Implementation and use of Spectral CT

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- 13 CT systems
  - 4 Philips Iqon (Dual-layer detector)
  - 3 Siemens Somatom Force (Dual Source)
  - 3 Siemens Somatom Flash (Dual Source)
  - 1 GE Revolution Apex (Rapid KV switching)
  - 1 Siemens Neotome Alpha (Photon Counting CT)
  - 1 Other

Dedicated Spectral/Dual energy CT scanners

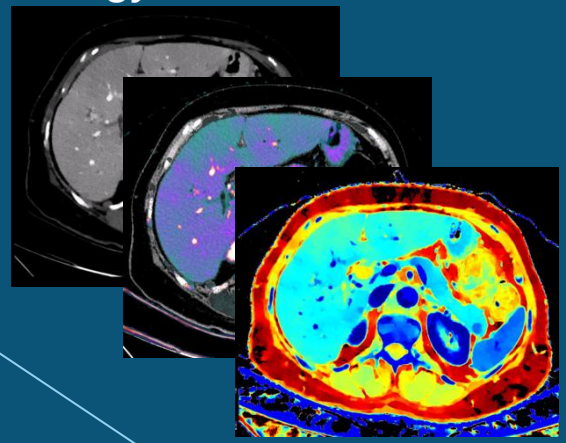
Implementation of spectral/dual-energy CT in clinical practice

- Pulmonary Embolism (Most scans since 2017)
- Abdominal Scans (All Scans since 2019)
- Upper and Lower Extremities (Since 2020)
- Oncology workups and follow-up (All Scans since 2020)

Implementation of spectral/dual-energy CT in clinical practice – Push to PACS

Intellispace/Syngovia/AWS

Dual-Energy Series



SBI/SPP
Files

Thin Slices

PACS

Implementation of spectral/dual-energy CT in clinical practice – Spectral magic glass and dedicated workstations

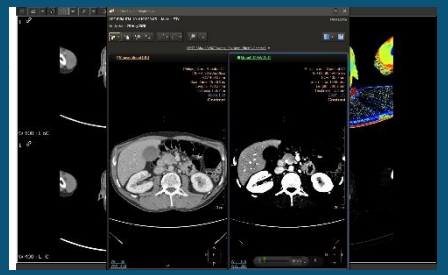
Intellispace/Syngovia/AWS

SBI/SPP
Files

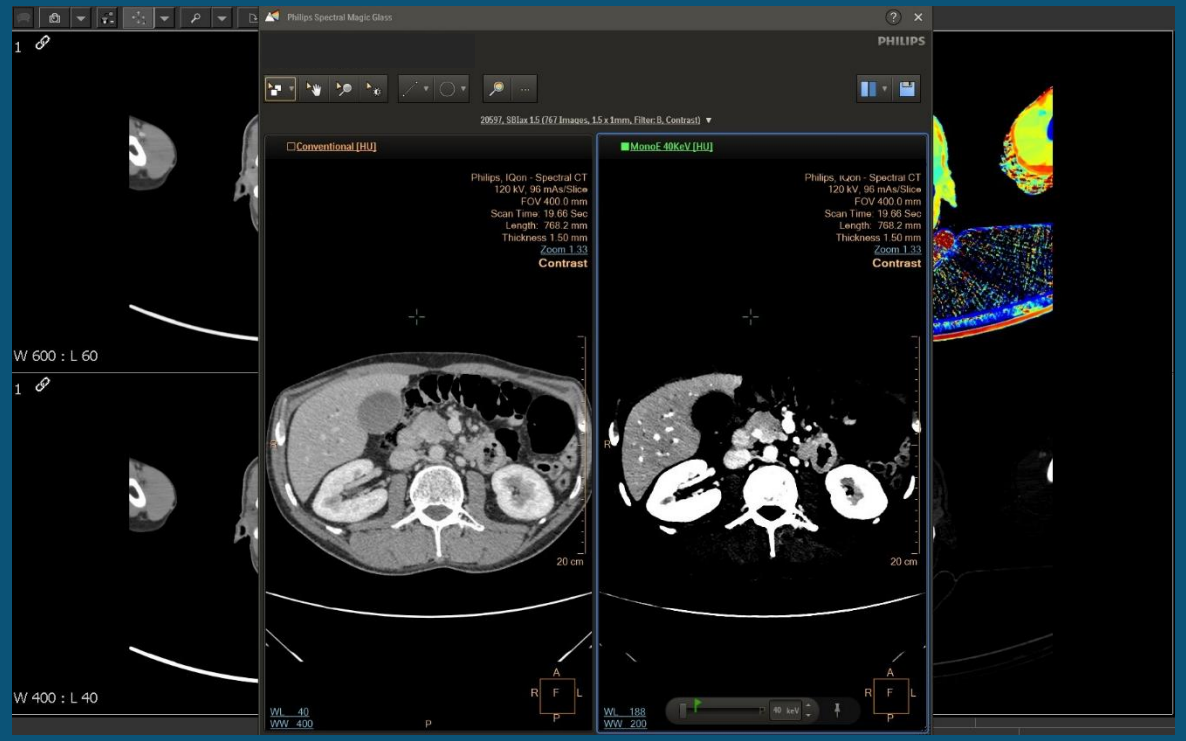
Thin Slices

PACS

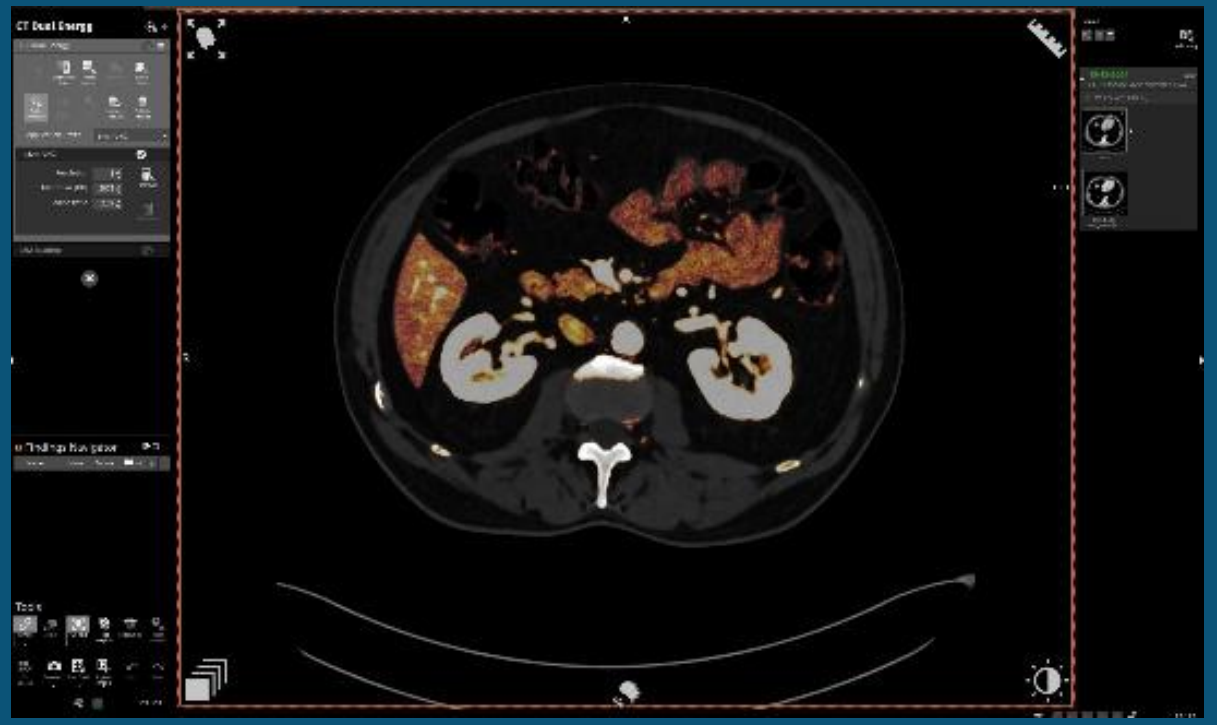
Magic glass



Implementation of spectral/dual-energy CT in clinical practice – Spectral magic glass and workstations



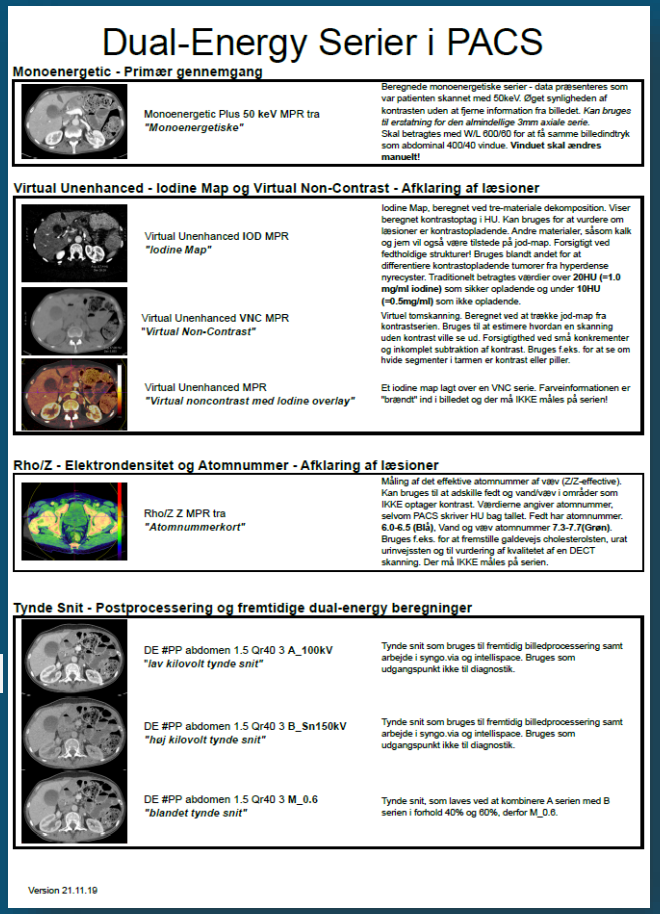
Magic glass in PACS



Intellispace portal/Syngovia/AWS

All abdominal and oncological scans

- Since 2019 and 2020 respectively
- Purpose
  - Increase conspicuity of lesions
  - Reduce follow-up scans
- Close to dose neutral and workload neutral
  - Noise and image quality matched to non-spectral protocol
  - Spectral/Dual Energy CT is mainly read in PACS!



Dual-Energy Serier i PACS

Monoenergetic - Primær gennemgang

Monoenergetic Plus 50 keV MPR tra
"Monoenergetiske"

Beregnede monoenergetiske serier - data præsenteres som var patienten skannet med 50keV. Øget synligheden af kontrasten uden at fjerne information fra billedet. *Kan bruges til erstatning for den almindellige 3mm axiale serie.* Skal betragtes med W/L 600/60 for at få samme billedindtryk som abdominal 400/40 vindue. **Vinduet skal ændres manuelt!**

Virtual Unenhanced - Iodine Map og Virtual Non-Contrast - Afklaring af læsioner

Virtual Unenhanced IOD MPR
"Iodine Map"

Iodine Map, beregnet ved tre-materiale dekomposition. Viser beregnet kontrastoptag i HU. Kan bruges for at vurdere om læsioner er kontrastopladende. Andre materialer, såsom kalk og jern vil også være tilstede på jod-map. Forsigtigt ved fedtholdige strukturer! Bruges blandt andet for at differentiere kontrastopladende tumorer fra hyperdense nyrecyster. Traditionelt betragtes værdier over **20HU (=1.0 mg/ml iodine)** som sikker opladende og under **10HU (=0.5mg/ml)** som ikke opladende.

Virtual Unenhanced VNC MPR
"Virtual Non-Contrast"

Virtuel tomskanning. Beregnet ved at trække jod-map fra kontrastserien. Bruges til at estimere hvordan en skanning uden kontrast ville se ud. Forsigtighed ved små konkrementer og inkomplet subtraktion af kontrast. Bruges f.eks. for at se om hvide segmenter i tarmen er kontrast eller piller.

Virtual Unenhanced MPR
"Virtual noncontrast med Iodine overlay"

Et iodine map lagt over en VNC serie. Farveinformationen er "brændt" ind i billedet og der må IKKE måles på serien!

Rho/Z - Elektrondensitet og Atomnummer - Afklaring af læsioner

Rho/Z Z MPR tra
"Atomnummerkort"

Måling af det effektive atomnummer af væv (Z/Z-effective). Kan bruges til at adskille fedt og vandvæv i områder som IKKE optager kontrast. Værdierne angiver atomnummer, selvom PACS skriver HU bag tallet. Fedt har atomnummer. **6.0-6.5 (Blå)**, Vand og væv atomnummer **7.3-7.7(Grøn)**. Bruges f.eks. for at fremstille galdevejs cholesterolsten, urat urinvejssten og til vurdering af kvalitetet af en DECT skanning. Der må IKKE måles på serien.

Tynde Snit - Postprocessering og fremtidige dual-energy beregninger

DE #PP abdomen 1.5 Qr40 3 **A_100kV**
"lav kilovolt tynde snit"

Tynde snit som bruges til fremtidig billedprocessering samt arbejde i syngo.via og intellispace. Bruges som udgangspunkt ikke til diagnostik.

DE #PP abdomen 1.5 Qr40 3 **B_Sn150kV**
"høj kilovolt tynde snit"

Tynde snit som bruges til fremtidig billedprocessering samt arbejde i syngo.via og intellispace. Bruges som udgangspunkt ikke til diagnostik.

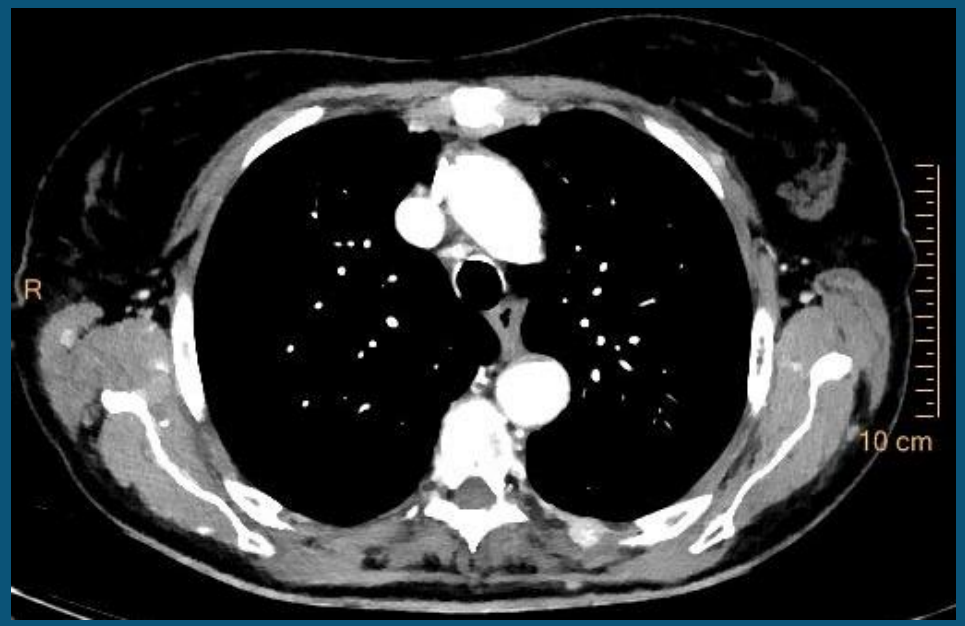
DE #PP abdomen 1.5 Qr40 3 **M_0.6**
"blandet tynde snit"

Tynde snit, som laves ved at kombinere A serien med B serien i forhold 40% og 60%, derfor M_0.6.

Version 21.11.19

Automatic series in abdominal/oncological scans

- Virtual MonoE at 50 keV – Replaces conventional CT images for primary assessment.



”Calculated virtual monoenergetic series – presented as if the patient was scanned at 50 keV. **Increases the conspicuity of contrast media** without removing information from the image. Can be used as **a replacement for the axial 3/3 series during initial assessment.**
To achieve same image impression as normal abdominal 400/40 window a **W/L 600/60** can be used for reconstruction.”

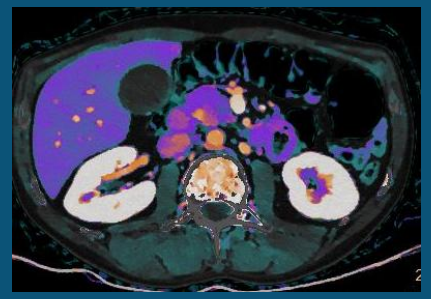
Automatic series in abdominal/oncological scans

- Iodine map and virtual non-contrast: Assessment of Lesions

"Iodine Map"

Iodine Map, calculated based on three-material decomposition. Shows contrast enhancement (i.e. ∆) in HU. Used for **assessment of contrast enhancement**. Other materials like calcium will also be present on the iodine map. **Careful when assessing potentially fat containing lesions!** Can be used to differentiate hyperdense renal cysts from contrast enhancing tumors. Traditionally lesions above **20HU (=0.8 mg/ml iodine)** are classified as enhancing and below **10HU (=0.4mg/ml)** as non-enhancing.

"***Virtual Non-Contrast (VNC)"***

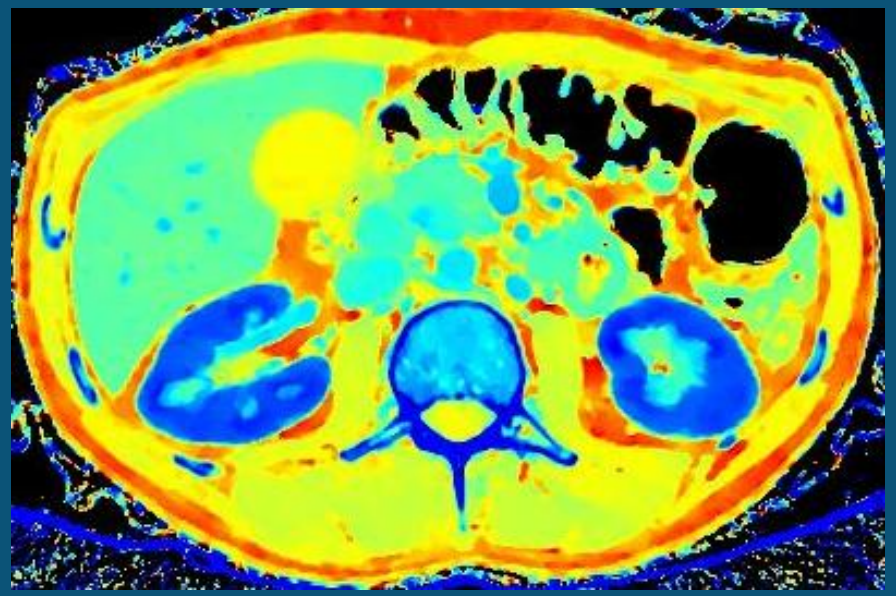


"Virtual noncontrast with Iodine overlay"

Virtuel Non-Contrast (VNC). Calculated by subtraction of the iodine map from the original series. Used as an **estimate for how a non-contrast image would appear**. Beware of subtraction of smaller calcifications (e.g. kidney stones) and incomplete subtraction. Can be used to determine for example if hyperdense lesions in the bowel are pills or iodine extravasation.

Automatic series in abdominal/oncological scans

- Effective atomic number/RhoZ



”Measurement of the effective atomic number of voxels/tissue (Z/Z-effective). Can be used to seperate fat and water/tissue in areas **NOT** uptaking contrast. The values represent atomic numbers, even though PACS denominates it as HU. Fat have atomic number **6.0-6.5 (Red/Philips – Blue/Siemens),** Water and tissue have atomic number **7,3-7,7 (Green/yellow**). Used for finding cholesterol stones in gallways, urat stones in the urinary tract and for quality assessment of a spectral/DE-CT scan. Measurement on the series in PACS is **NOT** allowed.”

General advice on reading

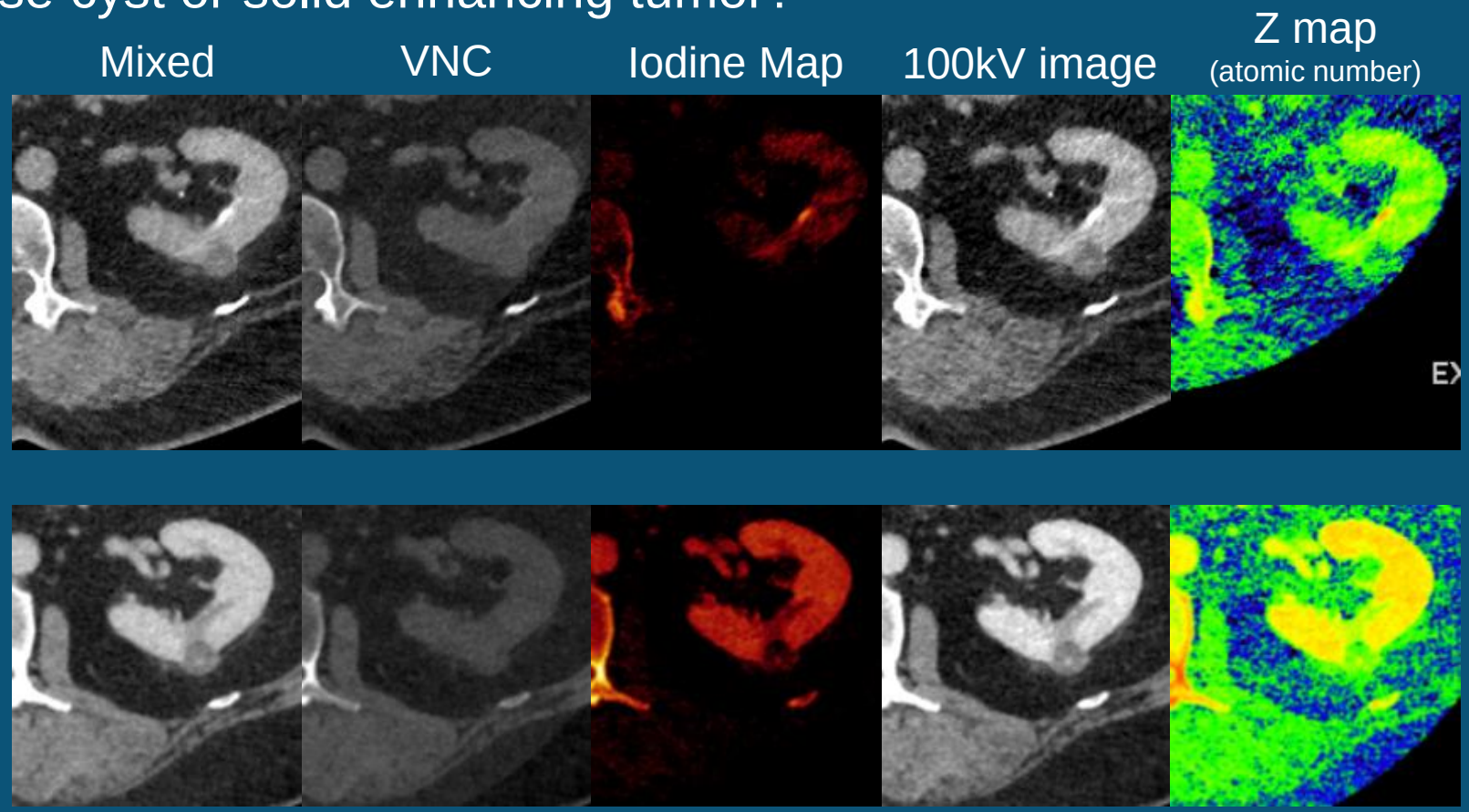
- Low virtual mono E (40-50 keV) – Primary reading series
  - Typically better signal to noise ratio compared to conventional series
  - Increase the conspicuity of both hypodense and hyperdense lesions
  - Window level settings have to be adjusted to organ and level of keV
    - Center around normal tissue, window width should be narrow 150-300 HU depending on the organ and preferred noise levels
- Effective Z (effective atomic number)
  - Always check gallbladder and gallways for cholesterol stones (values correspond to fat)

Technical limitations/challenges

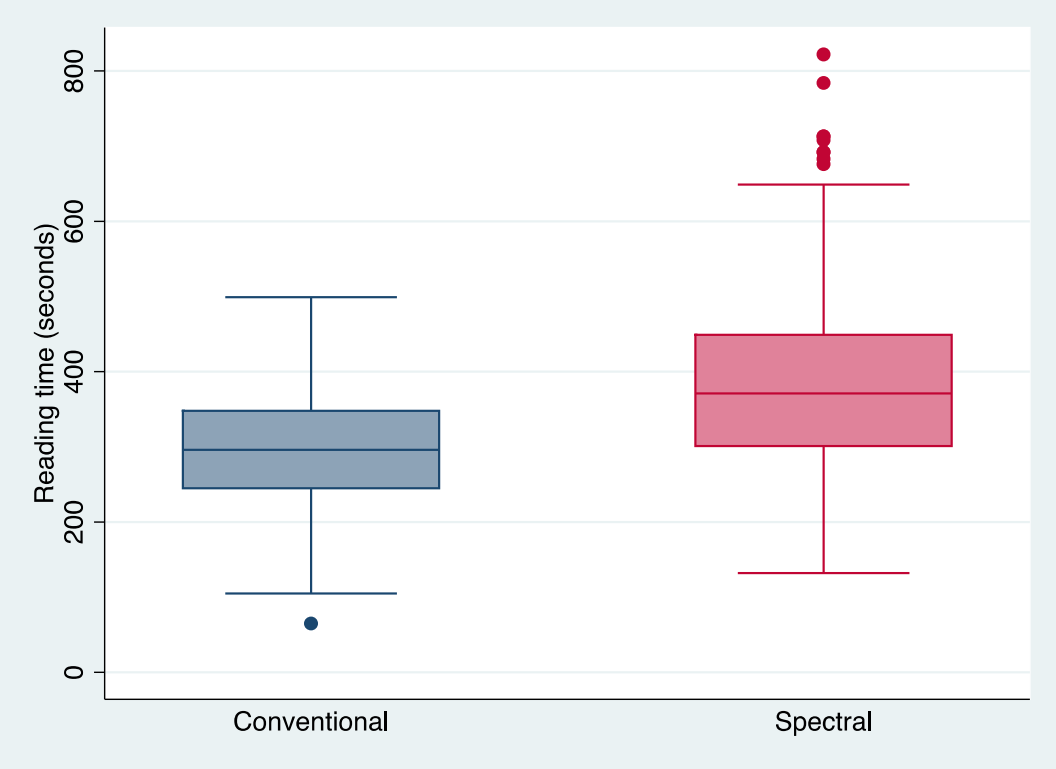
- Beam hardening/photon starvation
- Time consumption
- Quality control

Technical limitations - Beam hardening/photon starvation

- Hyperdense cyst or solid enhancing tumor?



Technical Challenges – Time consumption



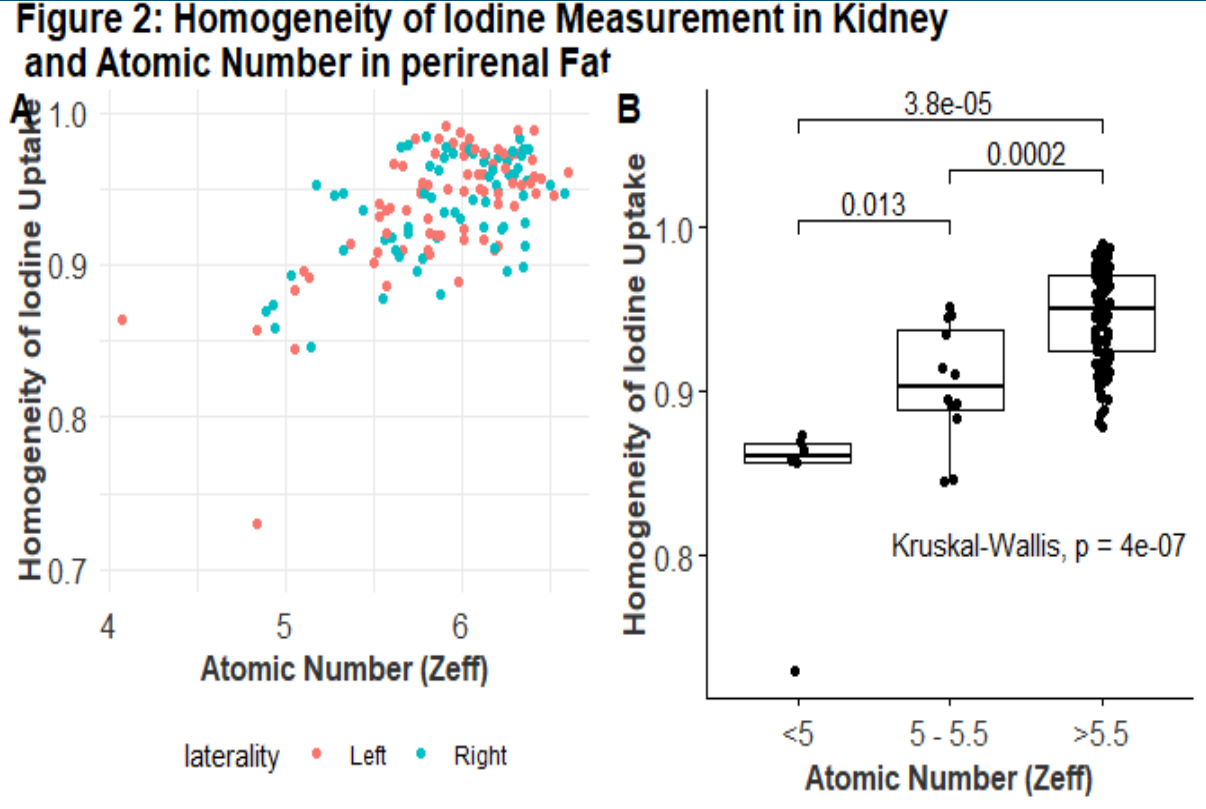
Reading time

Conventional:	300 seconds (65-499)
Spectral:	382 seconds (132-822)
Welch ttest:	p<0.00001

Mean reading time of spectral CT results increases with only **82 seconds**

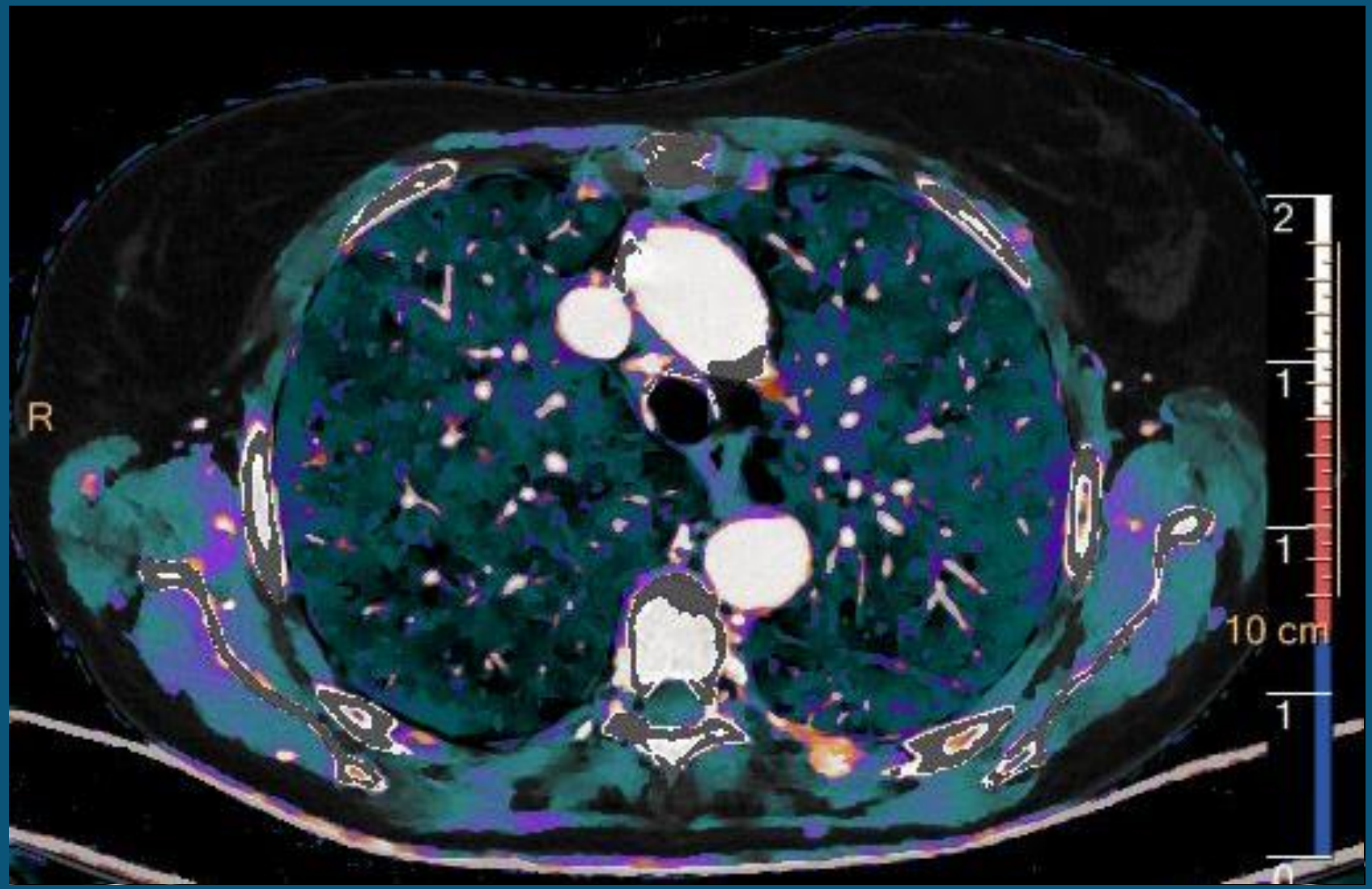
MB Andersen et al. **Impact of spectral body imaging in patients suspected for occult cancer: a prospective study of 503 patients.** Eur Radiol. 2020 Oct;30(10):5539-5550

Technical Challenges – Quality control

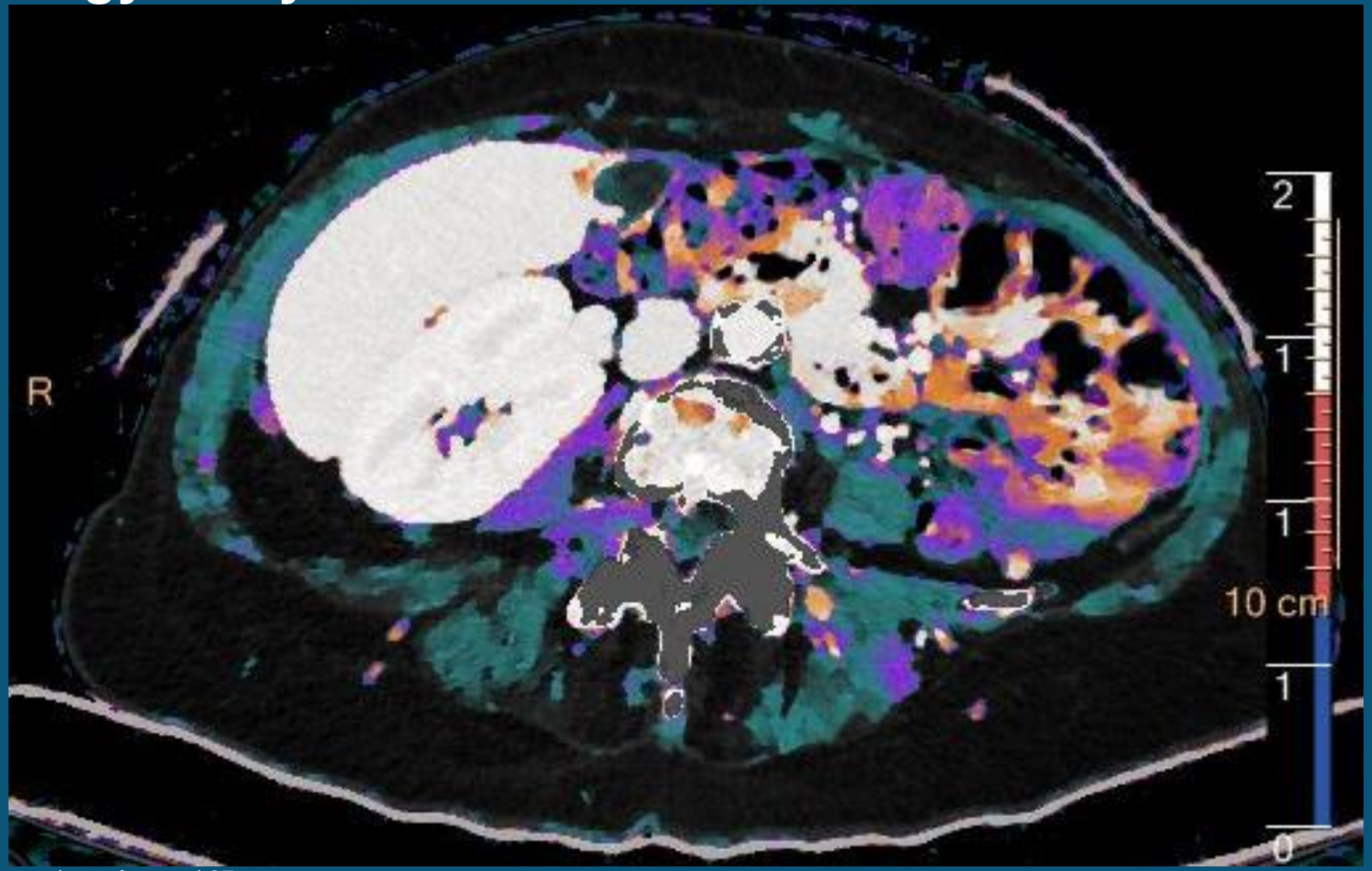


Z-effective
Measure areas close to lesions containing fat without contrast enhancement. Eg. Perirenal fat, intraabdominal fat or subcutaneous fat. If values are <6.0-6.5 results from iodine/VNC measurements can not be trusted.

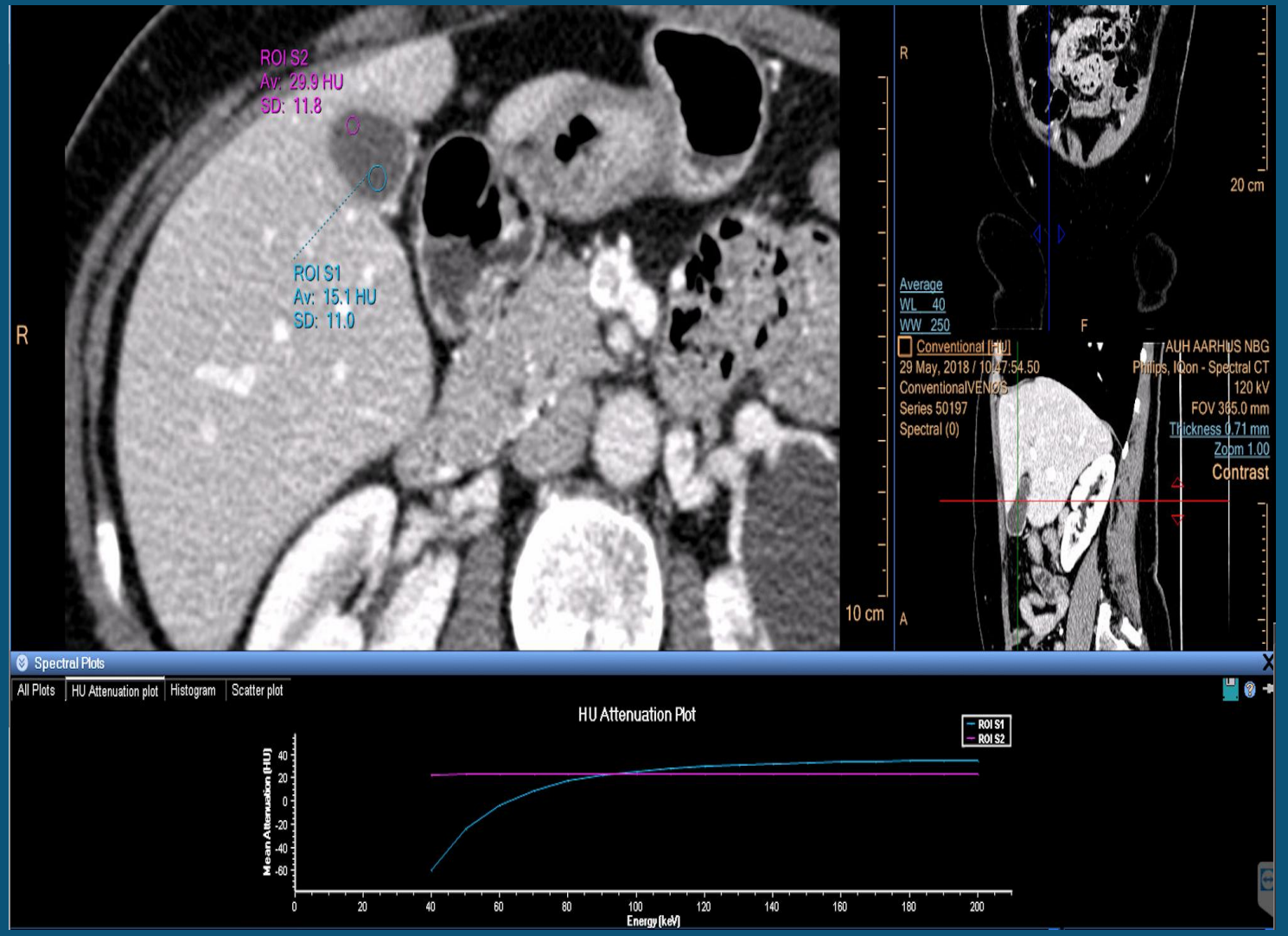
Oncology: Do you see the metastases?



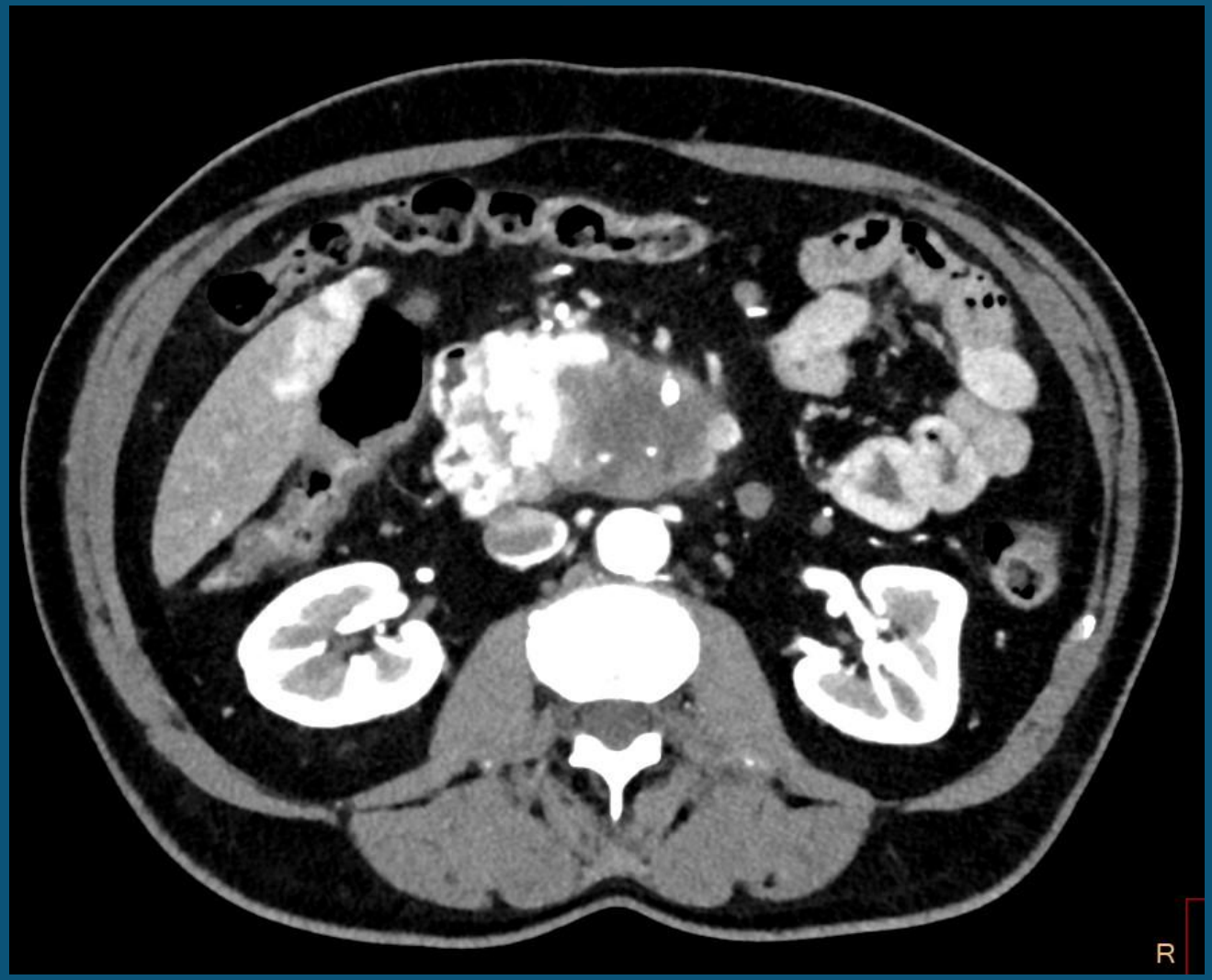
Oncology: Do you see the metastases?



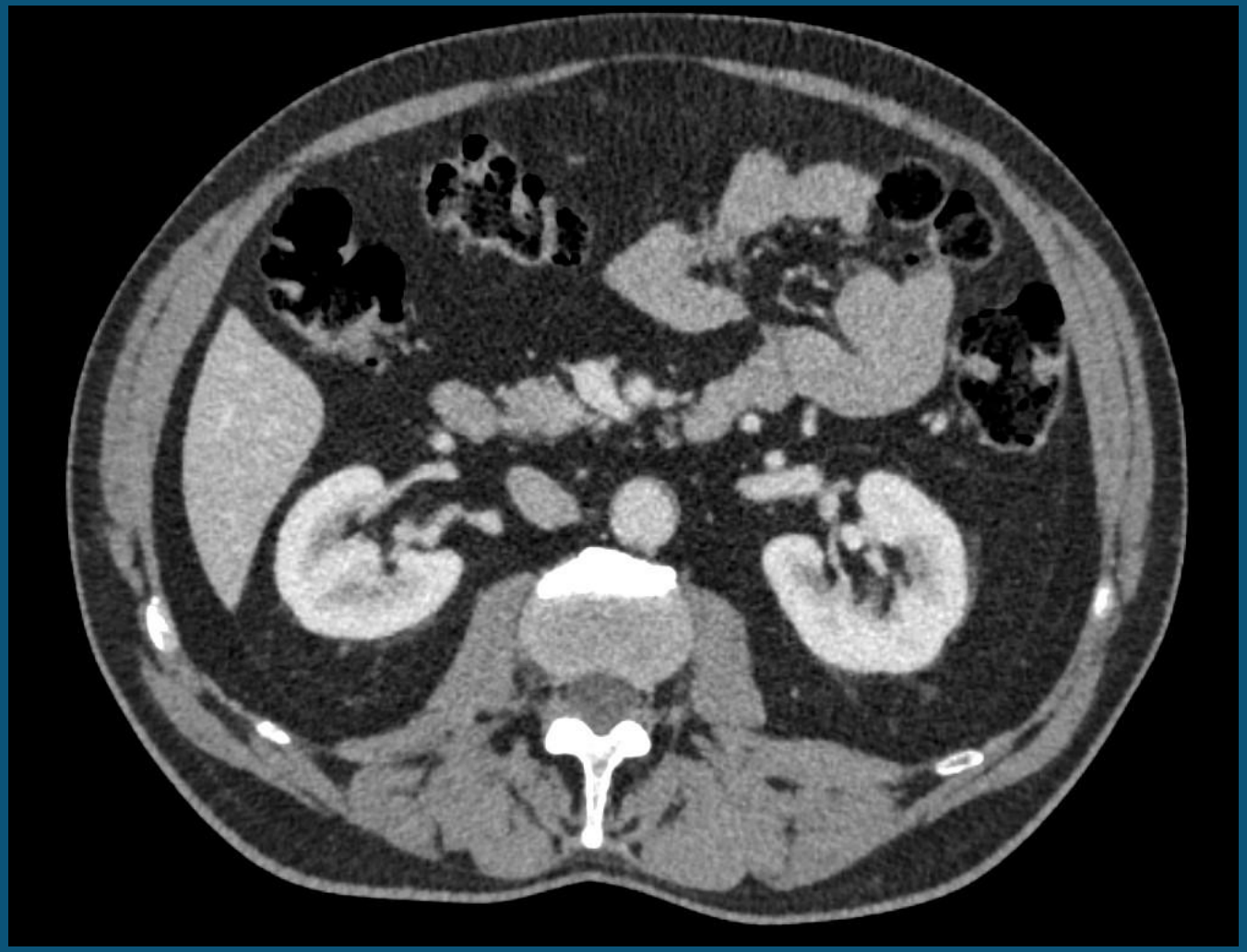
Oncology: Detection



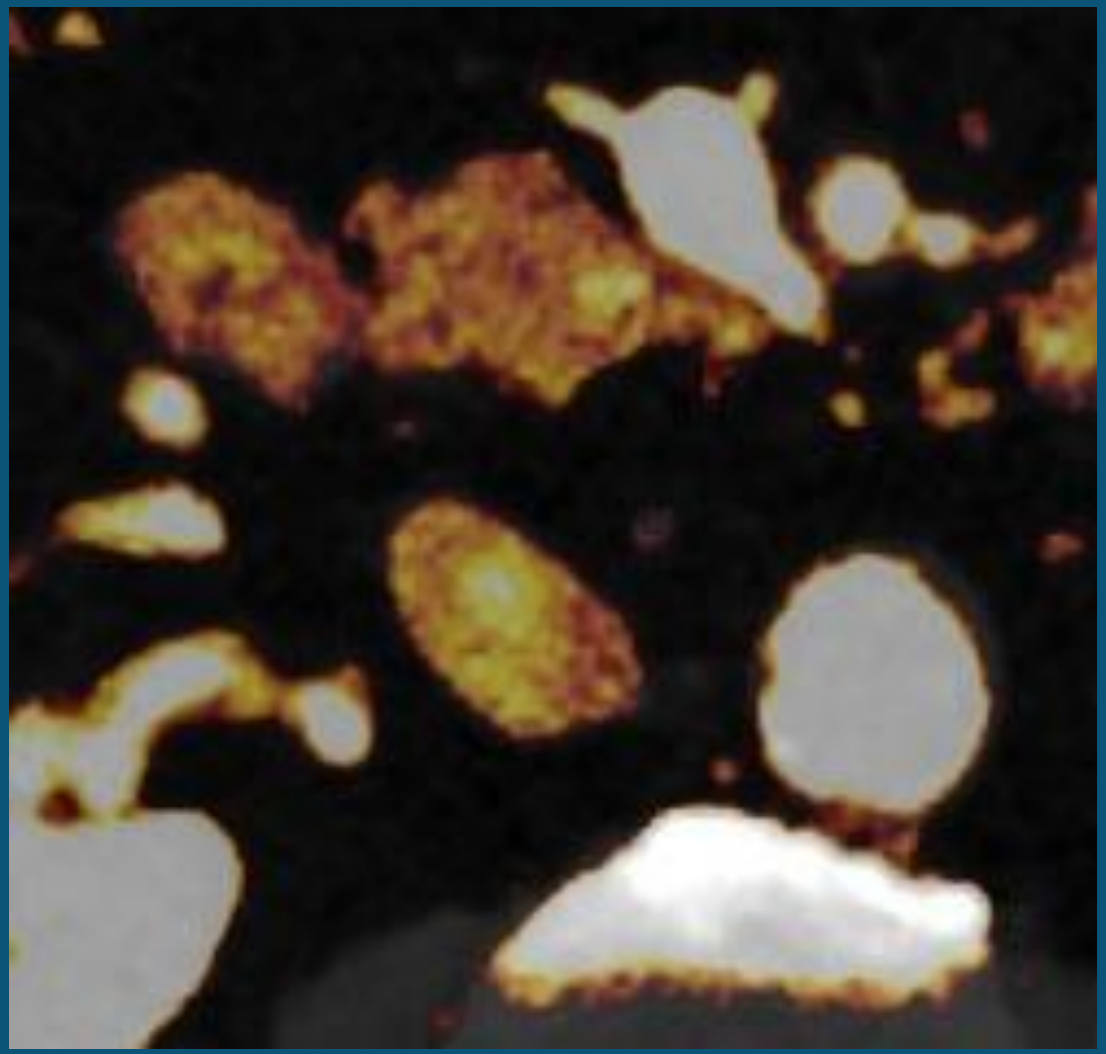
Detection - Pancreas



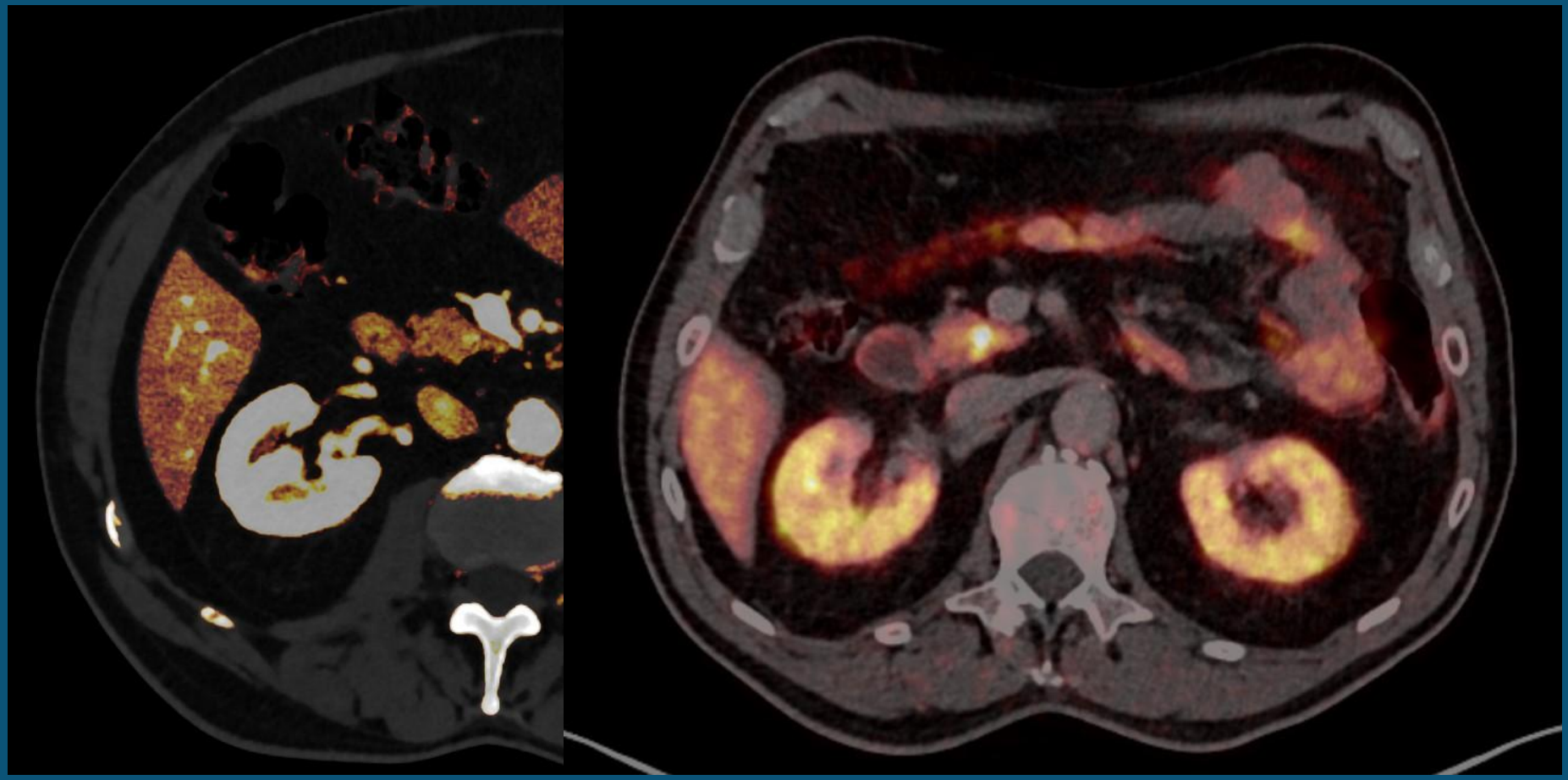
Detection - Pancreas



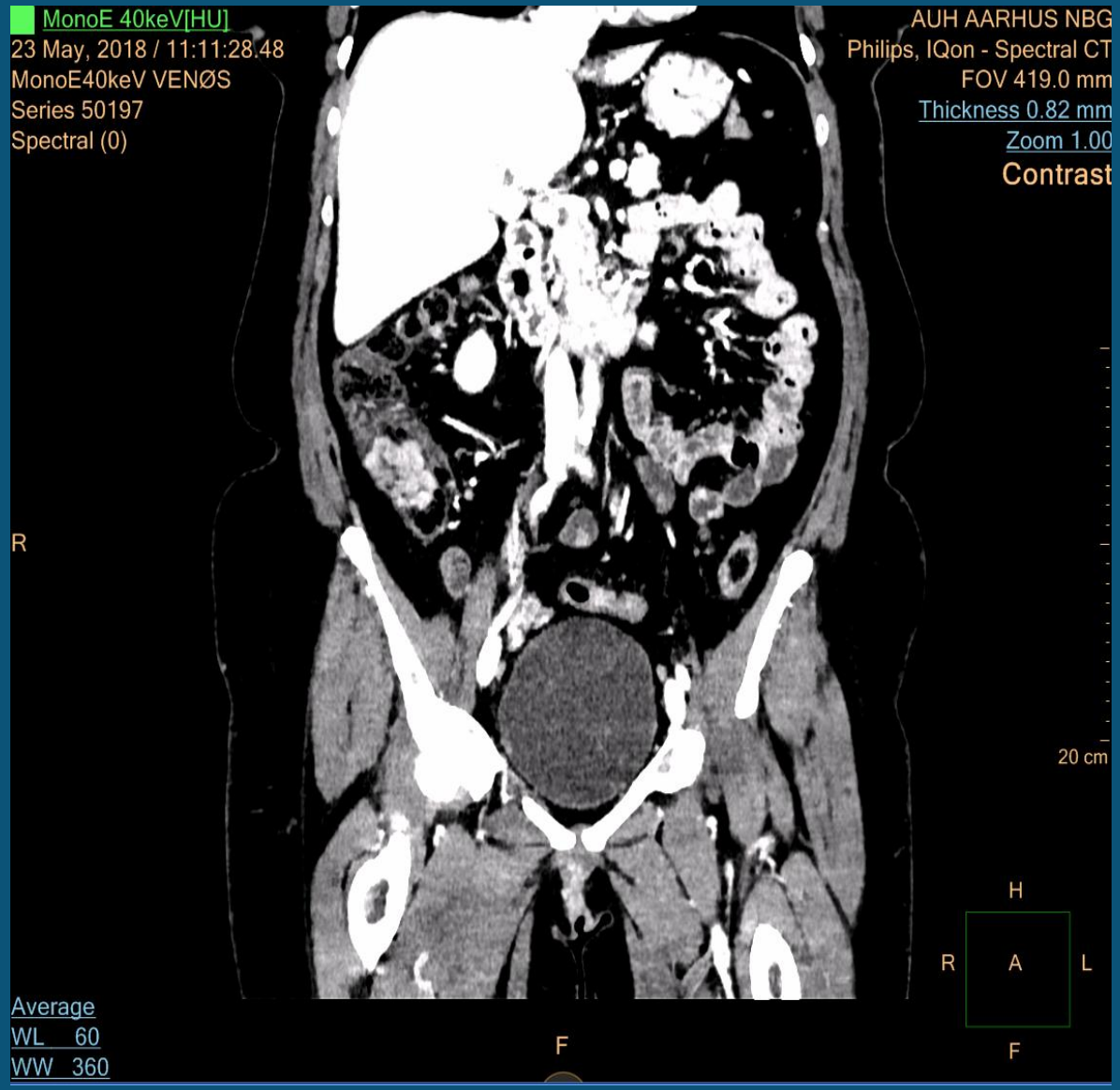
Detection - Pancreas



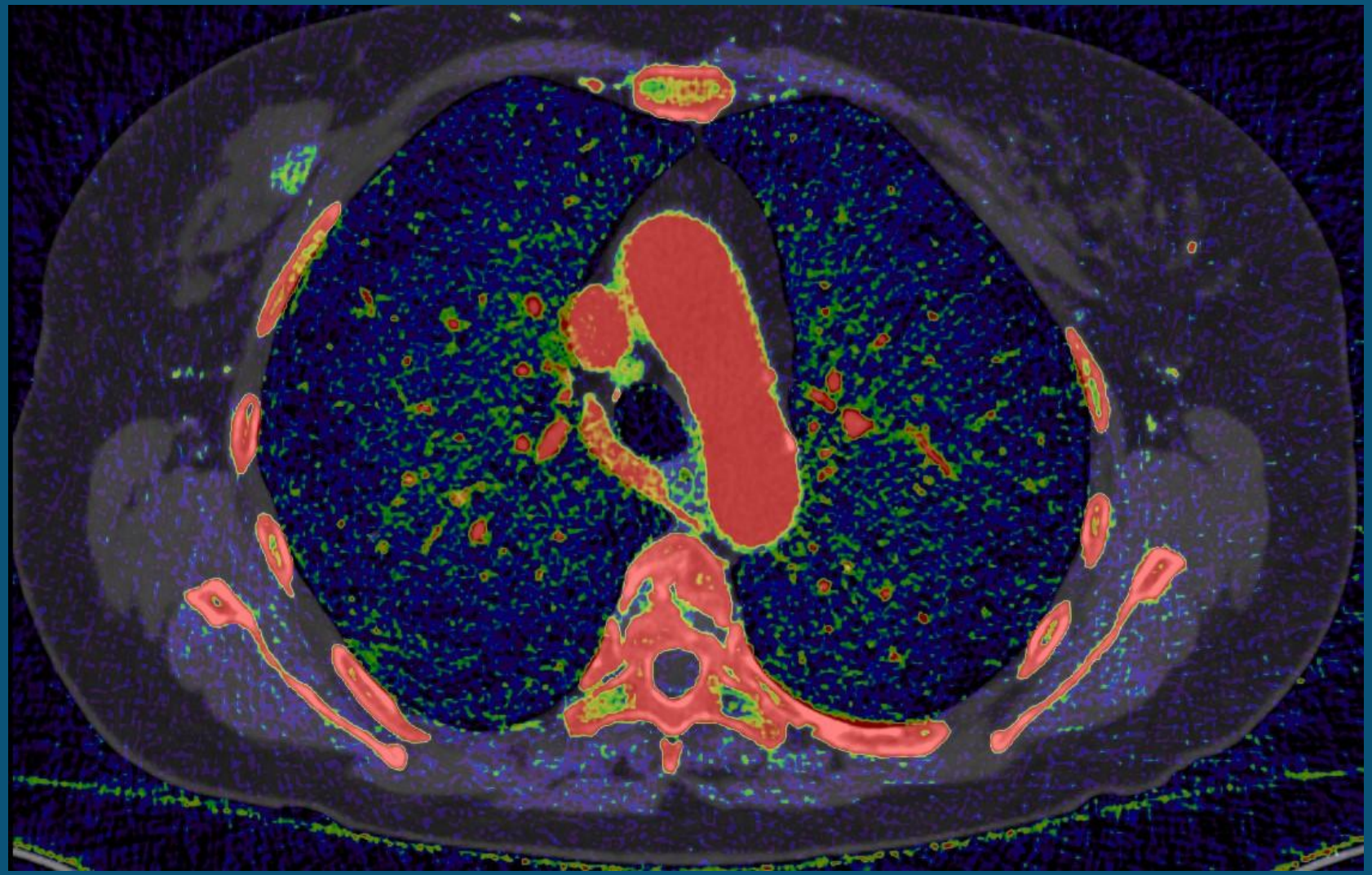
Detection - Pancreas



Detection – Colon

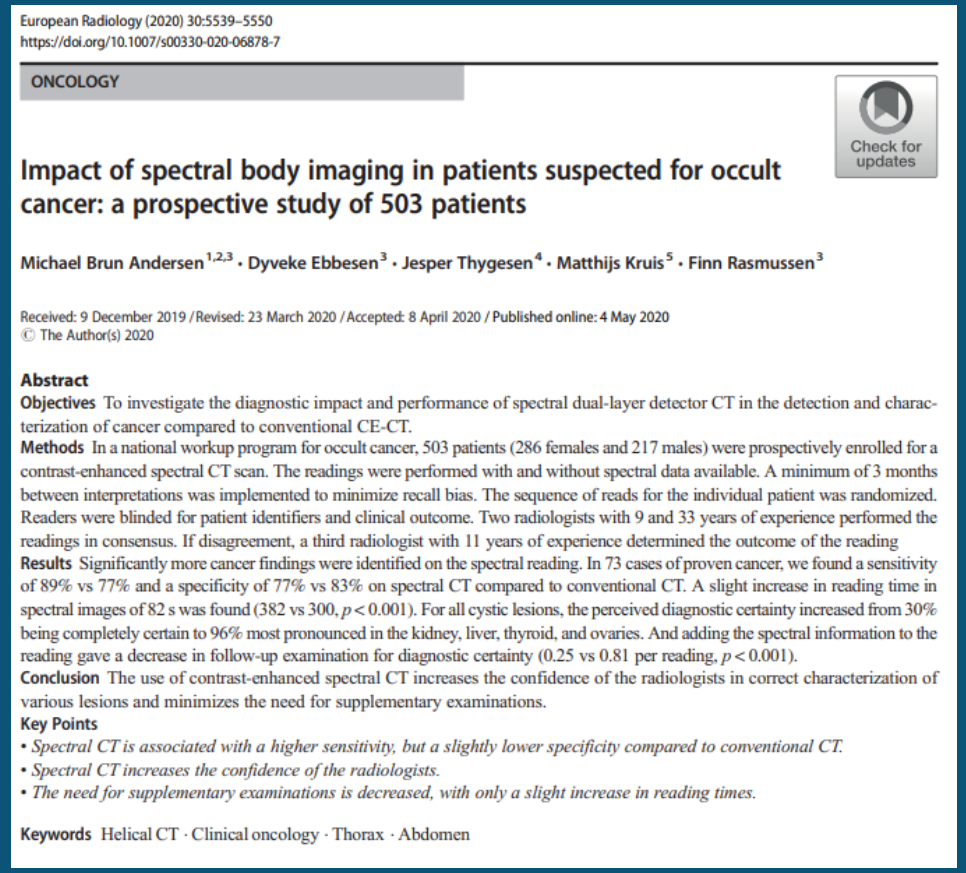


Detection – Mamma



Detection – Is Spectral/Dual-energy CT better?

- In a study of 503 patients suspected for serious illness that could be cancer
  - 73 proven cancers in the patient population
  - Sensitivity 89% vs 77%, p<0.005
  - Specificity 77 vs 83%, p<0.005
  - 18 suspected cancer findings on conventional CT excluded on spectral.



European Radiology (2020) 30:5539–5550
https://doi.org/10.1007/s00330-020-06878-7

ONCOLOGY

Check for updates

Impact of spectral body imaging in patients suspected for occult cancer: a prospective study of 503 patients

Michael Brun Andersen[1,2,3] · Dyveke Ebbesen[3] · Jesper Thygesen[4] · Matthijs Kruis[5] · Finn Rasmussen[3]

Received: 9 December 2019 / Revised: 23 March 2020 / Accepted: 8 April 2020 / Published online: 4 May 2020

Abstract

Objectives To investigate the diagnostic impact and performance of spectral dual-layer detector CT in the detection and characterization of cancer compared to conventional CE-CT.

Methods In a national workup program for occult cancer, 503 patients (286 females and 217 males) were prospectively enrolled for a contrast-enhanced spectral CT scan. The readings were performed with and without spectral data available. A minimum of 3 months between interpretations was implemented to minimize recall bias. The sequence of reads for the individual patient was randomized. Readers were blinded for patient identifiers and clinical outcome. Two radiologists with 9 and 33 years of experience performed the readings in consensus. If disagreement, a third radiologist with 11 years of experience determined the outcome of the reading

Results Significantly more cancer findings were identified on the spectral reading. In 73 cases of proven cancer, we found a sensitivity of 89% vs 77% and a specificity of 77% vs 83% on spectral CT compared to conventional CT. A slight increase in reading time in spectral images of 82 s was found (382 vs 300, $p < 0.001$). For all cystic lesions, the perceived diagnostic certainty increased from 30% being completely certain to 96% most pronounced in the kidney, liver, thyroid, and ovaries. And adding the spectral information to the reading gave a decrease in follow-up examination for diagnostic certainty (0.25 vs 0.81 per reading, $p < 0.001$).

Conclusion The use of contrast-enhanced spectral CT increases the confidence of the radiologists in correct characterization of various lesions and minimizes the need for supplementary examinations.

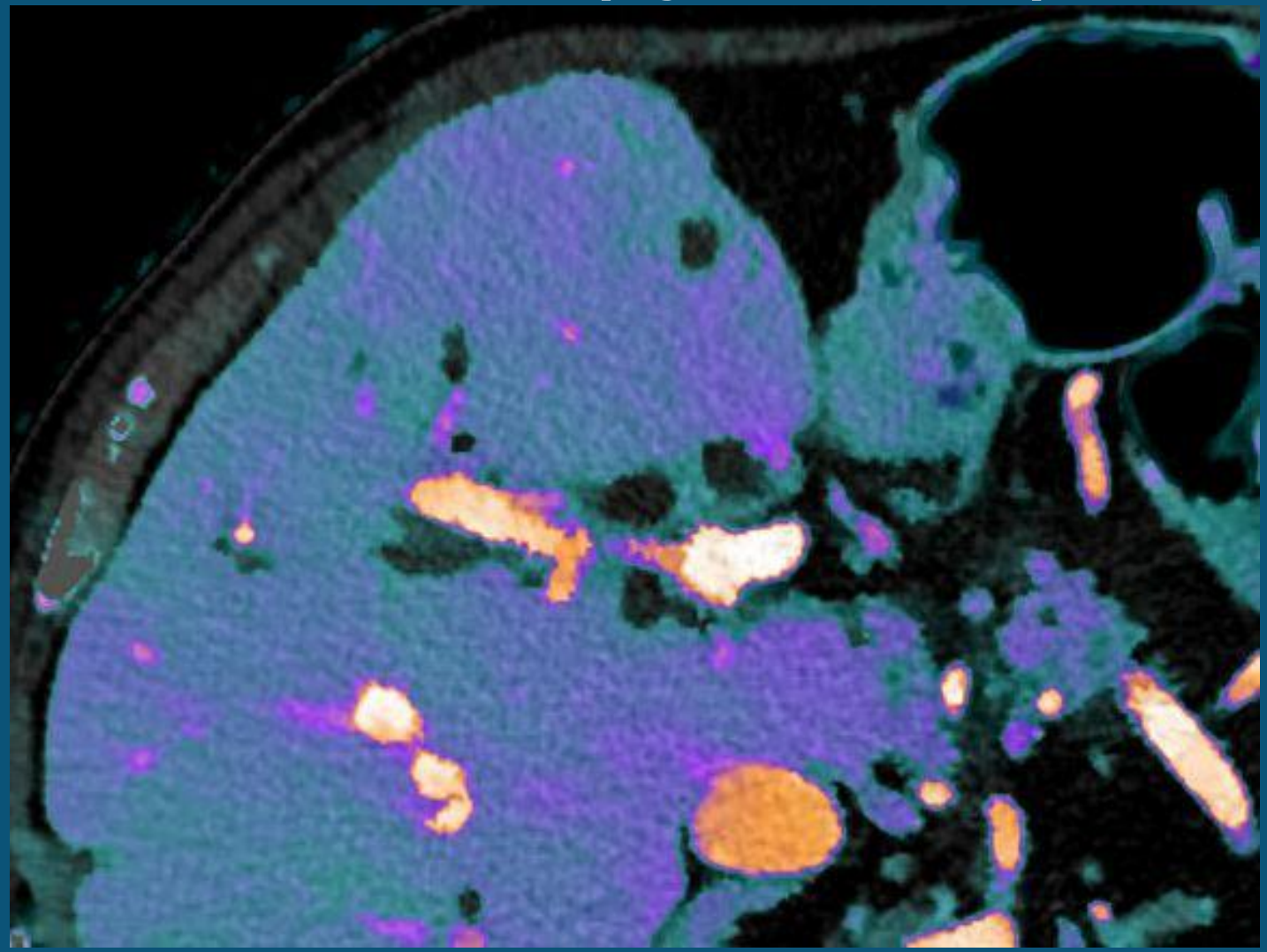
Key Points

- *Spectral CT is associated with a higher sensitivity, but a slightly lower specificity compared to conventional CT.*
- *Spectral CT increases the confidence of the radiologists.*
- *The need for supplementary examinations is decreased, with only a slight increase in reading times.*

Keywords Helical CT · Clinical oncology · Thorax · Abdomen

MB Andersen et al. **Impact of spectral body imaging in patients suspected for occult cancer: a prospective study of 503 patients.** Eur Radiol. 2020 Oct;30(10):5539-5550

Oncology – Characterization (Cysts/tumors)

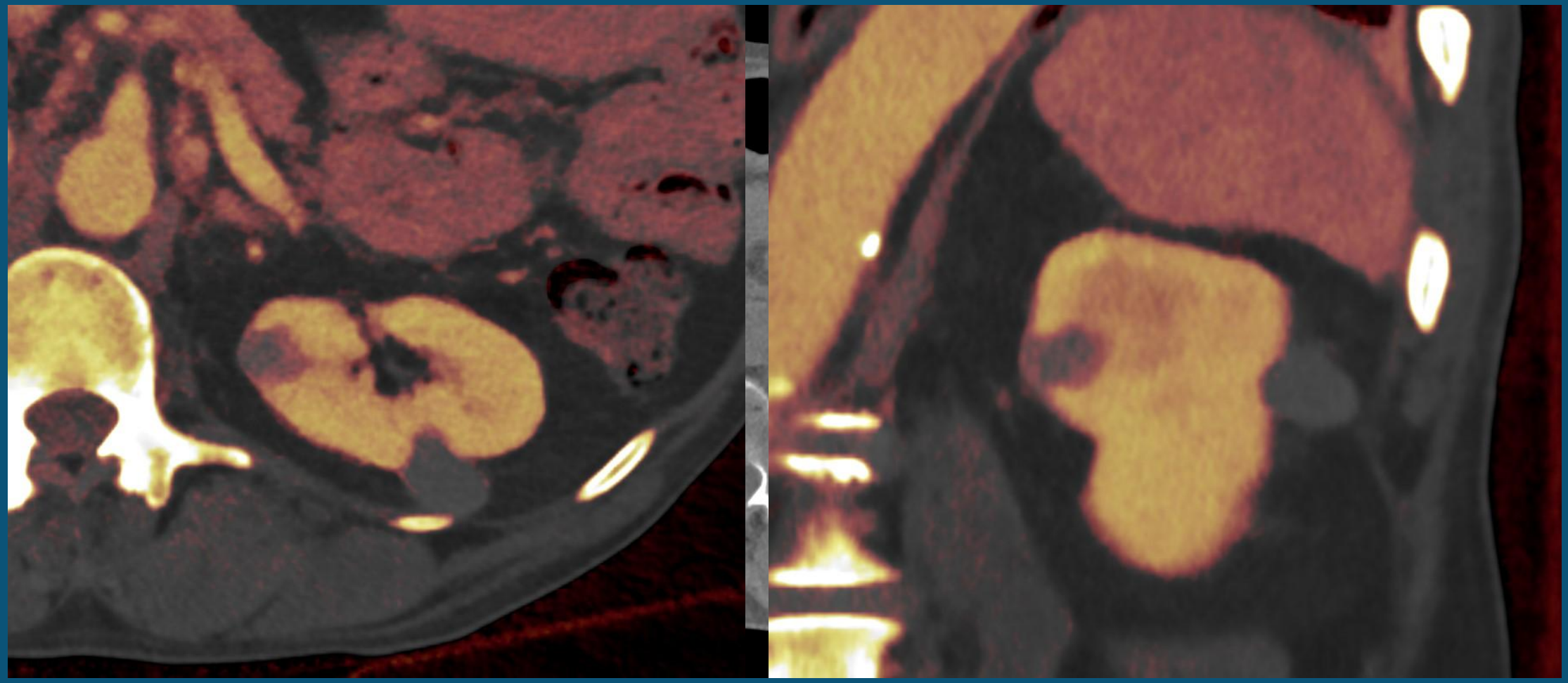


Oncology – Characterization (Cysts/tumors)

Oncology – Characterization (Cysts/tumors)

In imaging of the kidneys traditionally lesions with an increase of **20HU (=0.8 mg/ml iodine)** between true non contrast and contrast series are classified as enhancing and below **10HU (=0.4 mg/ml)** as non-enhancing.

Oncology – Characterization (Cysts/tumors)



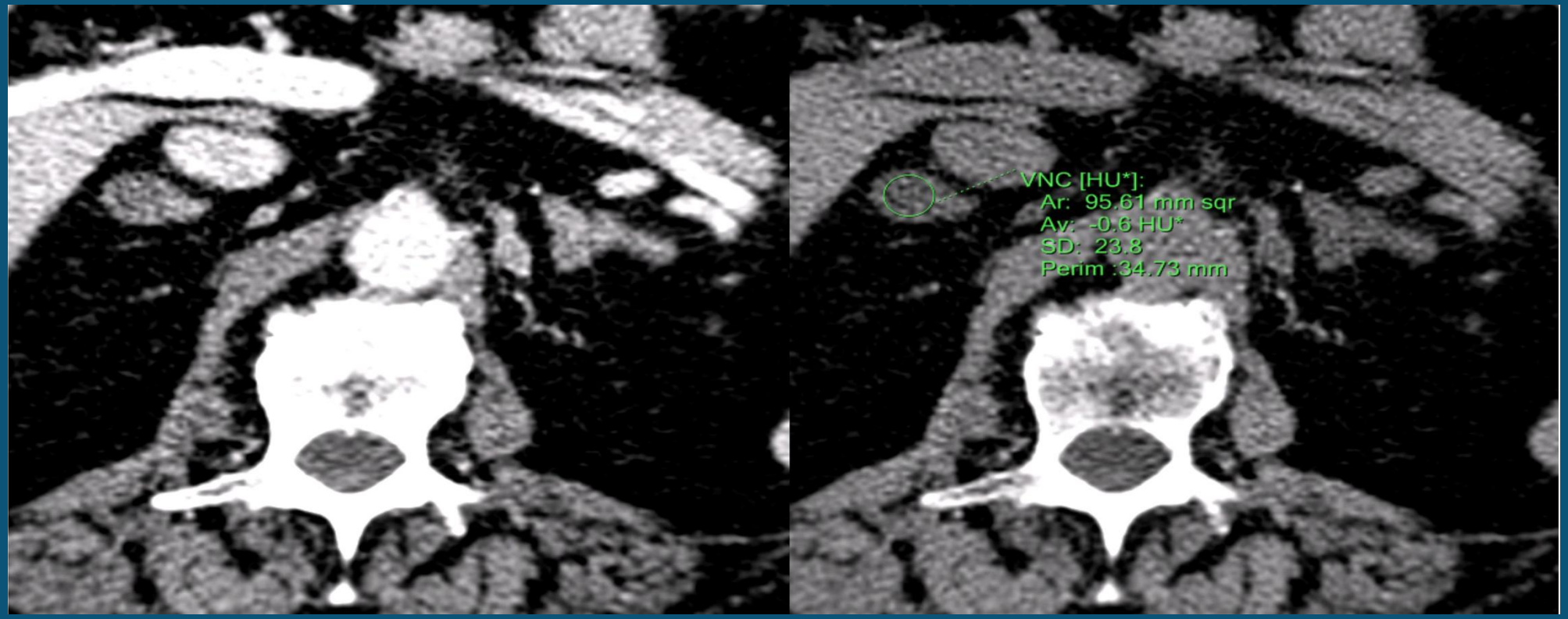
Case courtesy Erik Brandt, Copenhagen University Hospital

Oncology – Characterization (Adrenals)

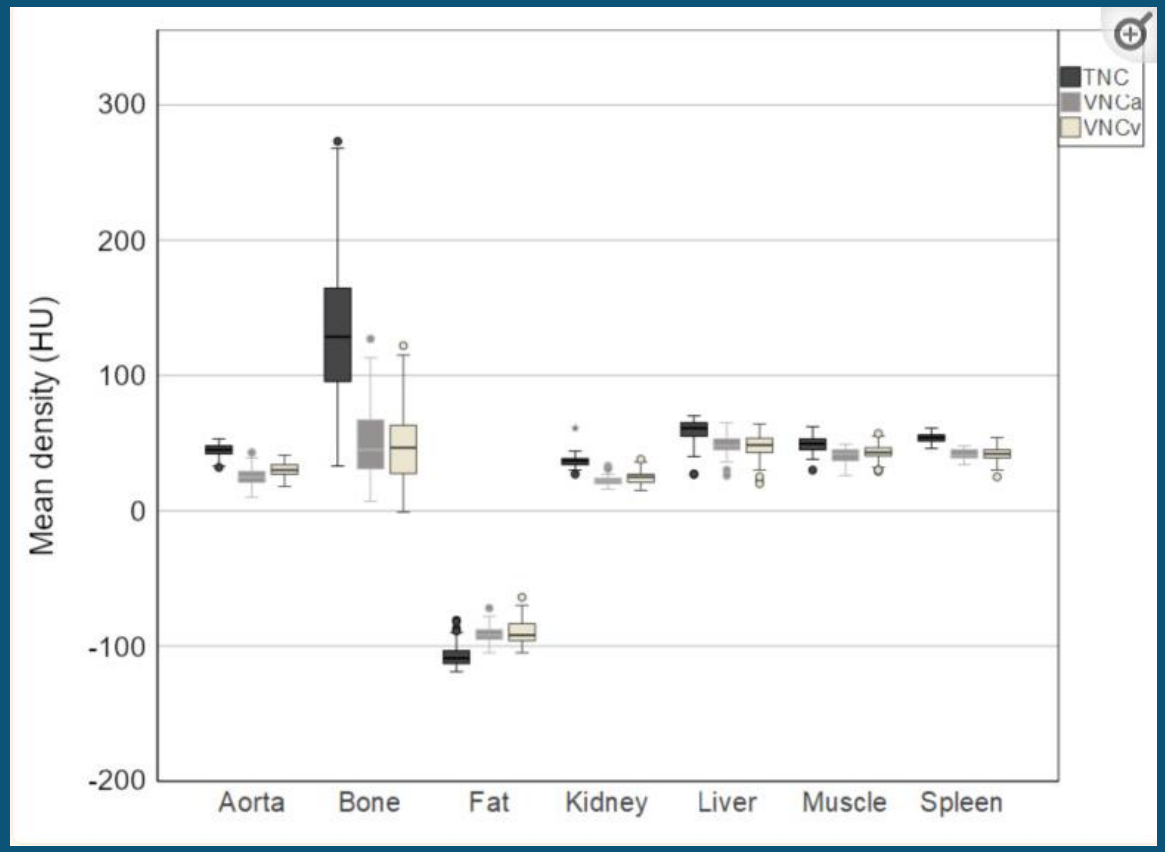
We use the traditional cut-off at 10 HU even on VNC.

Currently a cut-off at 15 HU is being implemented into the Danish guidelines

Oncology – Characterization (Adrenals)



Oncology – Characterization (Adrenals)



Usually VNC underestimates the contribution from fat and always have higher HU values in organs or areas of fat compared to true non-contrast.

Niehoff JH et al **Virtual Non-Contrast versus True Non-Contrast Computed Tomography: Initial Experiences with a Photon Counting CT Scanner Approved for Clinical Use** Diagnostics 2021 Dec; 11(12):2377

Follow-up examinations and economic implications

- A total of 400 patients with both CE-CT and CE-SCT
- Suggested follow-up procedures registered
- An estimated cost saving per patient for follow-up procedures of 130 Euro.

Area of interest	Frequency of follow-up following CE-CT	Frequency of follow-up following CE-SCT	Overall reduction in follow-up procedures	Healthcare system	Cost of follow-up after CE-CT	Cost of follow-up after CE-SCT	Reduction in costs	Reduction in percent (%)
Over all	573	370	203	DK	€ 207.603	€155.219	€ 52.384	25.2
				USA	$376.891	$3.8.054	$68.837	18.2

How we believe Spectral/Dual Energy CT should be utilized in clinical practice…

- Virtual MonoE/Quantitative maps
  - Think specific MRI sequences designed to visualize specific lesions/materials
  - We can specificly design our material decompositions to certain pathologies
    - Bone marrow edema, iodine quantification (perfussion)
- Requires training of radiologists to be confident in using the images similar to new MRI sequences.

Conclusions

- Actively choose to use spectral imaging in the departments
- Increased sensitivity for malignant findings
- Increased reading time – potentially overestimated due to learning curve
- Decreased number of follow-up procedures and cost savings of 130 Euro per patient