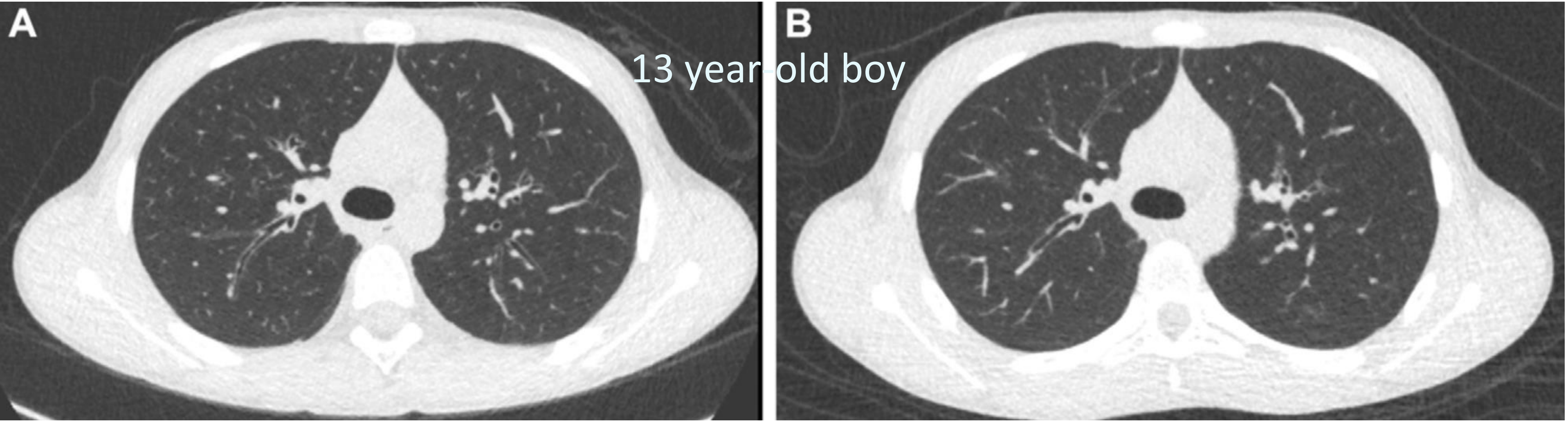
Electronic noise





Photon Counting CT

Low-dose applications



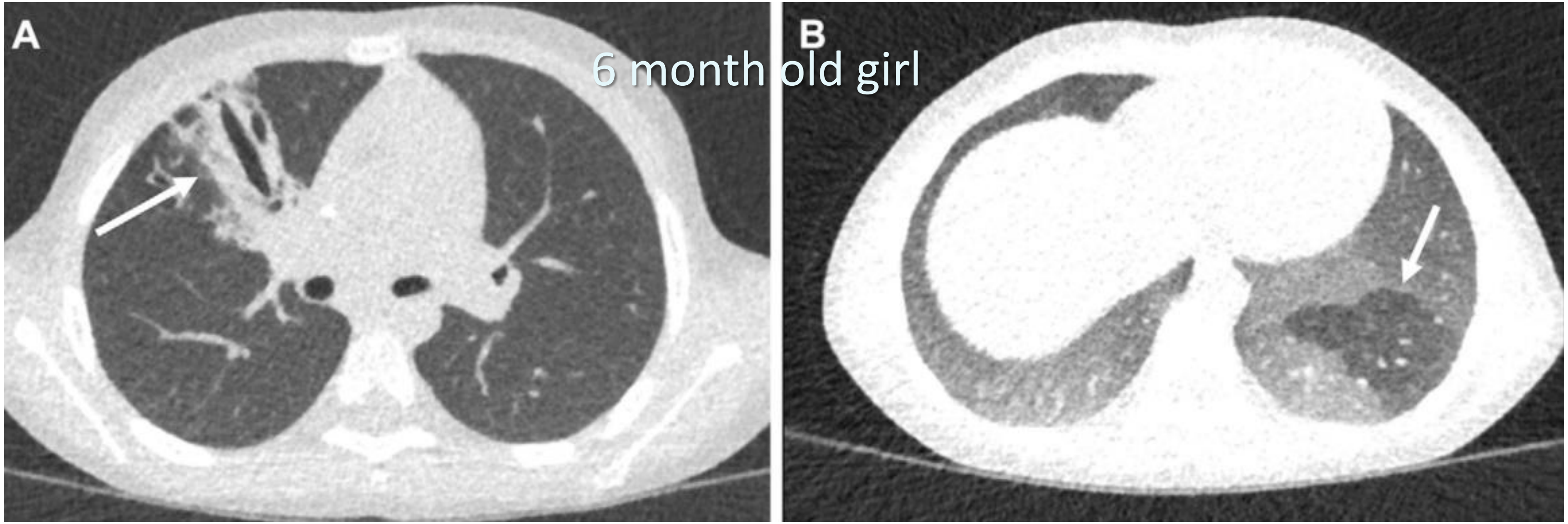
PCCT 0.24 mSv

Standard CT 0.57 mSv

Nehra A et al. Radiographics 2023; 43(5) e220158

Photon Counting CT

Ultralow-dose applications

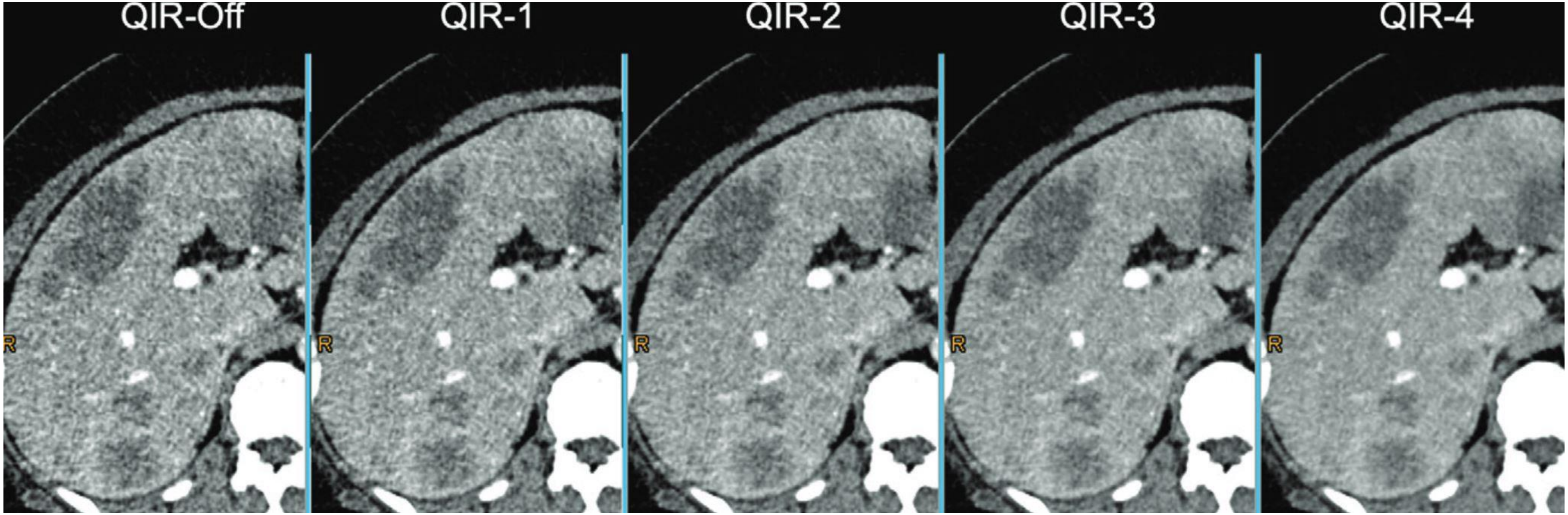


Inspiration $CTDI_{vol}$ 0.05 mGy

Expiration $CTDI_{vol}$ 0.05 mGy

Photon Counting CT

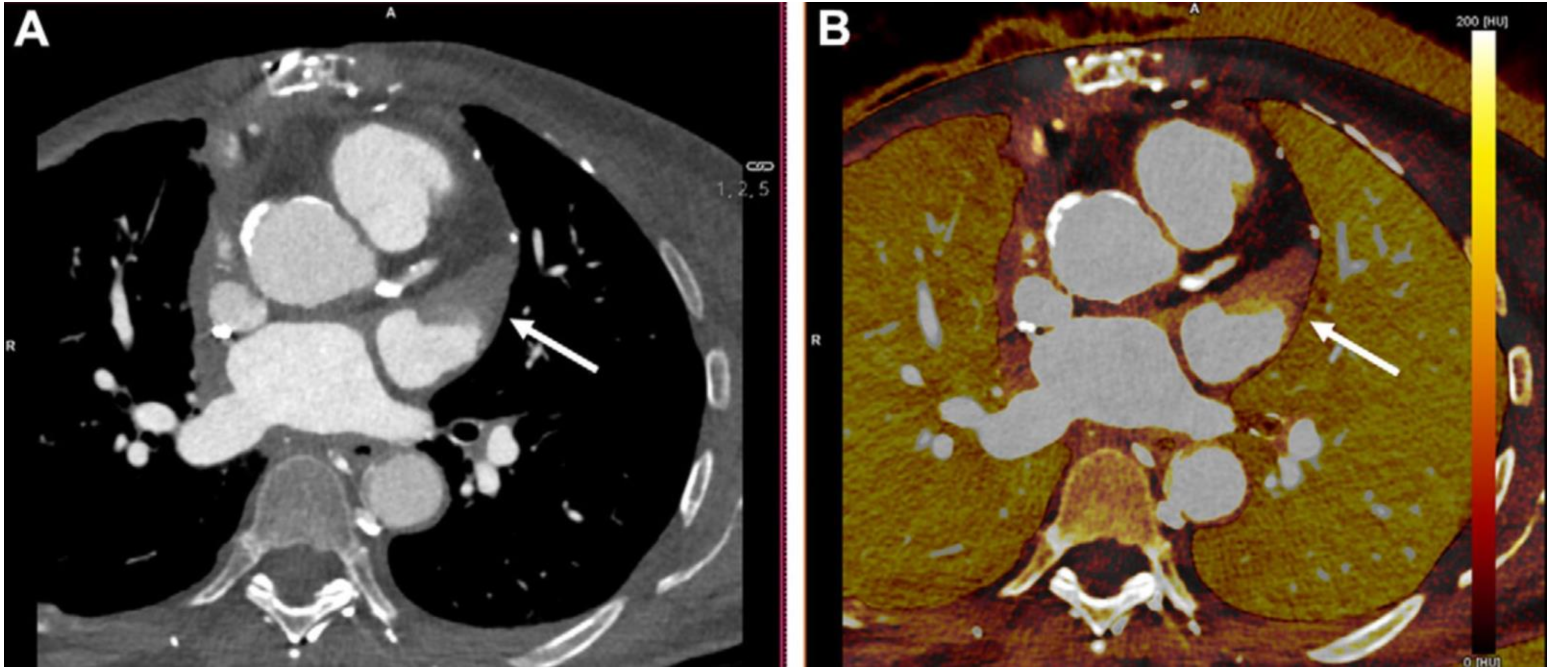
Novel iterative reconstructions



Sartoretti T et al. Radiology 2022; 303:339–348

Photon Counting CT

Dual energy – iodine map



Nehra A et al. Radiographics 2023; 43(5) e220158

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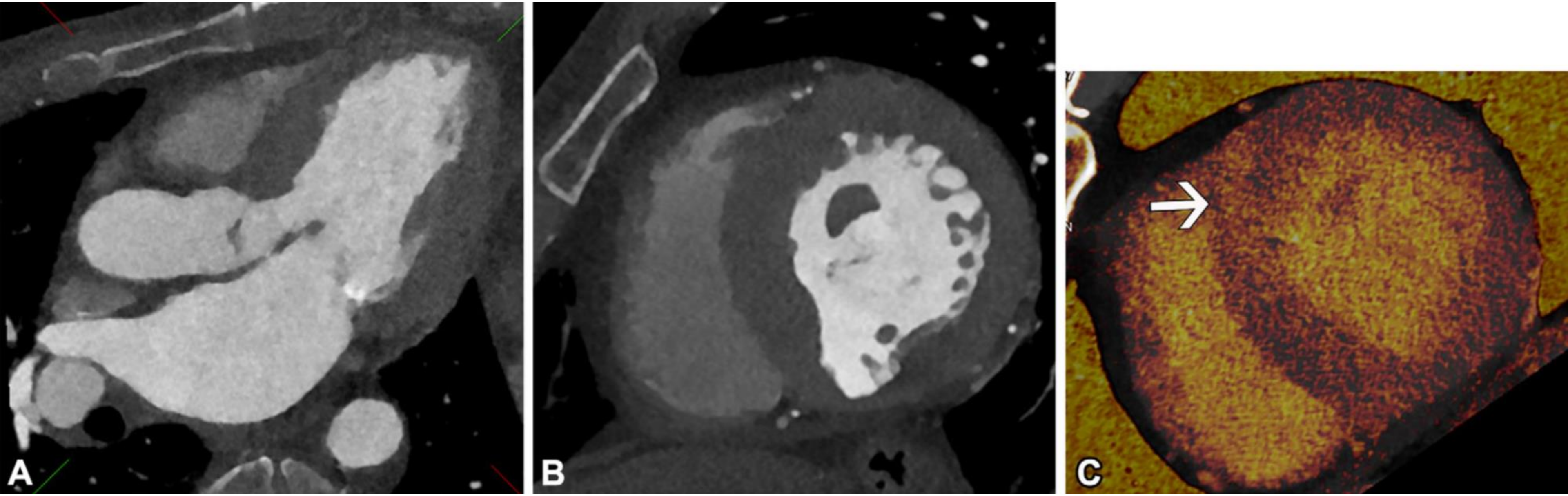
Photon Counting CT

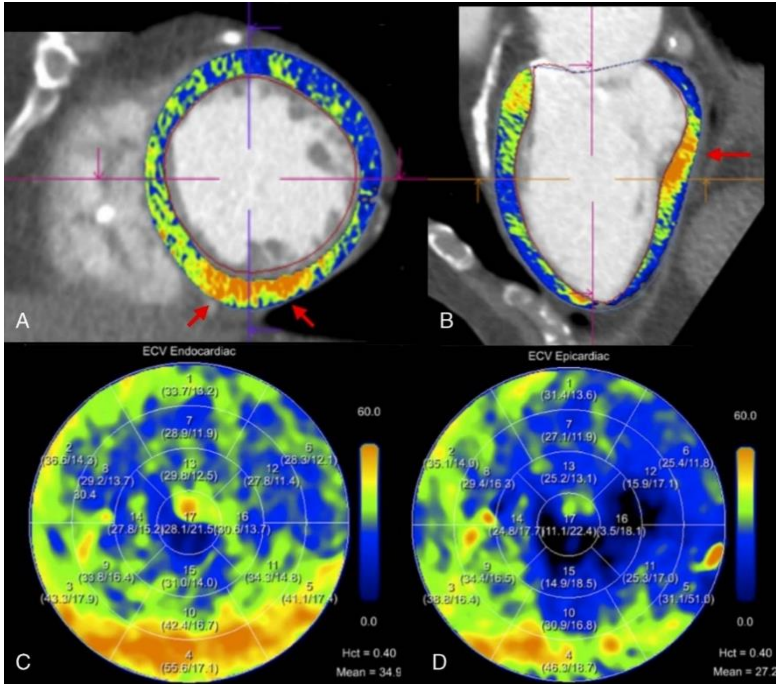
Dual energy – late enhancement

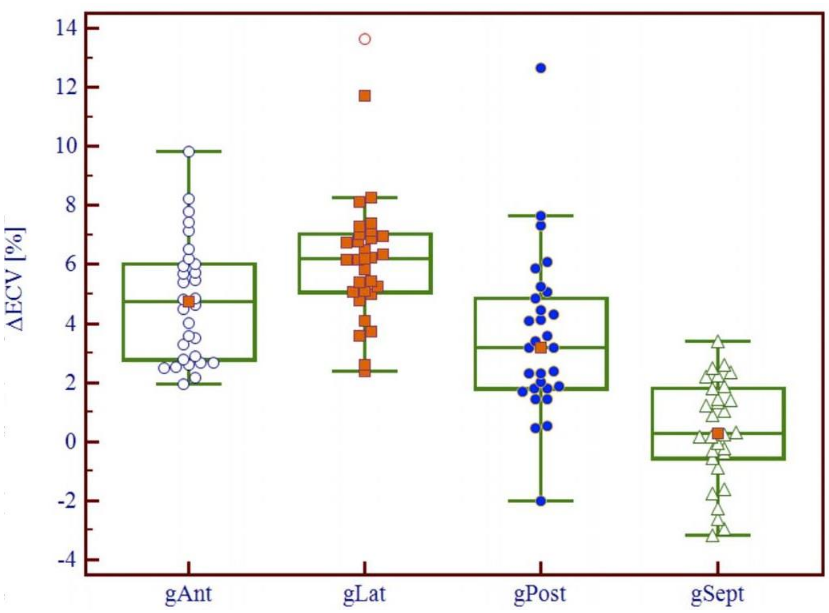


Nehra A et al. Radiographics 2023; 43(5) e220158

Photon Counting CT

Dual energy – extracellular volume quantification





Mergen V et al. Invest Radiol 2022; 57: 406–411

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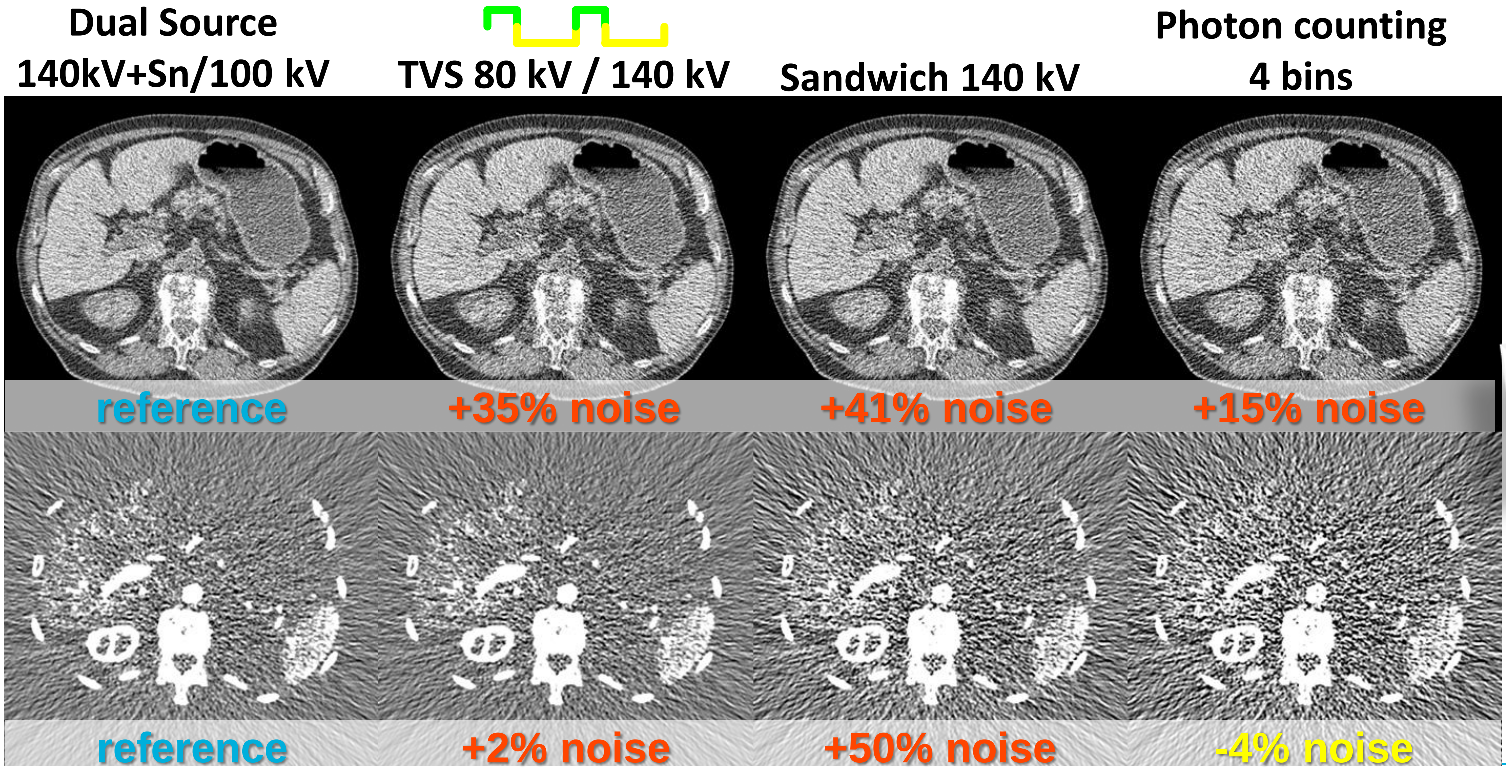
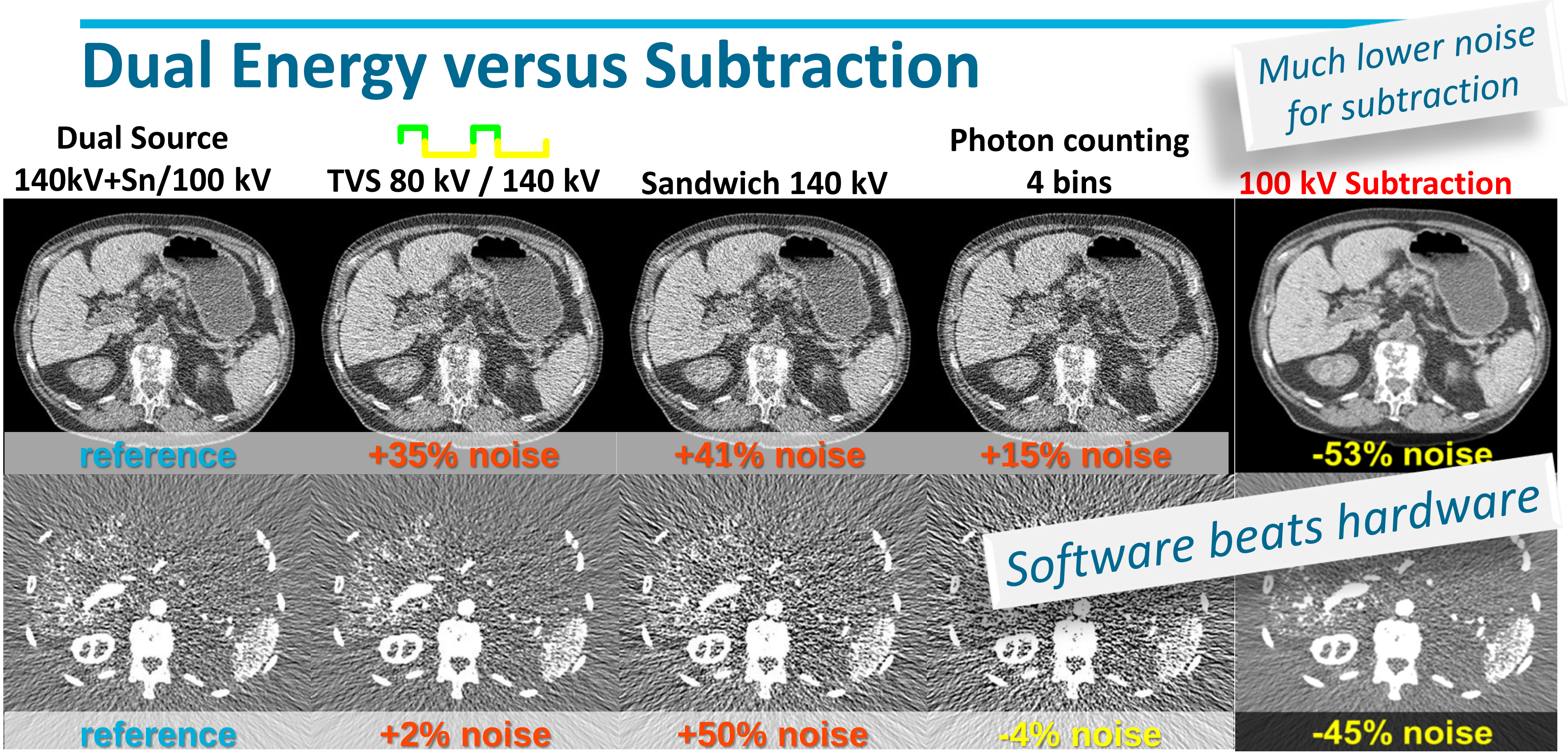
Dual Energy versus Subtraction



Least noise for dual source

Faby and Kachelrieß, MedPhys 42(7):4349

Dual Energy versus Subtraction



Faby and Kachelrieß, MedPhys 2015; 42(7):4349

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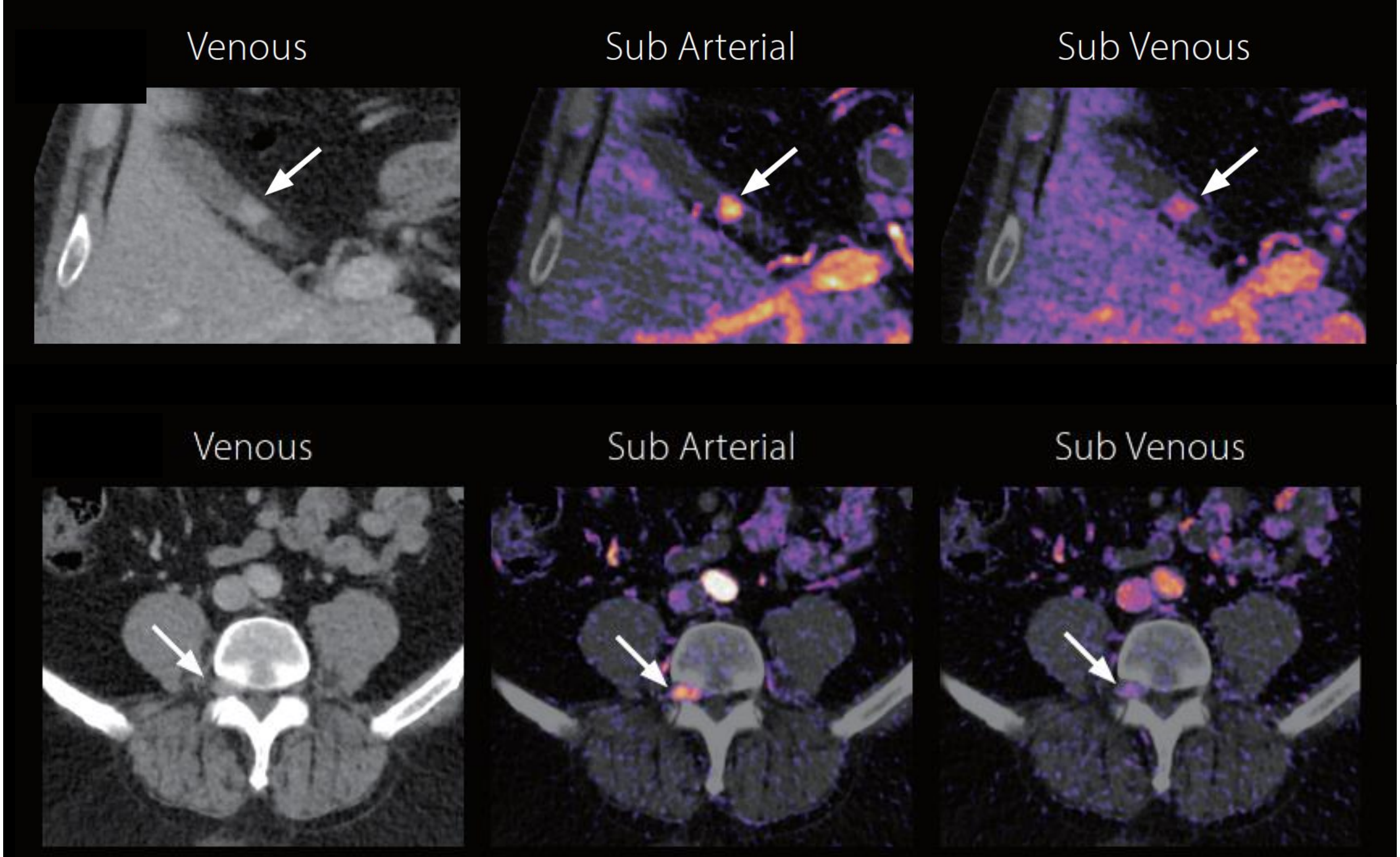

[redacted]
Venous
Sub Arterial
Sub Venous
[redacted]
Venous
Sub Arterial
Sub Venous

CT Technology

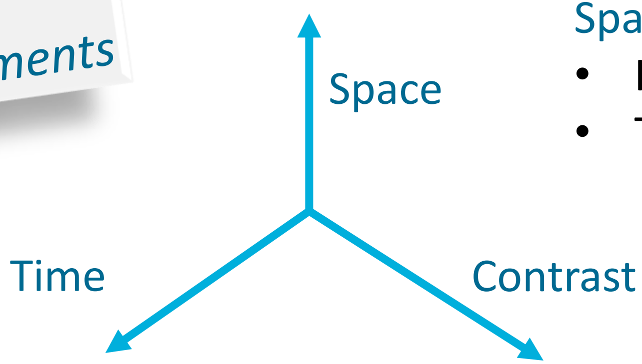
Beyond Industry Push

CT Technology

The dimensions of CT data

New direction of technological developments

Spatial resolution
- In-plane (XY)
- Through-plane (Z)



Change analysis
- Perfusion
- Motion
- Size over time

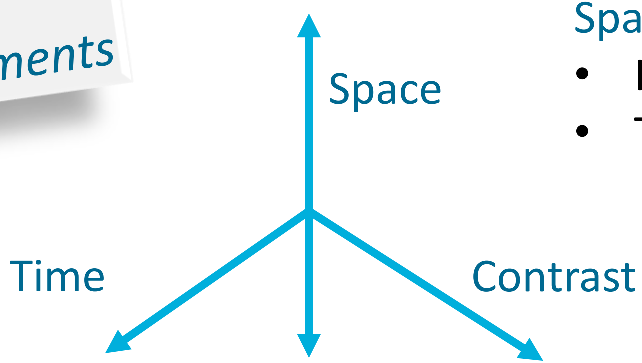
Hounsfield units
- Natural contrast
- Contrast agents
- DE techniques

CT Technology

The dimensions of CT data

New direction of technological developments

Spatial resolution
- In-plane (XY)
- Through-plane (Z)



Change analysis
- Perfusion
- Motion
- Size over time

Hounsfield units
- Natural contrast
- Contrast agents
- DE techniques

Usability
- Throughput
- Ease of use
- Interventions

Beyond Morphology

Necessary Technological Advances

Key technologies

1. Motion correction (raw data and image data)
2. Noise suppression
3. Easy presentation of complex information

Necessary for

- CT perfusion
- CT motion and ventilation analysis
- Analysis of temporal change on follow-up imaging

Important future applications

Beyond Morphology

Necessary Technological Advances

Key technologies

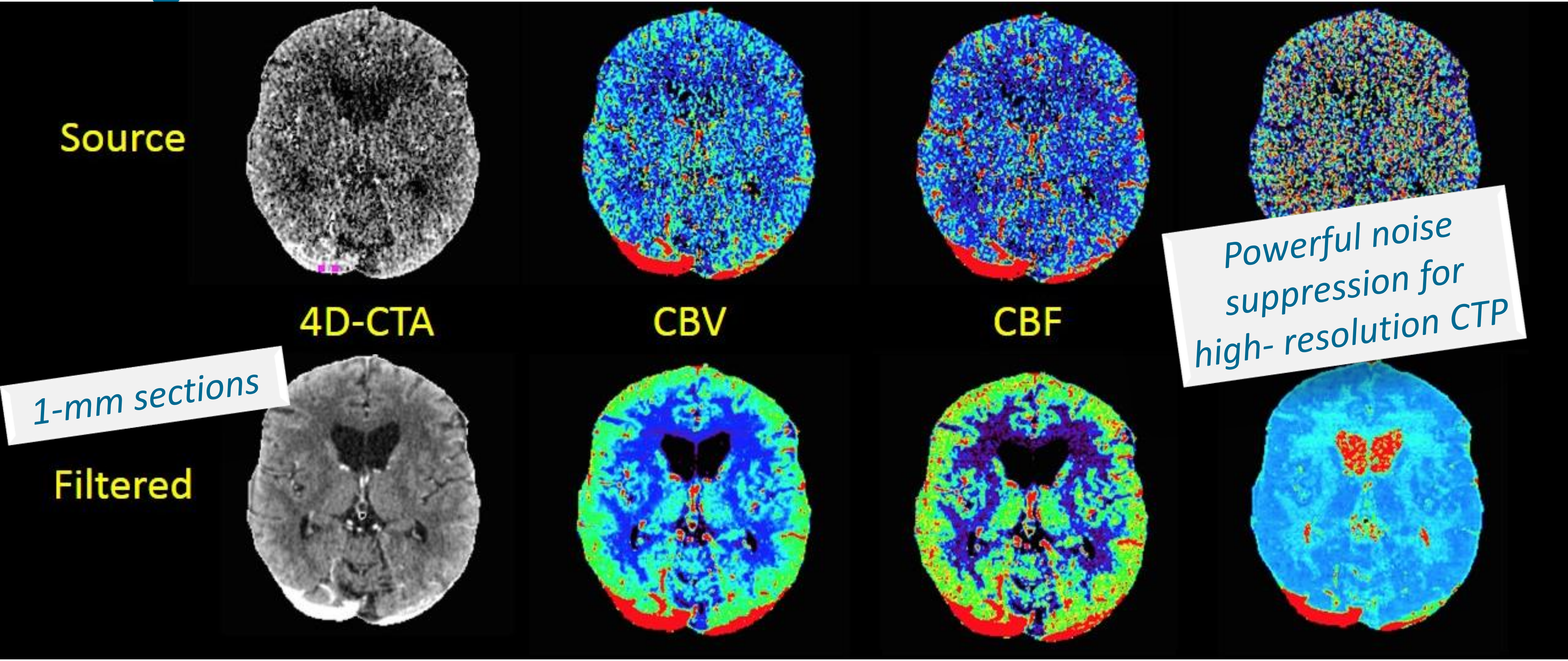
1. Motion correction – basis for any advanced processing and analysis
2. Noise suppression – required for acceptance (radiation dose)
3. Easy presentation – required for implementation

Anything that holds up reporting will not be accepted

Necessary for

- CT perfusion
- CT motion and ventilation analysis
- Analysis of temporal change on follow-up imaging

High-resolution CT Perfusion



Ewoud Smit, Nijmegen

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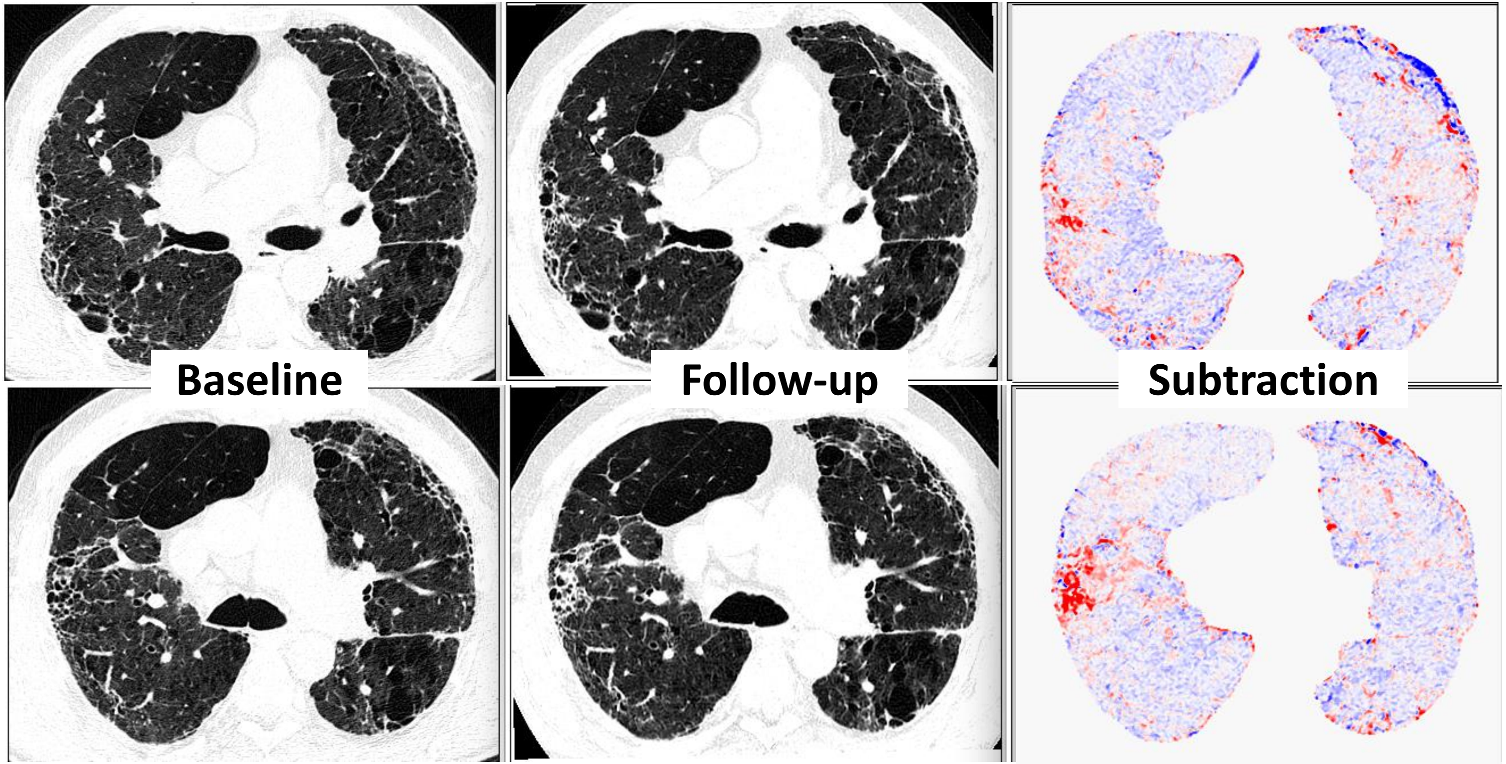
Temporal Subtraction



Hoen Oh Shin, Hannover Medical School

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CT Perfusion / Ventilation / Change Assessment

Future use cases

Why are we not there?

- We worked on it for the past 15 years
- It is difficult
- It requires patience and patients
- It requires successful clinical use cases and trials that prove them
- It should be (reasonably) easy to interpret
- It requires adequate reimbursement

Clinician pull

But if it has CLINICAL value, clinicians will order it, and we will do it

Clinical Pull

Example Wakeup Stroke

Where do we go from here in CT?

Necessary CT Technological Advances

Summary

Morphology

- Higher resolution provides better images, rarely different diagnoses (except for coronaries)
- Noise suppression and optimized reconstructions
- Image harmonization for AI / Radiomics

Function

- Completely under-utilized
- Profits most from PCCT (but small detectors hamper use)
- Workflow requires massive improvements

Necessary CT Technological Advances

Summary

Workflow

- Automation of everything:
  planning, scan range, dose, contrast injection, scanning, recon, processing
- Automation of complex evaluations (stroke, functional cardiac)

Treatment

- Automatic alignment of images to needle path
- Support for multiple needles
- Motion compensation for robotics
- Matching pre- / post-ablation