UZ LEUVEN

Non-invasive methods for screening, imaging and treatment of liver lesions

The role of MRI and Photon-Counting CT

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The role of MR and Photon-Counting CT

- Conflict of interest
  - I declare that I have no commercial or financial interests pertaining to the subject of this presentation or its content.
- Recordings
  - No recordings of the presentation are allowed, for personal nor commercial purposes.

Focal liver lesions and imaging

Patient characteristics

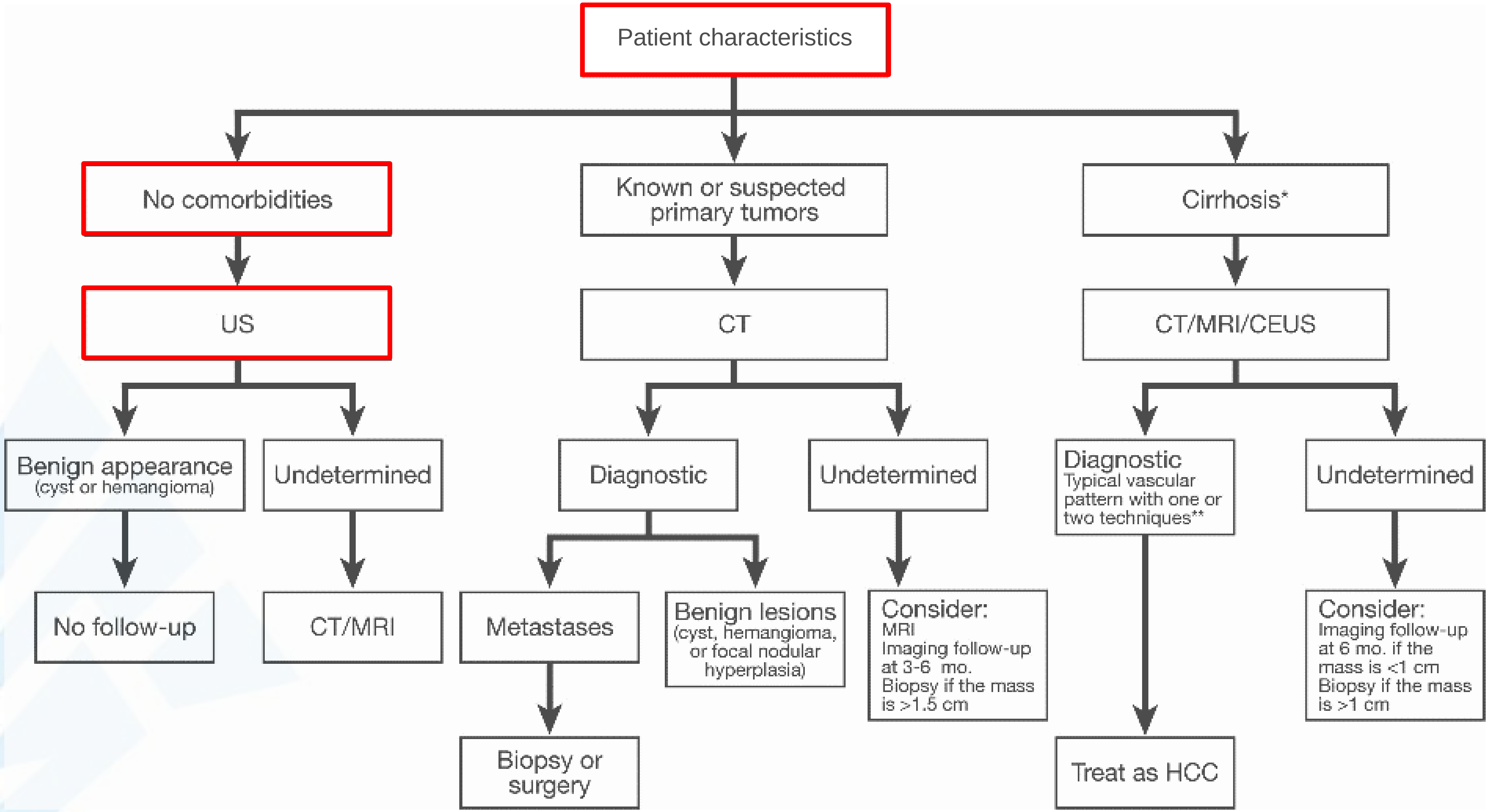
- No comorbidities?
- Known or suspected primary tumour?
- History of cirrhosis?

Imaging modalities

- Ultrasound (US or CEUS)?
- Computer tomography (CT)?
- Magnetic resonance (MR)?
- Nuclear medicine (PET-CT or PET-MR)?

1. Marin D, et al. (2009) Clinical Gastroenterology and Hepatology 7:624-634.

Focal liver lesions and imaging



1. Marin D, et al. (2009) Clinical Gastroenterology and Hepatology 7:624-634.

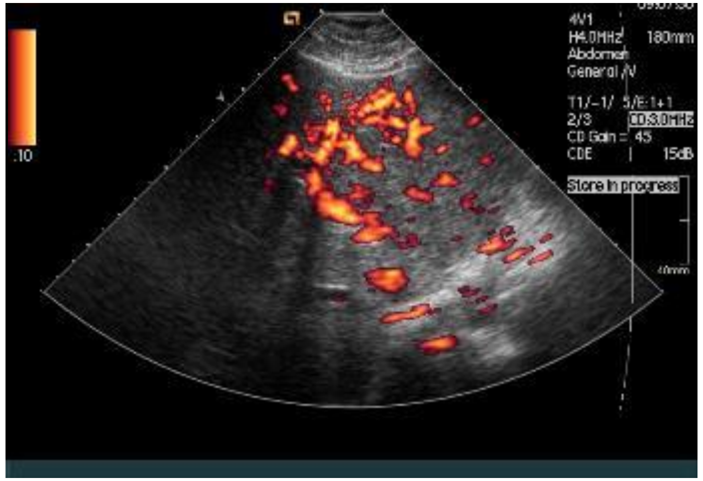
No comorbidities

- US >> CT > MRI
- "Daily business" lesions
  - cyst
  - haemangioma
  - undetermined
    - focal nodular hyperplasia (FNH)?
    - adenoma?
    - haemangioma in steatotic liver?
    - …

No comorbidities - US

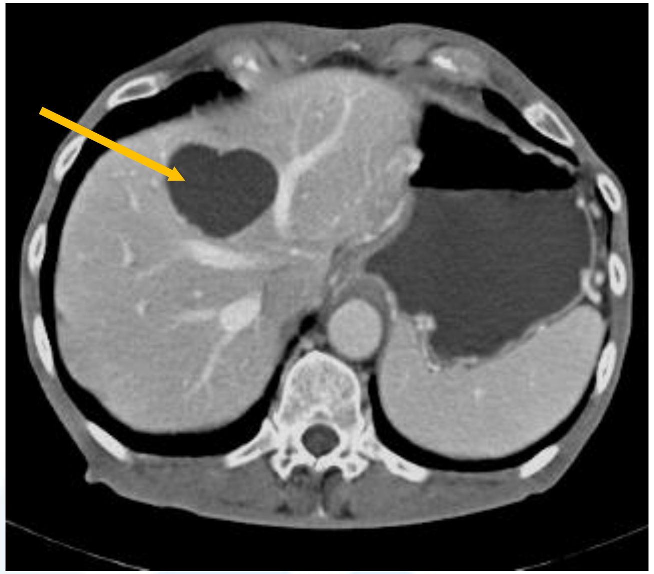
cyst

haemangioma

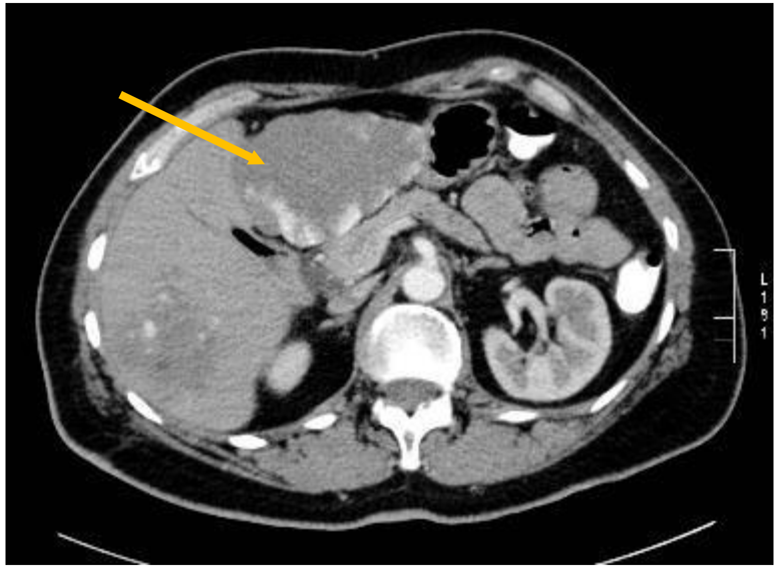


undetermined

No comorbidities - CT



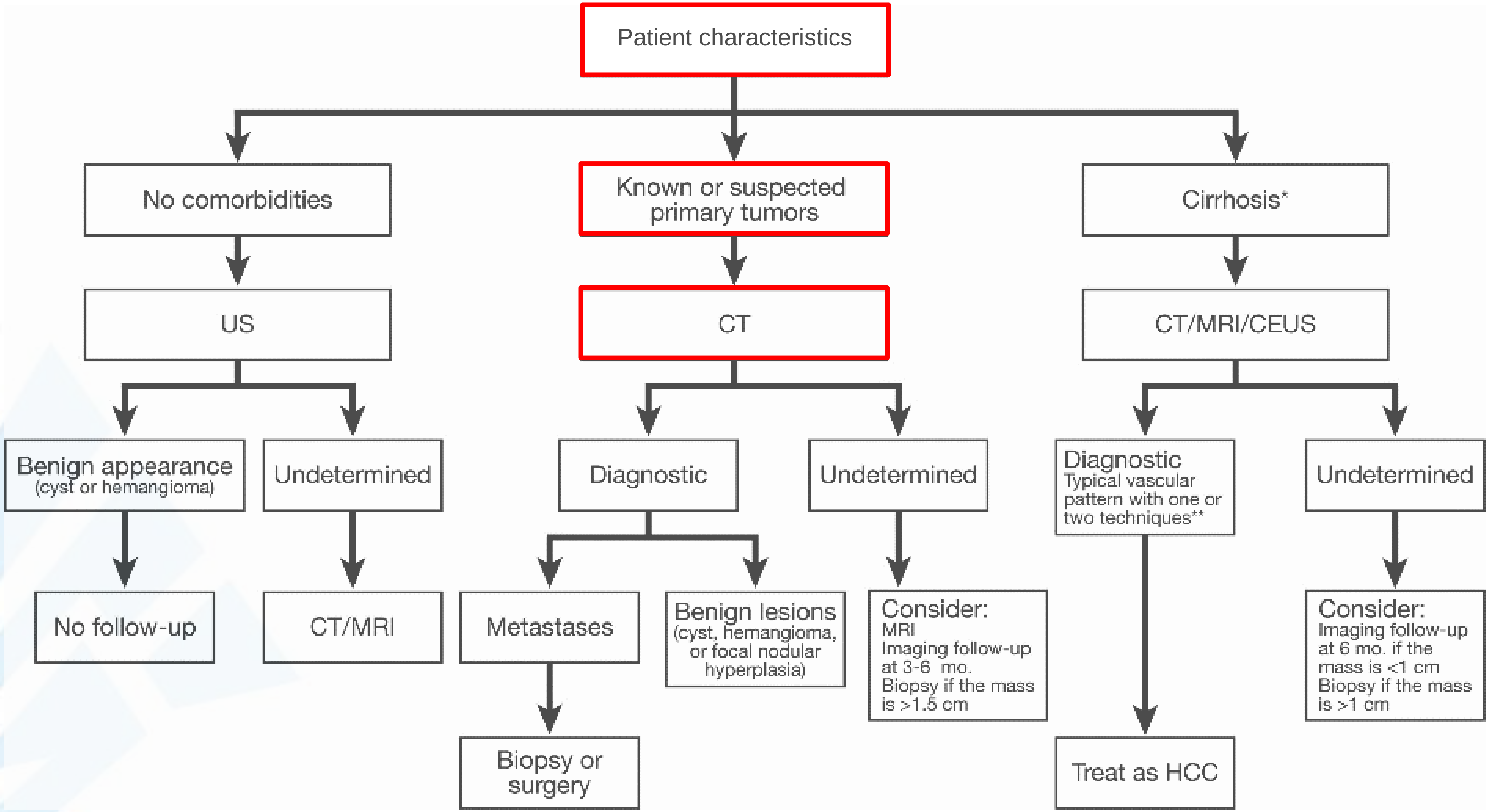
cyst



haemangioma

FNH

Focal liver lesions and imaging



1. Marin D, et al. (2009) Clinical Gastroenterology and Hepatology 7:624-634.

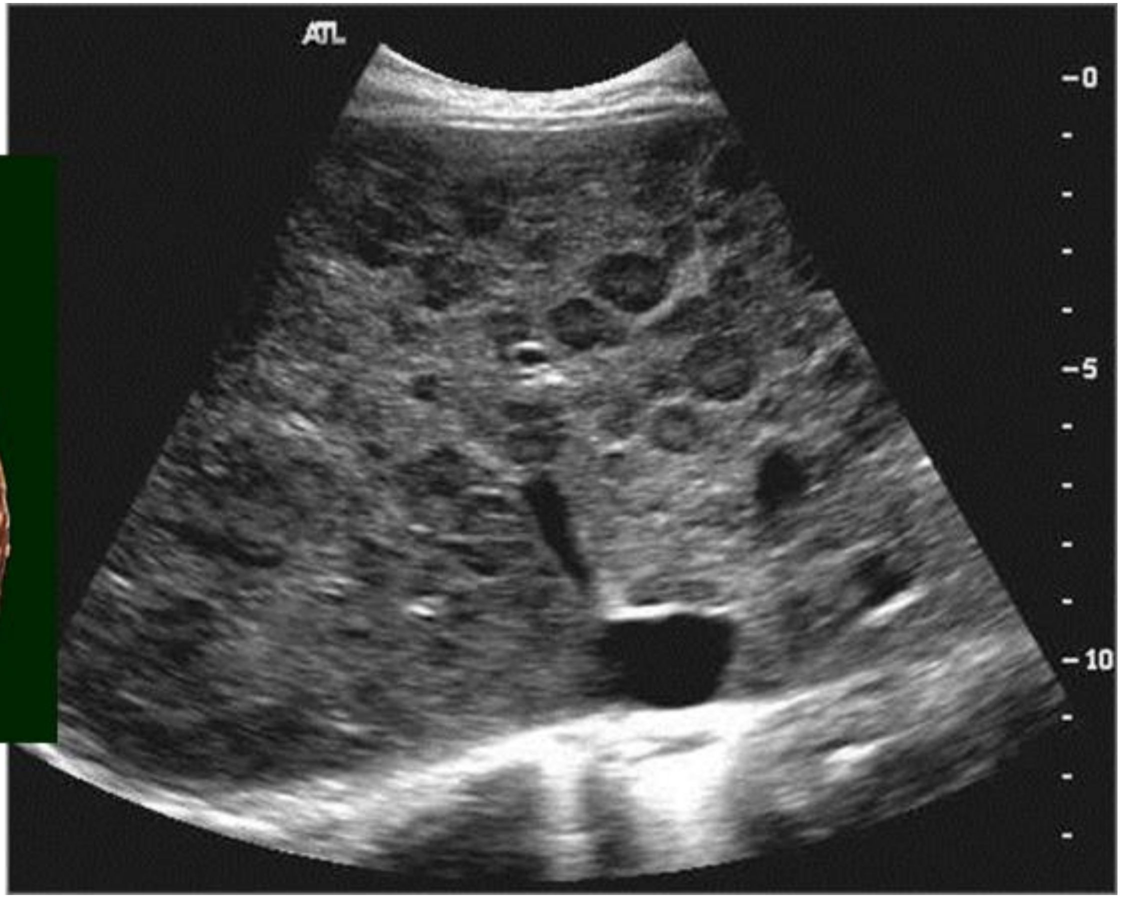
Known or suspected primary tumour

- CT >> US > MRI
  - liver metastasis
  - undetermined
    - cholangiocarcinoma?
    - hepatocellular carcinoma?
    - …

Known or suspected primary tumour - CT

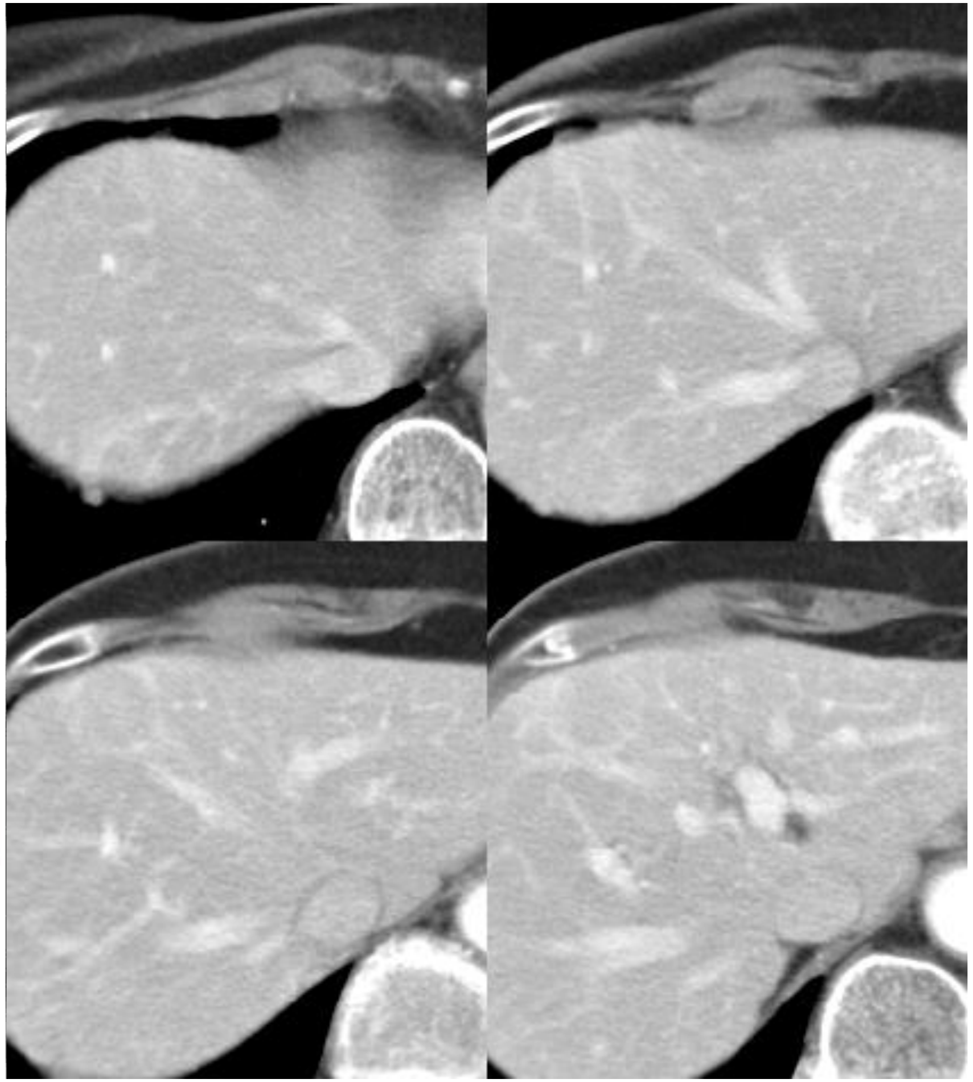
Hypovascular metastasis CRC

Known or suspected primary tumour - US

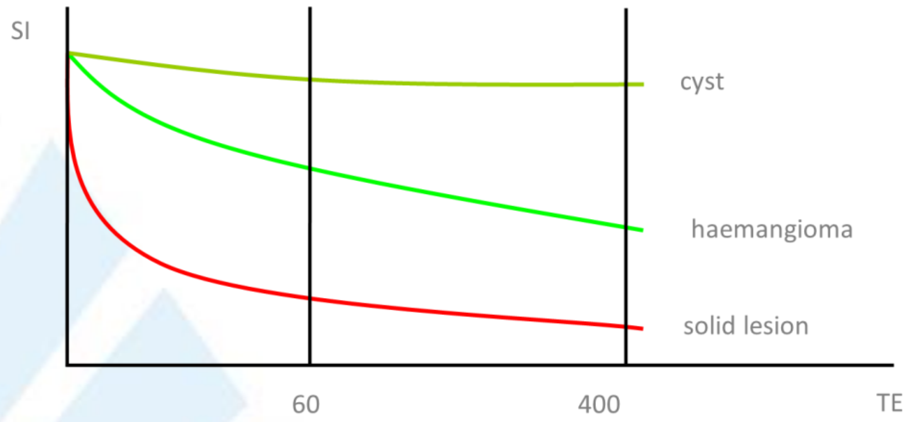


"TARGET" sign

Known or suspected primary tumour - MRI

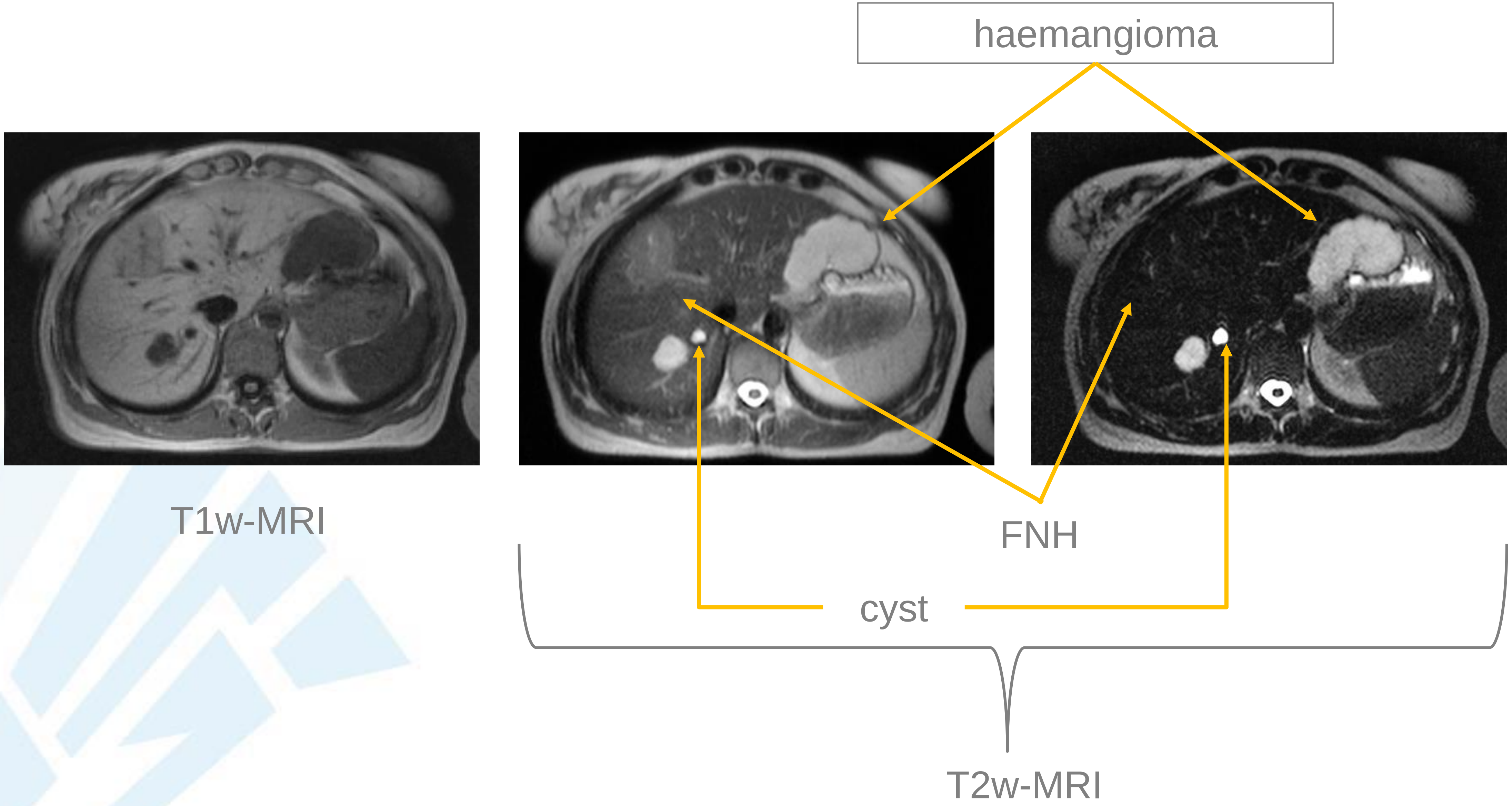


Signal intensity T2w – Rule of thumb

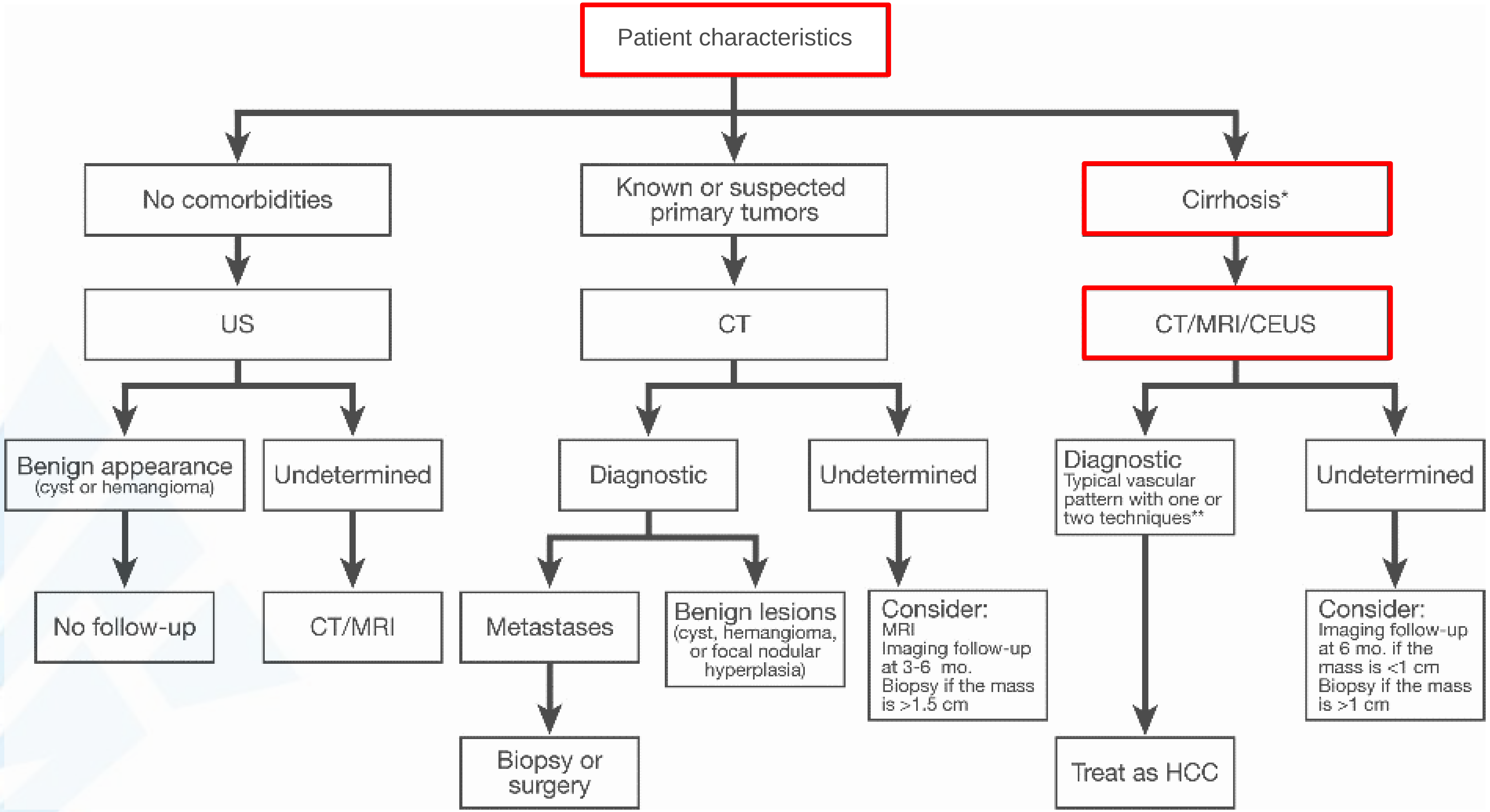


SI TE 60	SI TE 300-400	Lesion type
++ / +++	SI ~ SI Cerebrospinal fluid (CSF)	cyst
+ / ++	SI ~ SI Cerebrospinal fluid (CSF)	haemangioma
± / +	SI ~ SI Liver	solid

Signal intensity T2w – Rule of thumb



Focal liver lesions and imaging

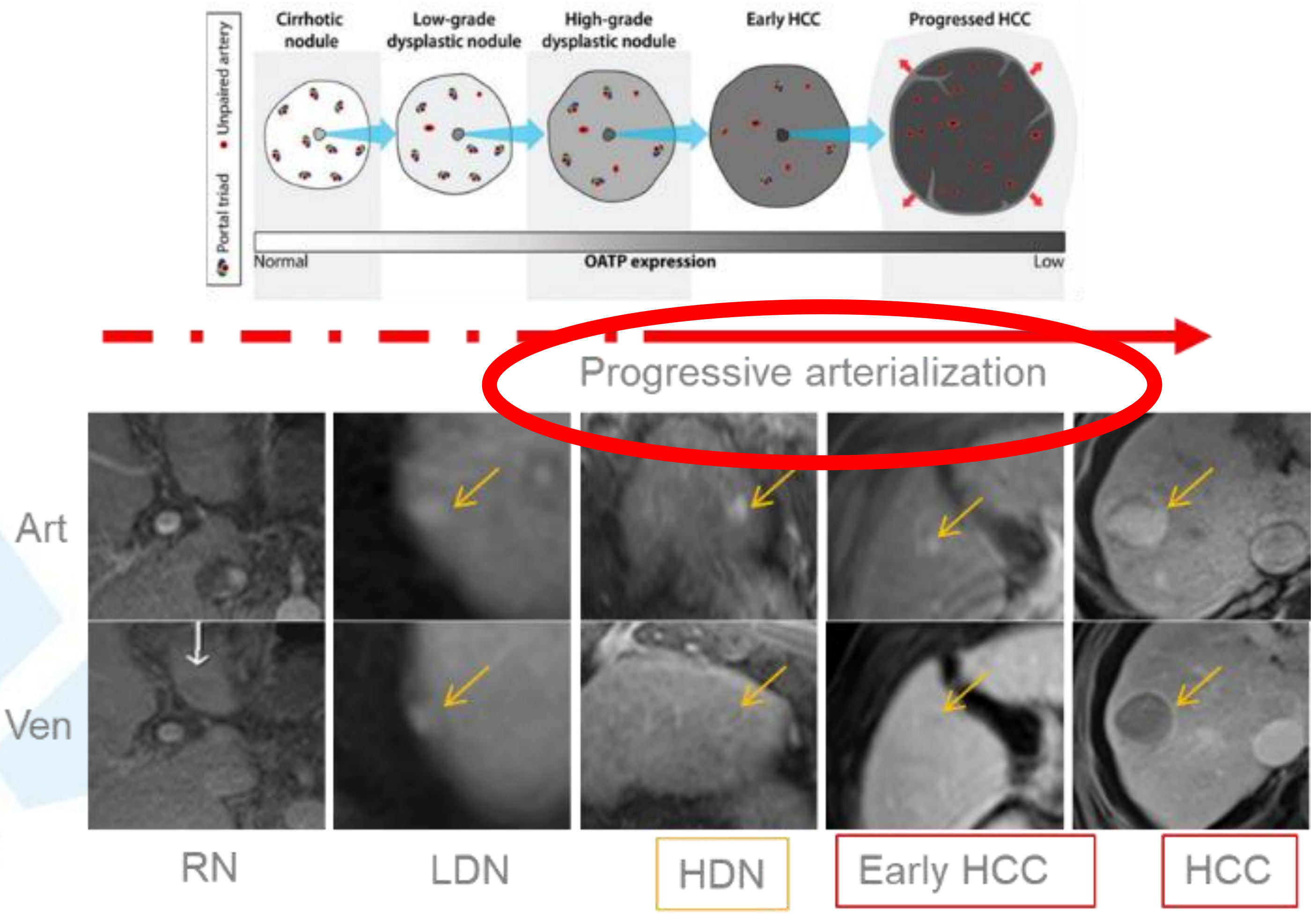


1. Marin D, et al. (2009) Clinical Gastroenterology and Hepatology 7:624-634.

History of cirrhosis

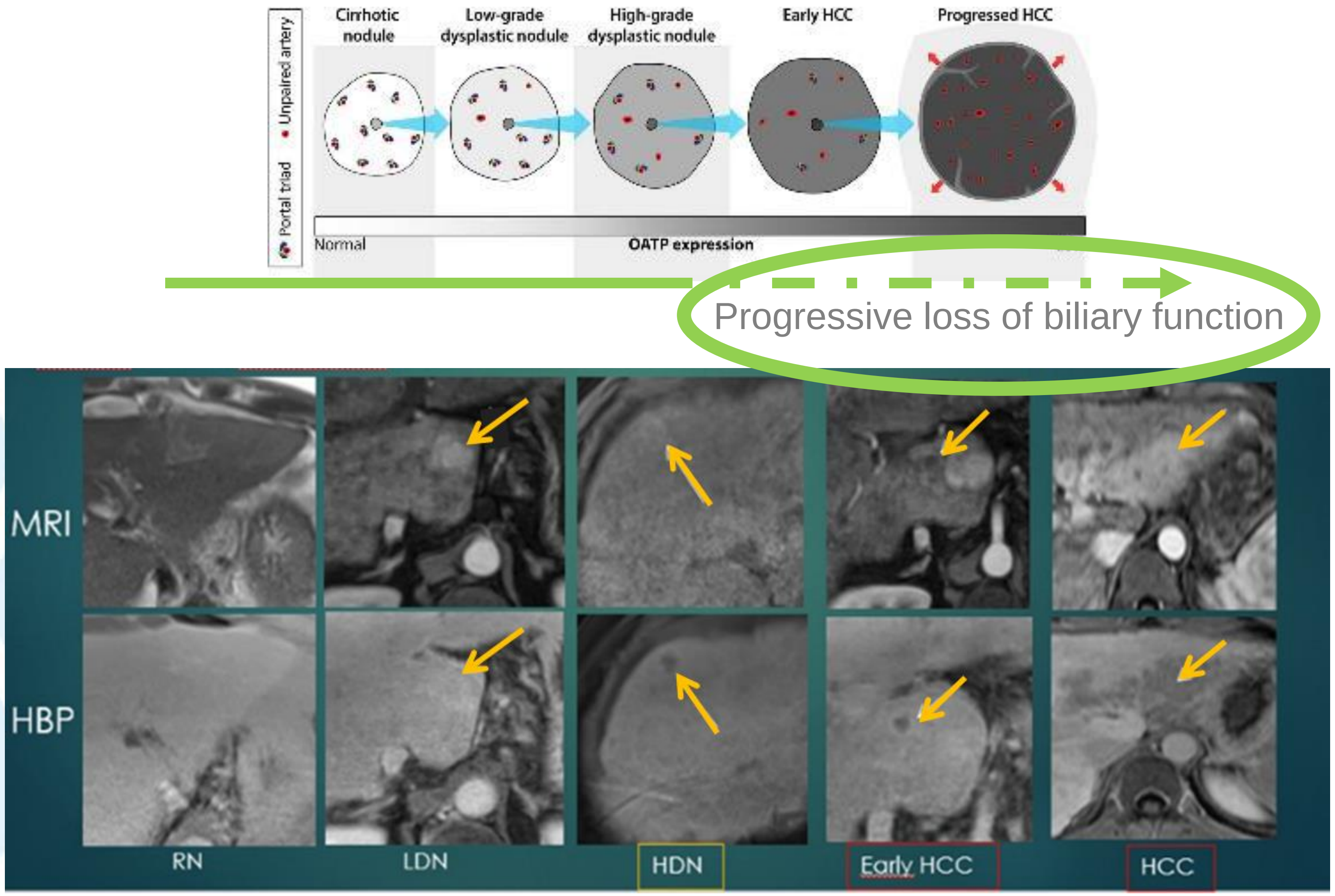
- MRI >> CT > US
  - Regenerative nodule
  - Dysplastic nodule
    - Low grade
    - High grade
  - Hepatocellular carcinoma
    - Early HCC (de novo – in situ)
    - Advanced HCC (sequence)
    - Well differentiated
    - Moderate differentiated
    - Poorly differentiated

Key factors in the diagnosis of HCC



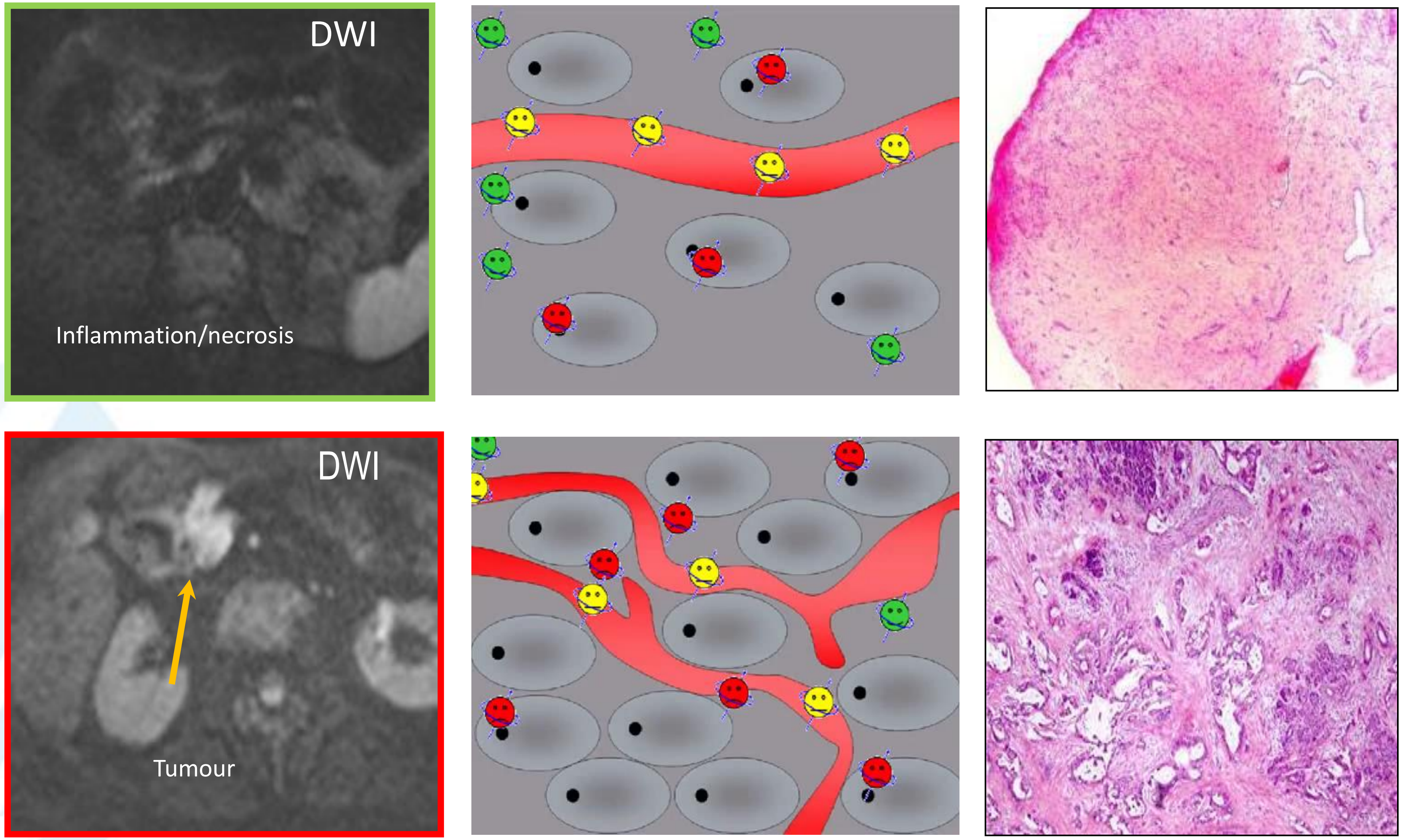
1. Narsinh KH, et al. (2018) Abdominal Radiology 43:158-168.

Key factors in the diagnosis of HCC



1. Narsinh KH, et al. (2018) Abdominal Radiology 43:158-168.

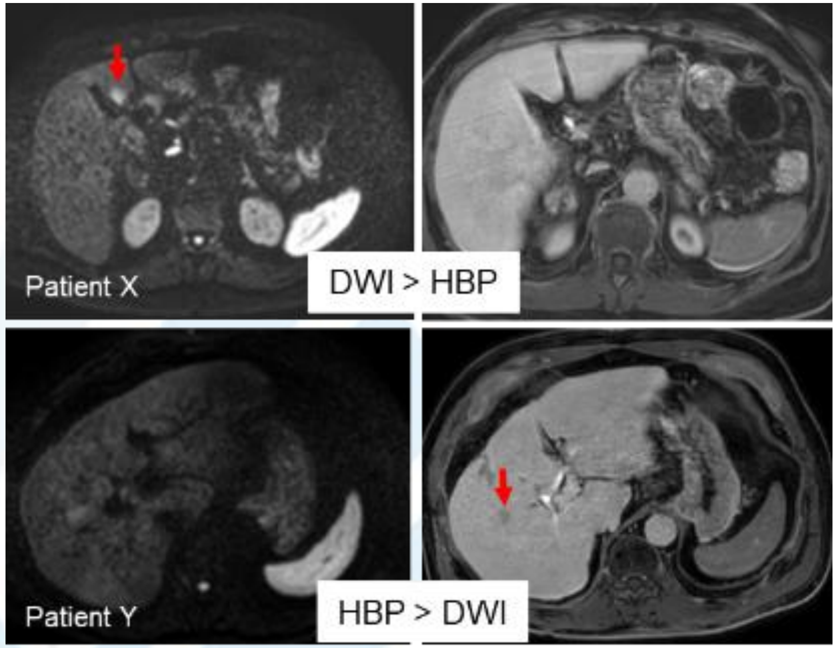
Key factors in the diagnosis of HCC



History of cirrhosis - CT versus MRI?

Overall MRI preferred over CT due to higher sensitivity lesions < 2 cm

- MRI advantage of functional imaging evaluation[1]
- Combined DWI and hepatobiliary phase imaging[2]



Sensitivity and Positive Predictive Values for the Detection of 179 HCCs

	Observer 1		Observer 2		Observer 3		Pooled Data	
Lesion Group and Imaging Modality	Sensitivity[*]	PPV[†]	Sensitivity[*]	PPV[†]	Sensitivity[*]	PPV[†]	Sensitivity[*]	PPV[†]
All lesions (n = 179)								
Gadoxetic acid set	81.0 (145)	98.6 (2)	82.1 (147)	98.7 (2)	80.5 (144)	98.0 [3]	81.4 (437)[‡]	98.4 [7]
DW imaging set	79.9 (143)	96.6 (5)	77.7 (139)	97.2 (4)	78.8 (141)	96.6 [5]	78.8 (423)[‡]	96.8 [14]
Combined set	92.7 (166)[§]	98.2 (3)	91.1 (163)[§]	98.2 (3)	93.3 (167)[§]	97.1 [5]	92.4 (496)[‡]	97.8 [11]
Lesions ≤1.0 cm (n = 55)								
Gadoxetic acid set	58.2 (32)	94.1 (2)	61.8 (34)	94.4 (2)	56.4 (31)	93.9 [2]	58.8 (97)	94.2 [6]
DW imaging set	63.6 (35)	87.5 (5)	56.4 (31)	88.6 [4]	60.0 (33)	89.2 [4]	60.0 (99)	88.4 [13]
Combined set	85.5 (47)[§]	94.0 (3)	81.8 (45)[§]	93.8 [3]	87.3 (48)[§]	92.3 [4]	84.8 (140)[§]	93.3 [10]
Lesions >1.0 cm (n = 124)								
Gadoxetic acid set	91.13 (113)	100 (0)	91.13 (113)	100 [0]	91.13 (113)	99.1 [1]	91.1 (339)[‡]	99.7 [1]
DW imaging set	87.1 (108)[‖]	100 (0)	87.1 (108)[‖]	100 [0]	87.1 (108)[‖]	99.1 [1]	87.1 (324)[‡]	99.7 [1]
Combined set	96.0 (119)[‖]	100 (0)	95.2 (118)[‖]	100 [0]	96.0 (119)[‖]	99.2 [1]	95.7 (356)[‡]	99.7 [1]

1. Li J, et al. (2019) European Radiology 29:6519-6528.
2. Park MJ, et al. (2012) Radiology 264:761-70.

MRI standard examination for HCC[1]

- T1-weighted MRI
- T2-weighted MRI
- T1-weighted MRI + liver specific contrast
  - Including late phase 20' after gadoxetate disodium (Primovist®) or 60' after gadobenate dimeglumine (Multihance®) injection
- Diffusion weighted imaging DWI
- Standardization in classification and reporting[2]

1. Park MJ, et al. (2012) Radiology 264:761-70.
2. Chernyak V, et al. (2018) Radiology 289:816-830.

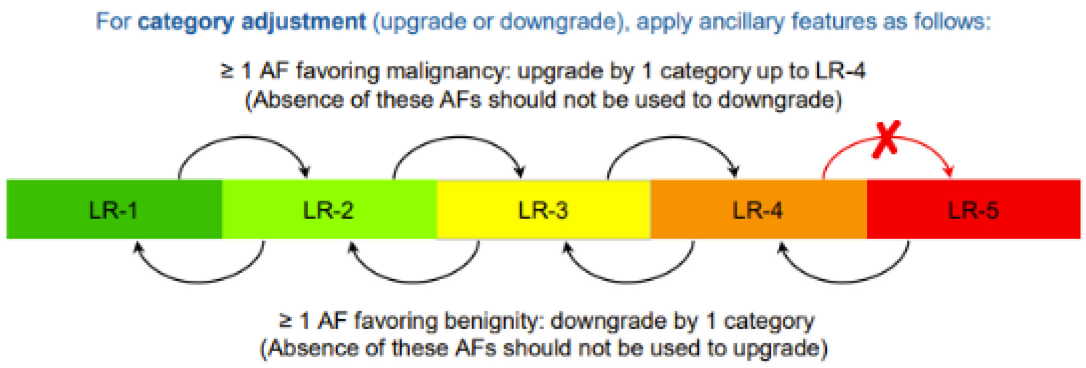
Standardization in classification and reporting

- Liver Imaging Reporting and Data System (LI-RADS) in imaging of HCC in At-Risk Patients[1-2]
  - From definitively benign, probably benign, intermediate probability of being HCC, probably HCC, and definitively HCC (corresponding to LI-RADS categories 1-5)[3]
- Simplified LI-RADS for HCC Diagnosis at Gadoxetic Acid-enhanced MRI[4]

CT/MRI Diagnostic Table

Arterial phase hyperenhancement (APHE)		No APHE		Nonrim APHE		
Observation size (mm)		< 20	≥ 20	< 10	10-19	≥ 20
Count additional major features: • Enhancing "capsule" • Nonperipheral "washout" • Threshold growth	None	LR-3	LR-3	LR-3	LR-3	LR-4
	One	LR-3	LR-4	LR-4	LR-4 / LR-5	LR-5
	≥ Two	LR-4	LR-4	LR-4	LR-5	LR-5

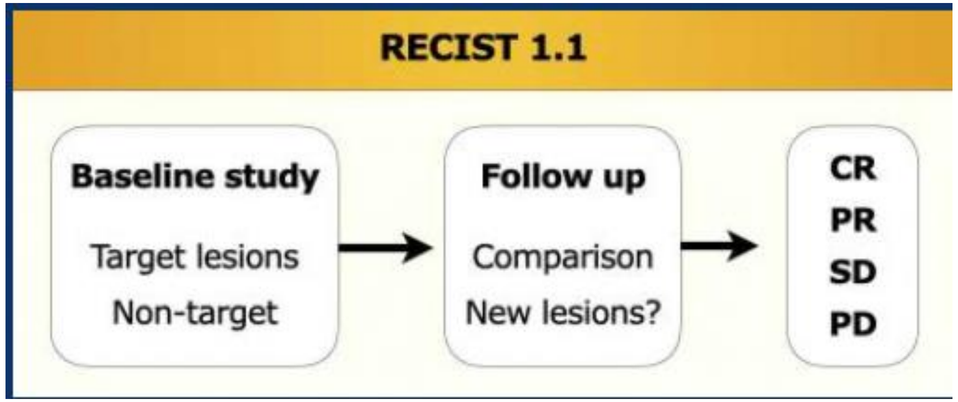
LR-4 / LR-5: Observations in this cell are categorized based on one additional major feature:
- LR-4 – if enhancing "capsule"
- LR-5 – if nonperipheral "washout" **OR** threshold growth

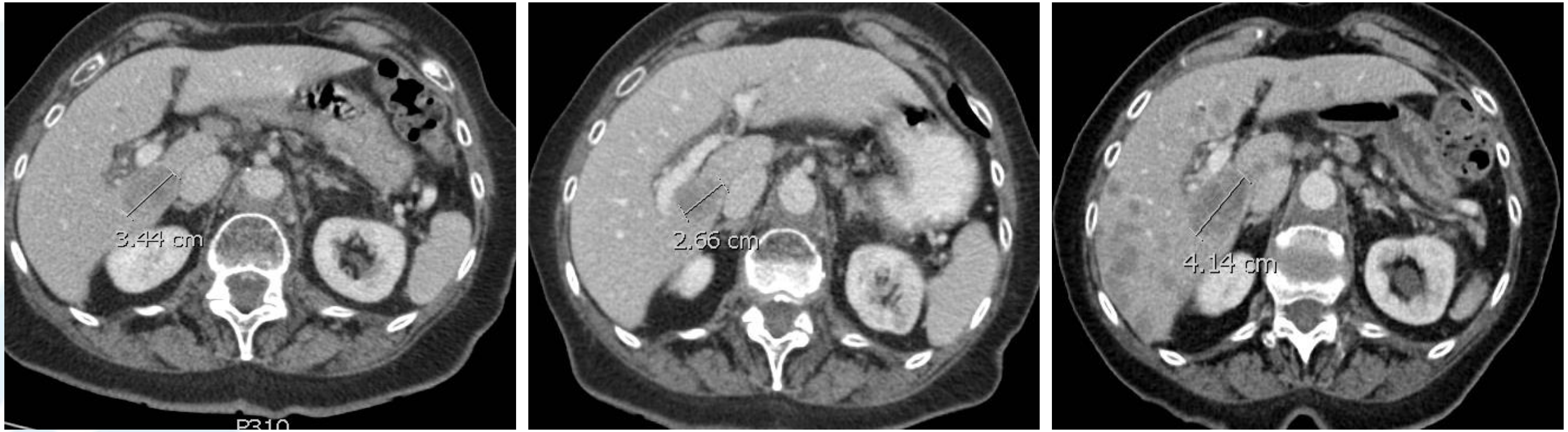


1. Santillan CS, et al. (2014) Magn Reson Imaging Clin N Am 22:337-52.
2. Chernyak V, et al. (2018) Radiology 289:816-830.
3. Mitchell DG, et al. (2015) Hepatology 61:1056-1065.
4. Kwag M, et al. (2022) Radiology:220659.

Response assessment of treatment

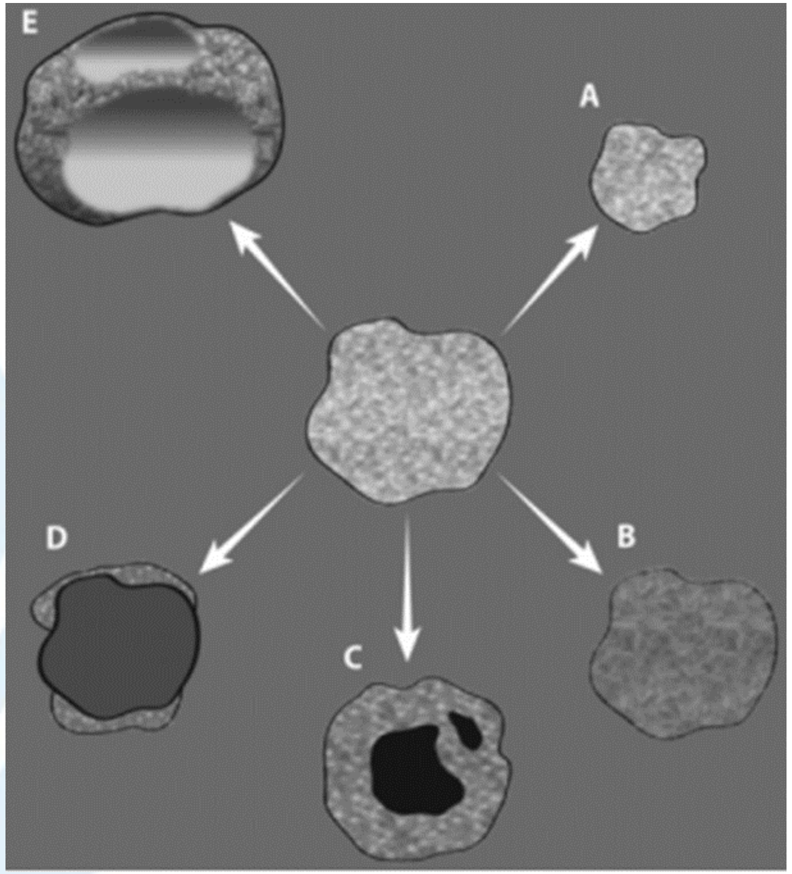
- RECIST 1.1
- Treatment reducing tumour size
  - Chemotherapy (Taxo-carbo, Folfox, Folfiri, Gem-cis, etc)





1. Gonzalez-Guindalini FD, et al. (2013) RadioGraphics 33:1781-1800.
2. Figueiras RG, et al. (2011) RadioGraphics 31:2059-2091.

Response assessment of treatment

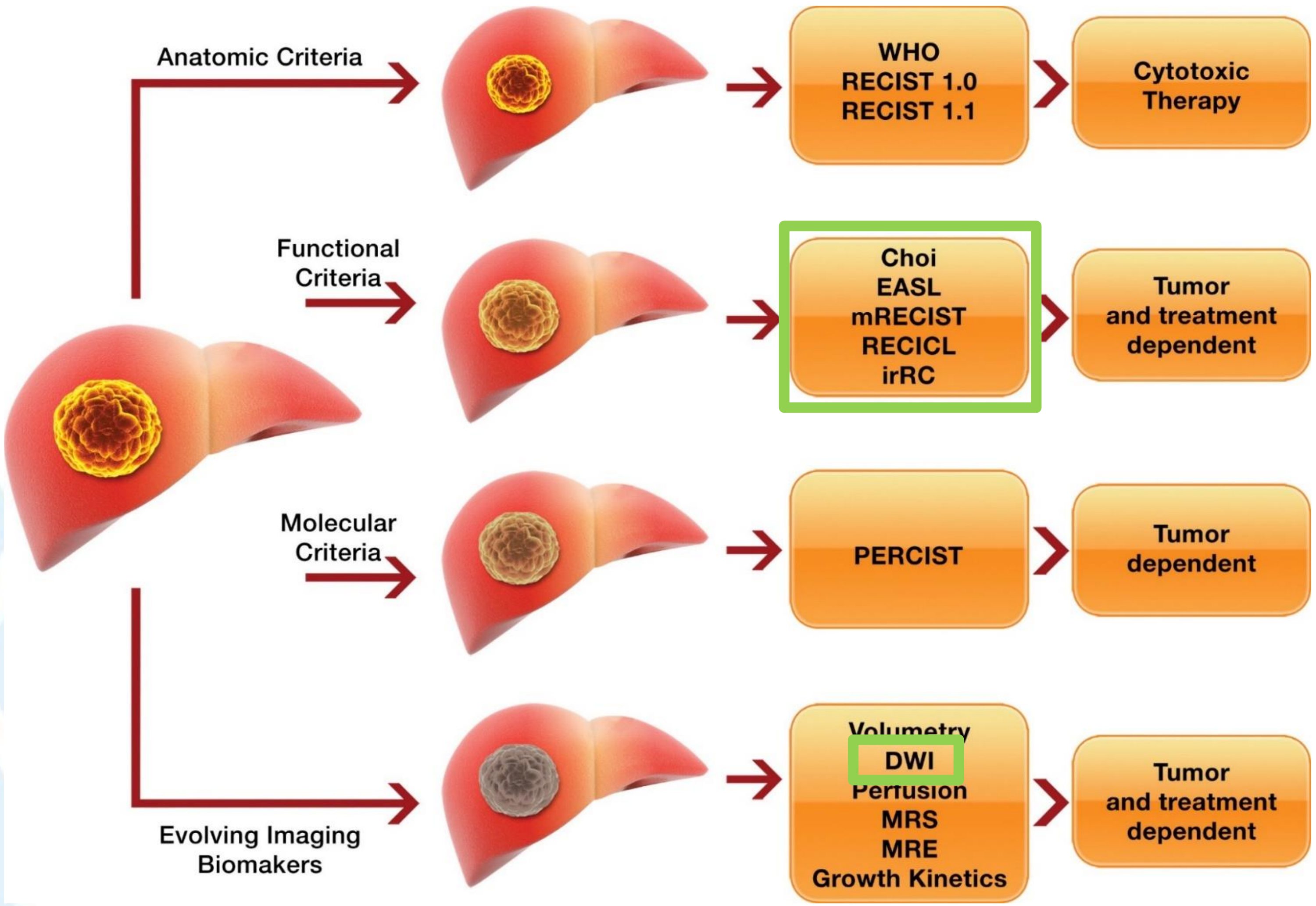


- Treatment not reducing tumour size
  - targeted therapies

A. Decrease in tumour size
B. Decrease in vascularity ± size reduction
C. Cystic changes ± size reduction
D. Cavitations ± size reduction
E. Tumour haemorrhage ± size reduction

1. Tirkes T, et al. (2013) Radiographics 33:1323-41.

Response assessment of treatment



1. Figueiras RG, et al. (2011) RadioGraphics 31:2059-2091.

MRI for focal liver lesions

- Advantages
  - MRI standard examination
    - For HCC[1]
    - For problem solving after US or/and CT
- Disadvantages
  - Long waiting lists!
  - Length of examination slot 30-45 min!
  - Need for expertise!
  - Patient conditions
    - Pacemakers, neurostimulators, claustrophobia, …

1. Park MJ, et al. (2012) Radiology 264:761-70.

Role of PCCT for focal liver lesions?

- What can PCCT offer to compete with MRI and/or EID CT?
  - Improved resolution
    - spatial, contrast and temporal
  - Lower dose
    - X-ray and contrast
  - Spectral analysis
    - monoenergetic images
    - material decomposition
  - …

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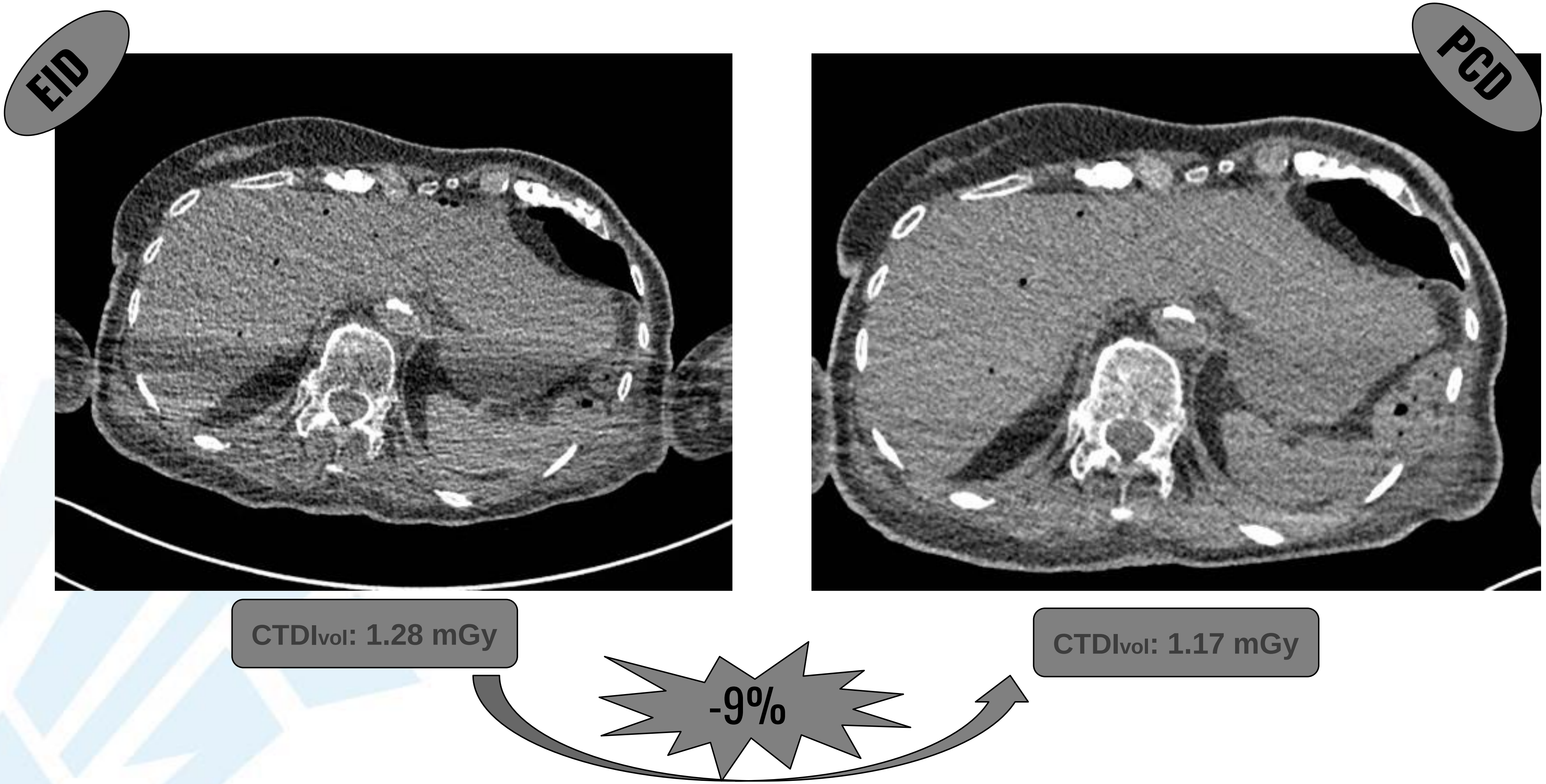
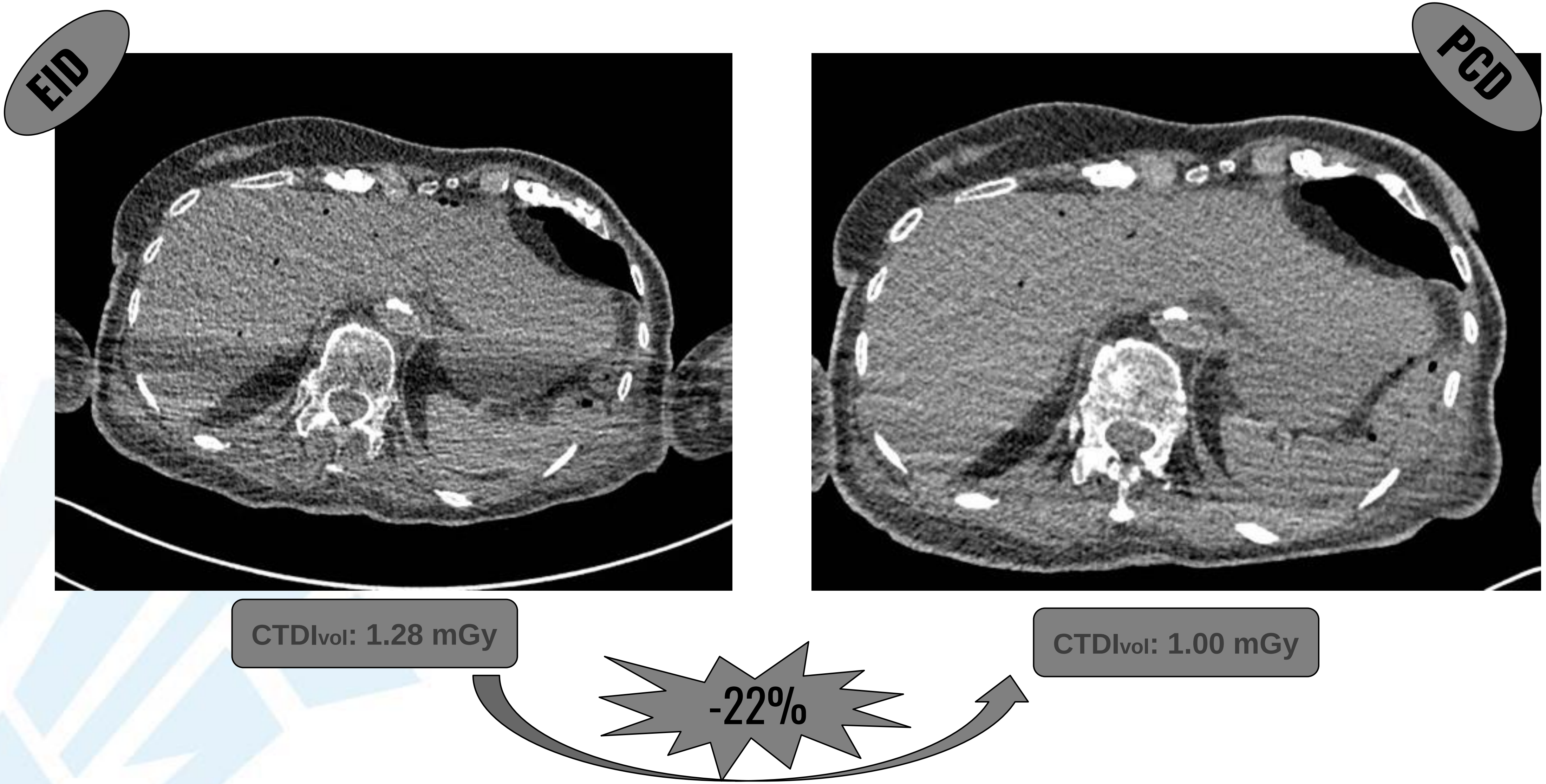
Dose reduction for low dose EID CT



1. Courtesy Joris Awouters et al @Pentalfa 16/12/2021

Dose reduction for low dose EID CT



1. Courtesy Joris Awouters et al @Pentalfa 16/12/2021

Dose reduction for low dose EID CT

Photon-counting CT: Technical Principles and Clinical Prospects

Martin J. Willemink, MD, PhD • Mats Persson, PhD • Amir Pourmorteza, PhD • Norbert J. Pelc, ScD • Dominik Fleischmann, MD

From the Department of Radiology (M.J.W., M.P., N.J.P., D.F.) and Stanford Cardiovascular Institute (D.F.), Stanford University School of Medicine, 300 Pasteur Dr, S-072, Stanford, CA 94305-5105; Department of Radiology, University Medical Center Utrecht, Utrecht, the Netherlands (M.J.W.); Departments of Bioengineering (M.P., N.J.P.) and Electrical Engineering (N.J.P.), Stanford University, Stanford, Calif; Department of Radiology and Department of Imaging Sciences and Biomedical Informatics, Emory University School of Medicine, Atlanta, Ga (A.P.). Received November 15, 2017; revision requested January 2, 2018; final revision received January 23; accepted February 5. **Address correspondence to** M.J.W. (e-mail: *m.j.willemink@stanford.edu*).

Conflicts of interest are listed at the end of this article.

Radiology 2018; 289:293–312 • https://doi.org/10.1148/radiol.2018172656 • Content code: CT

Photon-counting CT is an emerging technology with the potential to dramat… CT uses new energy-resolving x-ray detectors, with mechanisms that differ substa… de-tectors. Photon-counting CT detectors count the number of incomi… results in higher contrast-to-noise ratio, improved spatial resolution, an… radiation exposure, reconstruct images at a higher resolution… and create opportunities for quantitative imaging relativ… technical principles of photon-counting CT in non… of the current status of photon-counting CT, th…

©RSNA, 2018

… of the low inherent contrast between different types of soft tissues. In clinical imaging, this is addressed with the administration of contrast agents. However, that brings up a third limitation: Iodinated contrast agents used in CT can cause kidney damage and can trigger allergic reactions (1).

… photon-counting CT technology is followed by a discussion of potential clinical applications.

Physical Principles

Conflicts of Interest

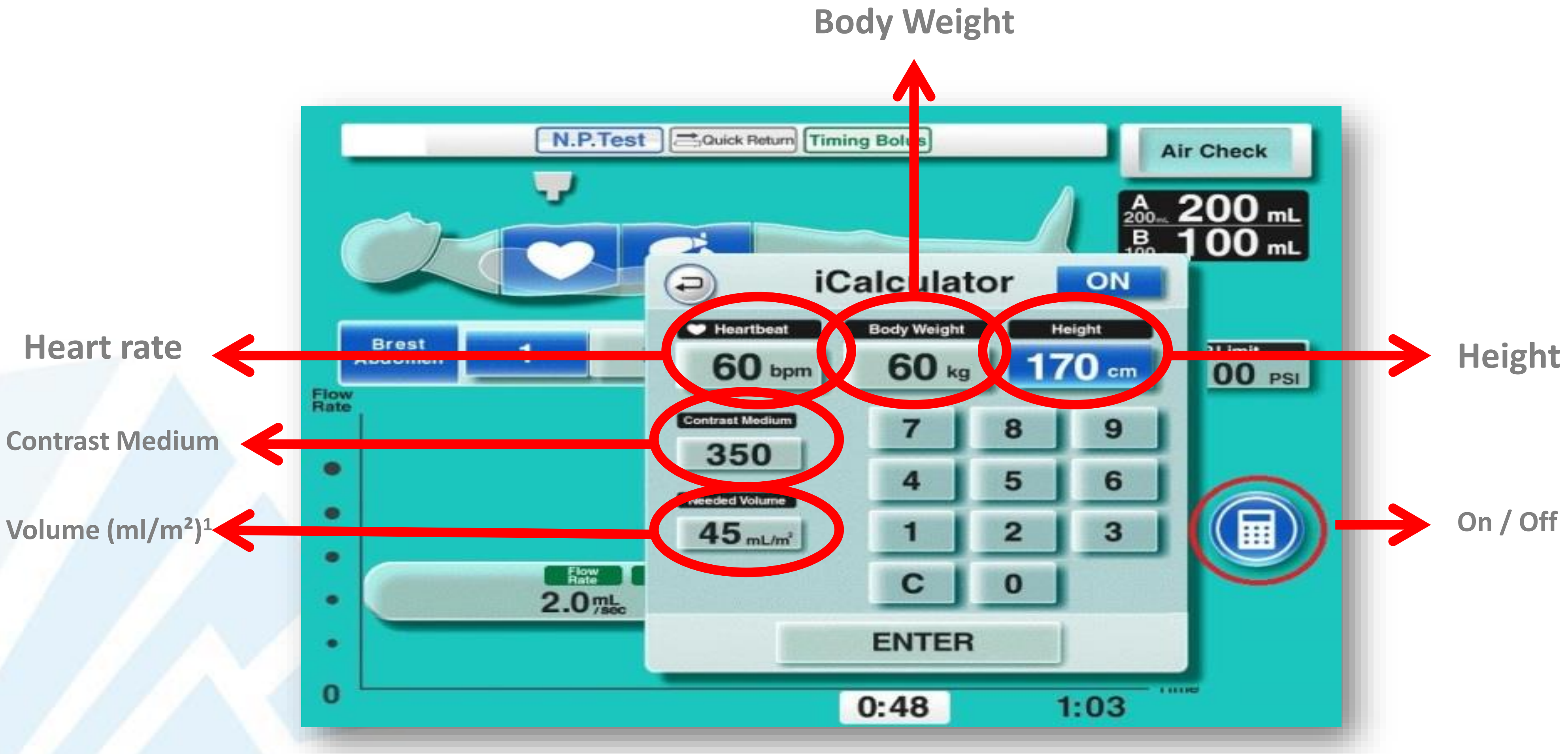
None of the authors are industry employees. One author (M.P.) is a stockholder and consultant for Prismatic Sensors, a commercial spin-off from KTH Royal Institute of Technology in Stockholm, Sweden. One author (N.J.P.) is on the scientific advisory board of the same spin-off, …

1. Courtesy Joris Awouters et al @Pentalfa 16/12/2021
2. Willemink MJ, et al. (2018) Radiology 289:293-312.

Role of PCCT for focal liver lesions?

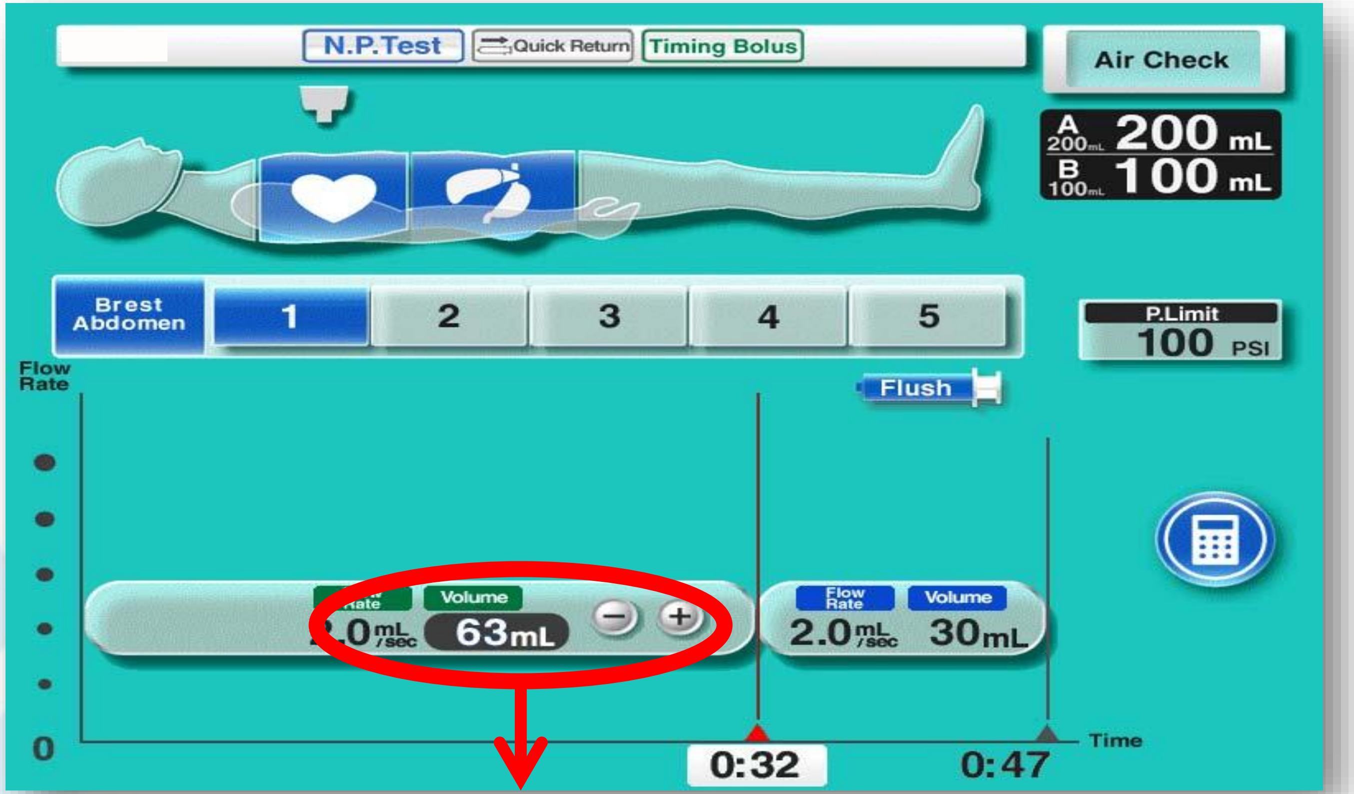
- What can PCCT offer to compete with MRI and/or EID CT?
  - Improved resolution
    - spatial, contrast and temporal
  - Lower dose
    - X-ray and contrast
  - Spectral analysis
    - monoenergetic images
    - material decomposition
  - …

Patient tailored contrast dose



1. Yanaga Y, et al. (2010) AJR Am J Roentgenol 194:903-8.
2. Raymakers D, et al. (2019) J Belg Soc Radiol 103:57.
3. Courtesy Walter Coudyzer et al @RSNA and ECR

Patient tailored contrast dose



Suggested Volume

1. Yanaga Y, et al. (2010) AJR Am J Roentgenol 194:903-8.
2. Raymakers D, et al. (2019) J Belg Soc Radiol 103:57.
3. Courtesy Walter Coudyzer et al @RSNA and ECR

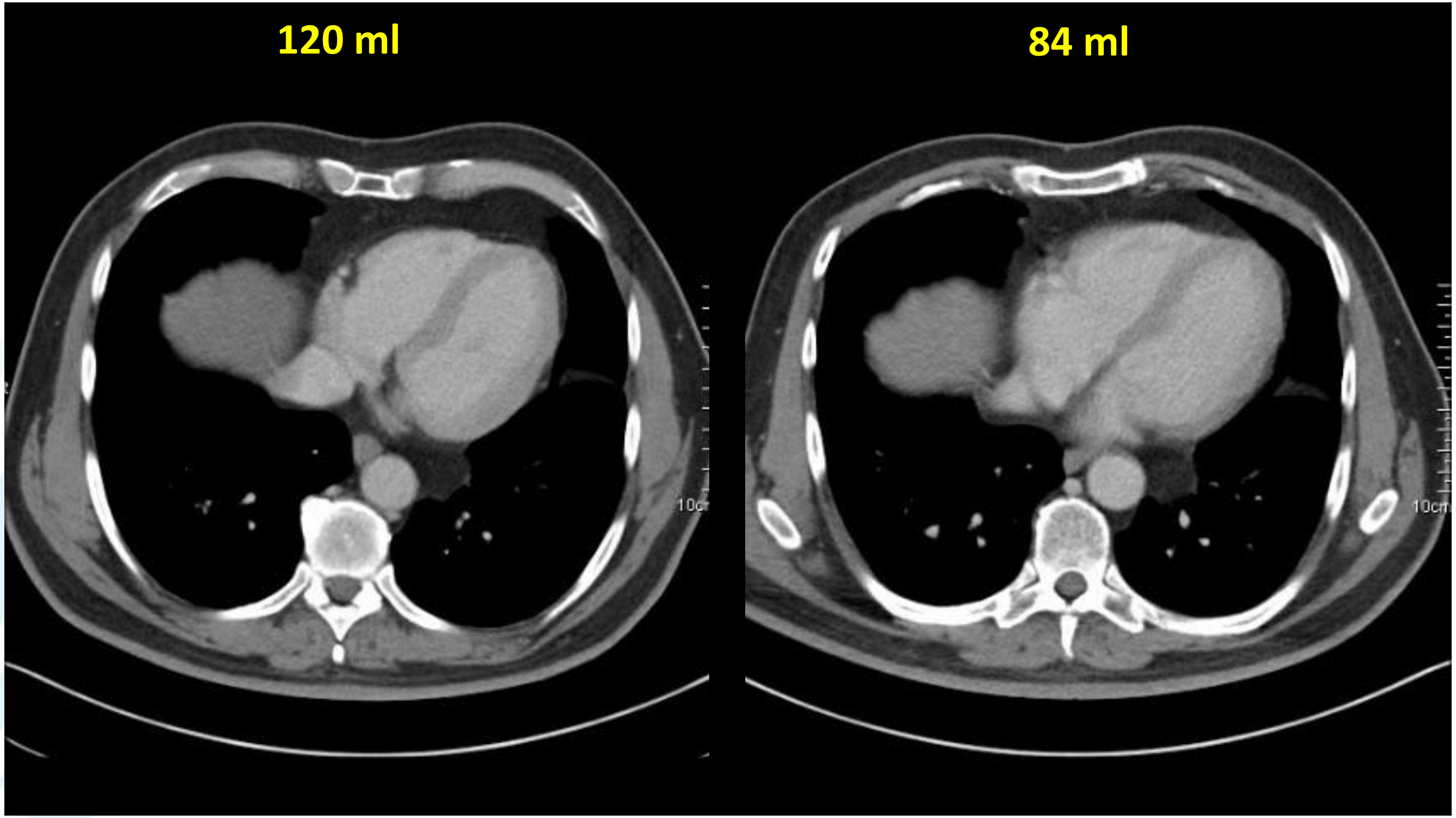
Patient tailored contrast dose

- Reduction in the average indexed volume ...
  - Minus 28,50%
- … and in the costs for the hospital!

	Mean Used CM volume (ml)	Mean % reduction vs standard 120 ml
Men (n=2291)	93,67	-22 %
Women (n=2709)	79,12	-34 %
Total (5000)	85,79	-28,50 %
	107243 EUR	150000 EUR

1. Courtesy Walter Coudyzer et al @RSNA and ECR

Patient tailored contrast dose



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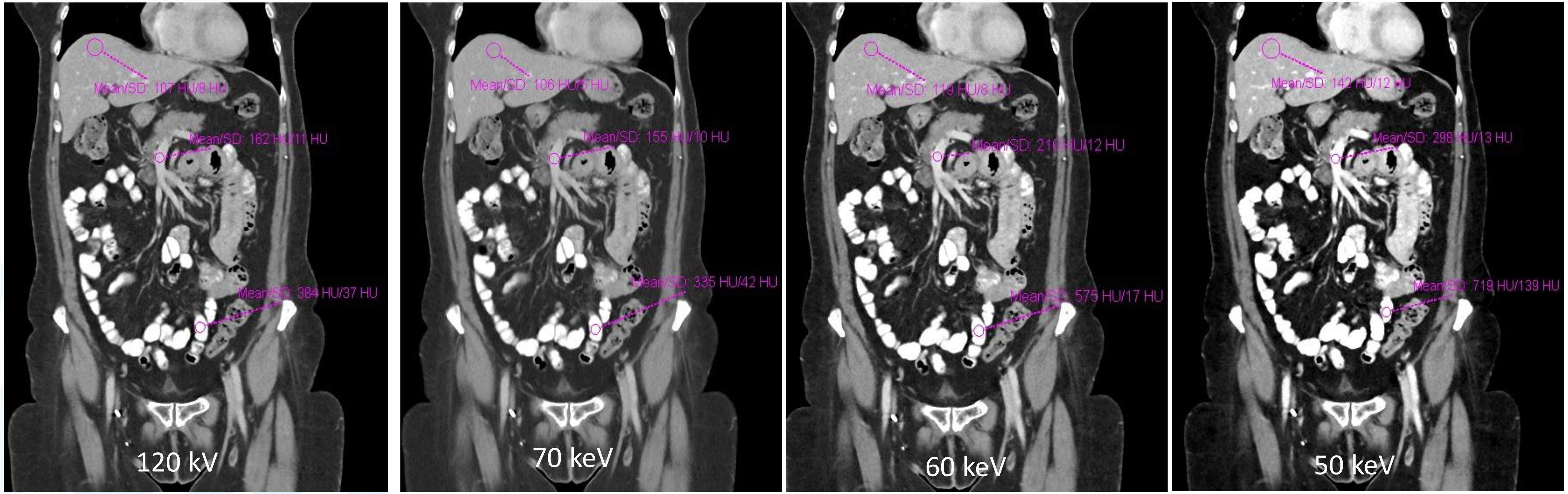
  - …

The PCCT effect on iodine HU



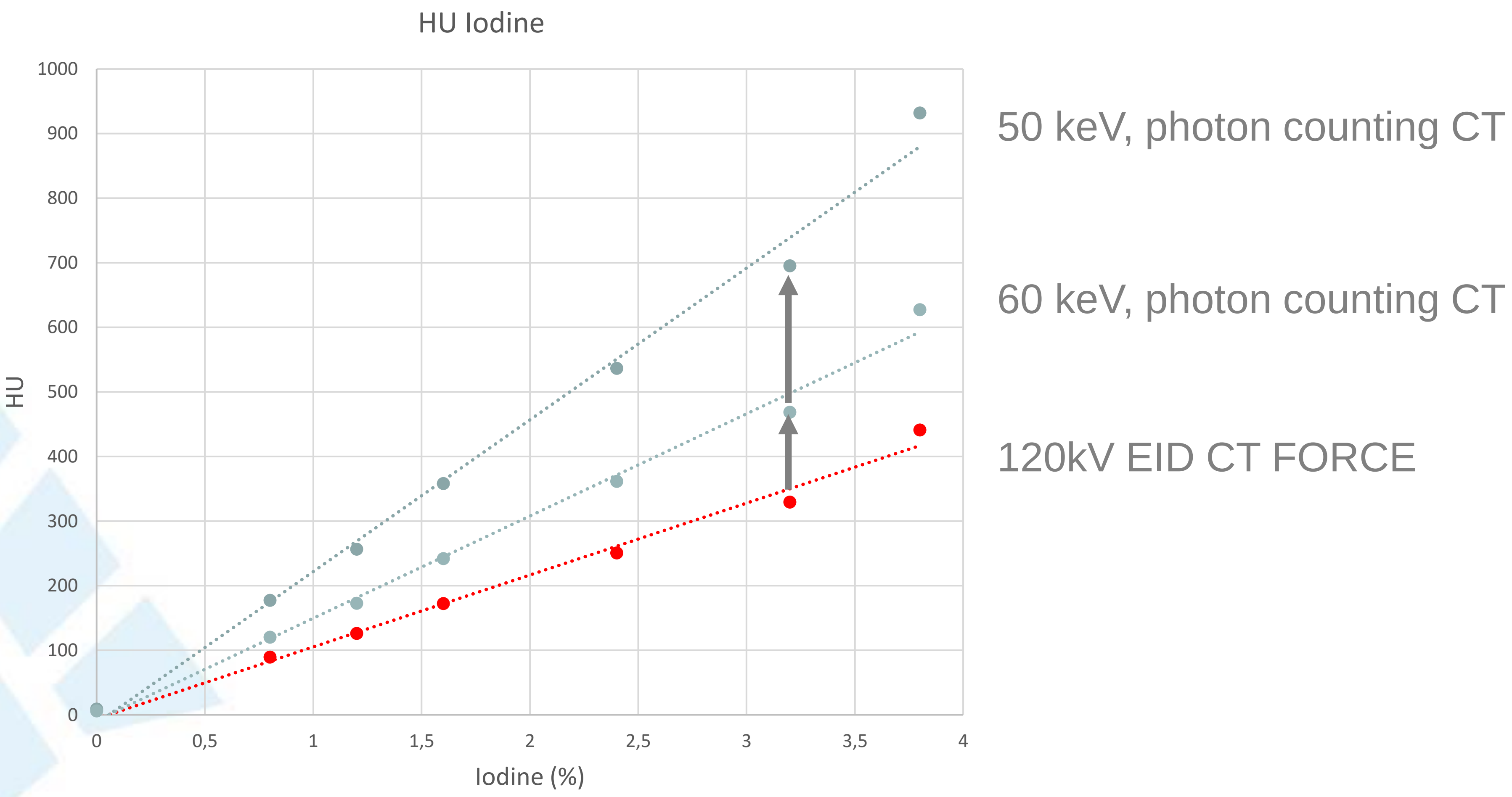
107 HU

106 HU

119 HU

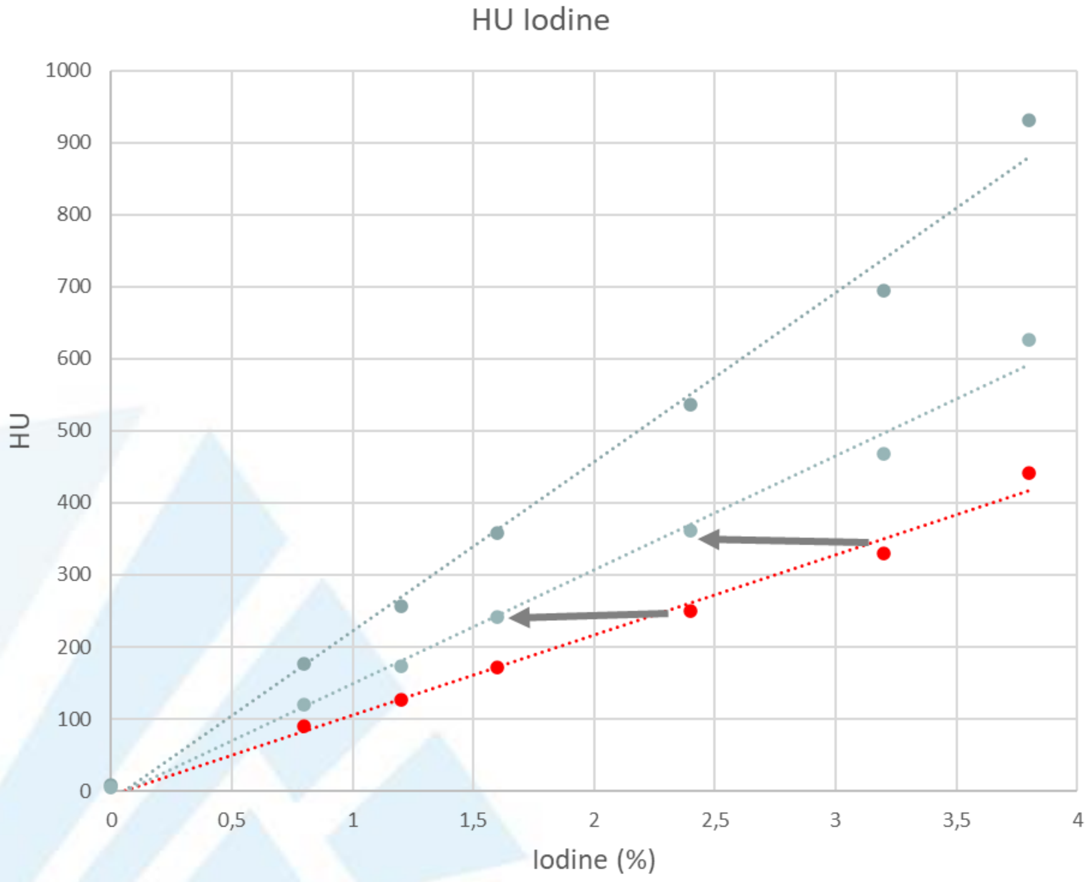
142 HU

The PCCT effect on iodine HU



1. Courtesy Joke Binst et al @Dublin August 2022

The PCCT effect on iodine HU



- Dilution proposal:
  - 120kV CT FORCE → 60keV PC CT
    - 70% of original concentrations
  - 120kV CT FORCE → 50keV PC CT
    - 50% of original concentrations!

1. Courtesy Joke Binst et al @Dublin August 2022

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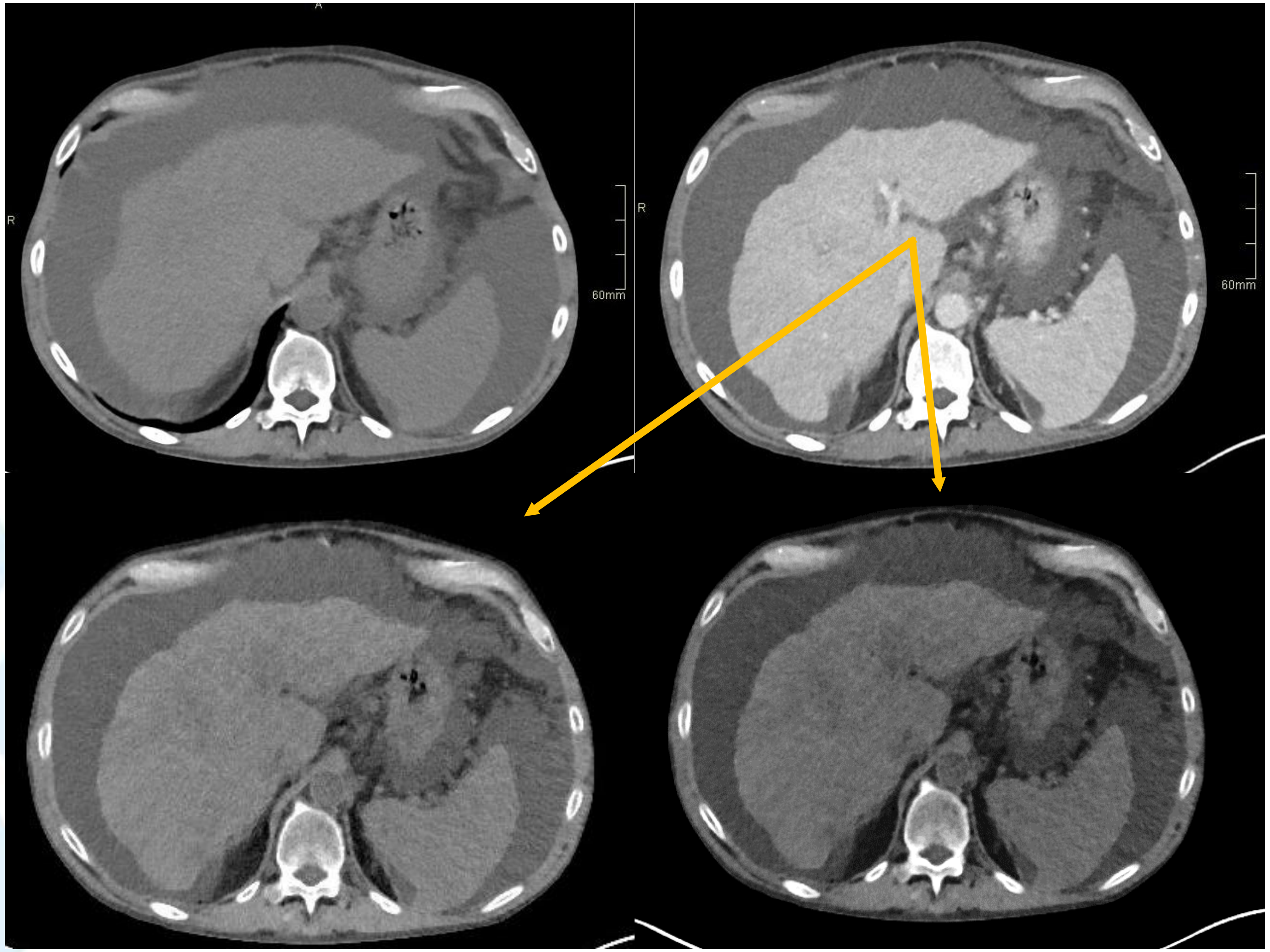
  - …

PCCT and Virtual Non Contrast imaging



1. Mergen V, et al. (2022) Radiology 0:213260.
2. Sosna J. (2022) Radiology 0:221173.

PCCT and Multiple contrast agents

Photon-counting CT for simultaneous imaging of multiple contrast agents in the abdomen: an in vivo study

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[1]Radiology and Imaging Sciences – National Institutes of Health Clinical Center, Bethesda, MD, USA

[2]Siemens Healthcare GmbH, Forchheim, Germany

[3]Siemens Medical Solutions Inc., Malvern, PA

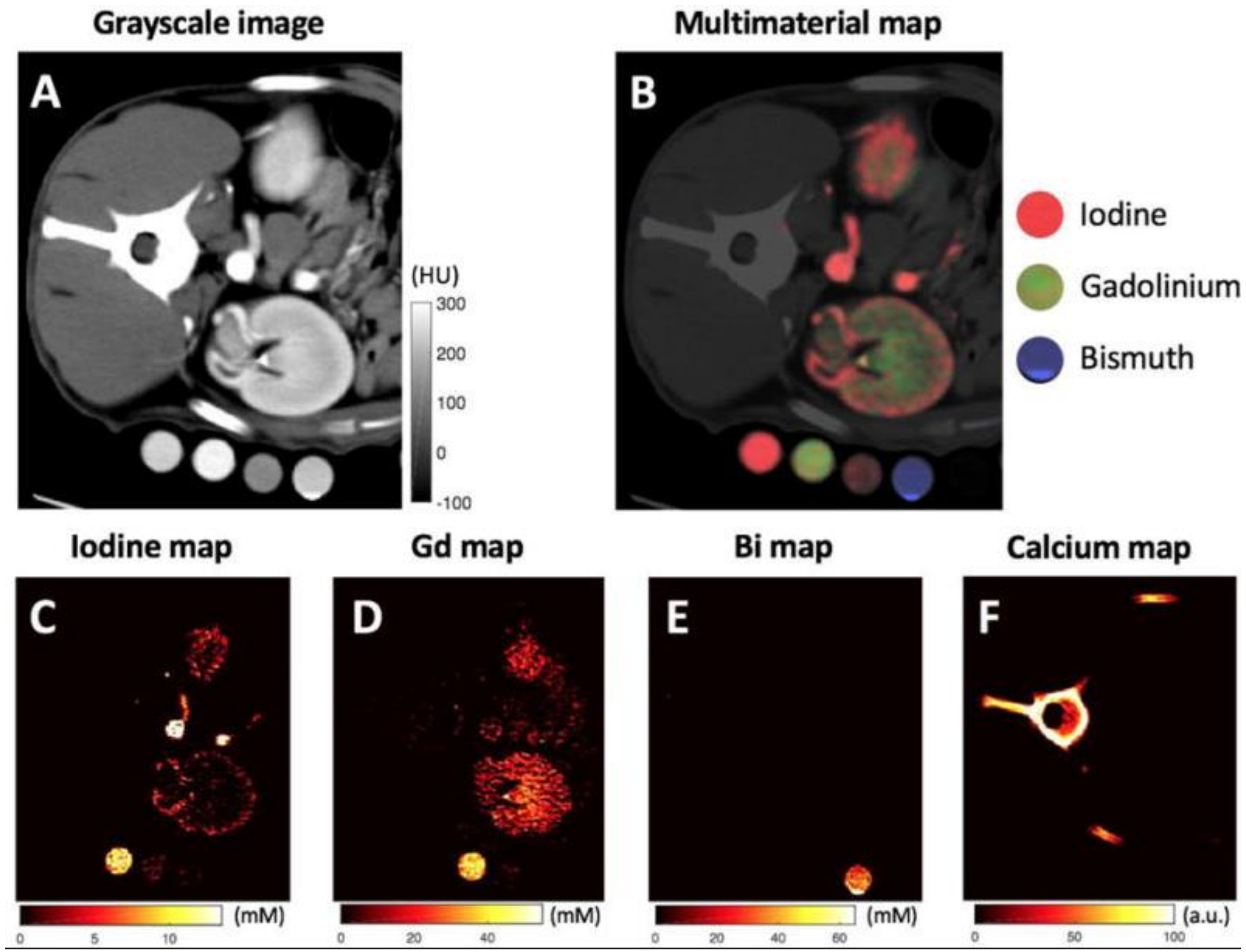
Abstract

Purpose—To demonstrate the feasibility of spectral imaging using photon-counting detector (PCD) x-ray computed tomography (CT) for simultaneous material decomposition of 3 contrast agents in vivo in a large animal model.

Methods—This Institutional Animal Care and Use Committee-approved study used a canine model. Bismuth subsalicylate was administered orally 24–72 hours before imaging. PCD CT was performed during intravenous administration of 40–60 ml gadoterate meglumine; 3.5 minutes later, iopamidol 370 was injected intravenously. Renal PCD CT images were acquired every 2 seconds for 5–6 minutes to capture the wash-in and wash-out kinetics of the contrast agents. Least mean squares linear material decomposition was used to calculate the concentrations of contrast agents in the aorta, renal cortex, renal medulla and renal pelvis.

Results—Using reference vials with known concentrations of materials, we computed molar concentrations of the various contrast agents during each phase of CT scanning. Material concentration maps allowed simultaneous quantification of both arterial and delayed renal enhancement in a single CT acquisition. The accuracy of the material decomposition algorithm in a test phantom was −0.4±2.2 mM, 0.3±2.2 mM for iodine and gadolinium solutions, respectively. Peak contrast concentration of gadolinium and iodine in the aorta, renal cortex, and renal medulla were observed 16, 24, and 60 seconds after the start each injection, respectively.

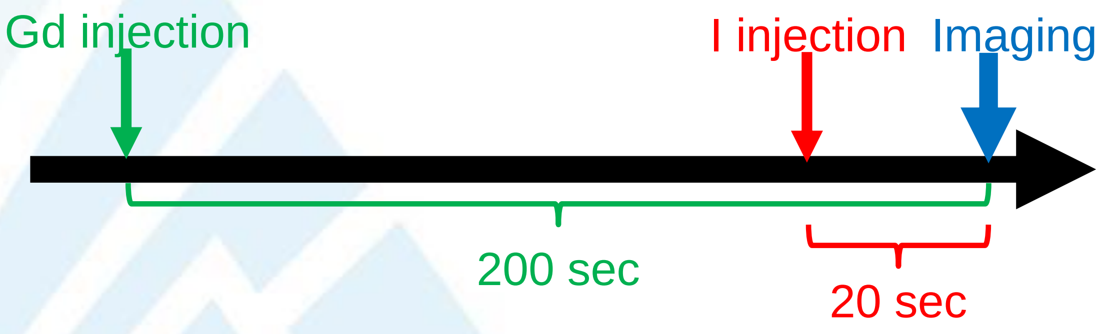
Conclusion—Photon-counting spectral CT allowed simultaneous material decomposition of multiple contrast agents in vivo. Besides defining contrast agent concentrations, tissue enhancement at multiple phases was observed in a single CT acquisition, potentially obviating the need for multi-phase CT scans and thus reducing radiation dose.

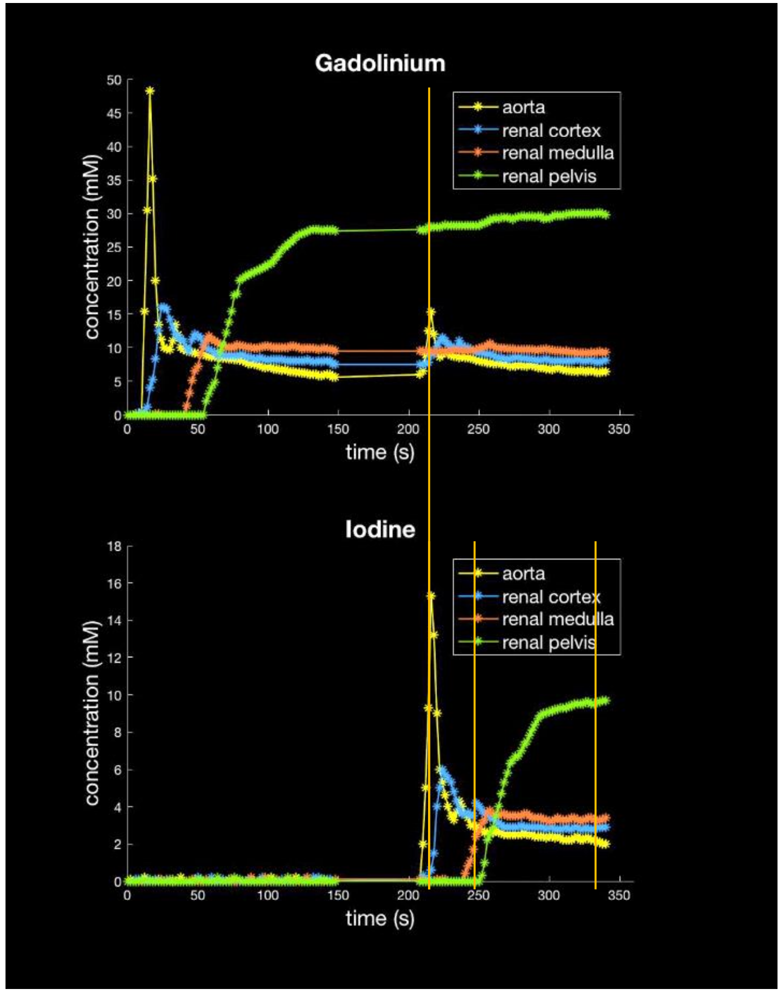


1. Symons R, et al. (2017) Int J Cardiovasc Imaging 33:1253-1261.
2. Symons R, et al. (2017) Med Phys 44:5120-5127.

PCCT and Multiple contrast agents

- One image acquisition
  - Late enhancement Gadolinium, first pass Iodine





1. Symons R, et al. (2017) Int J Cardiovasc Imaging 33:1253-1261.
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Take home messages

- MRI is the imaging modality of choice
  - For problem solving after equivocal CT and/or US
    - Patients with no comorbidities
    - Patients with known or suspected primary tumour
  - In diagnosis and staging of HCC in cirrhosis
- PCCT promising technique
  - Improved spatial, contrast and temporal resolution
  - Lower X-ray and contrast dose
  - Future perspectives
    - Use of multiple contrast agents simultaneously?
    - Imaging targeted nanoparticles?
    - …

Ackowledgements

- Radiology
  - J. Awouters
  - V. Broeckhoven
  - E. Dresen
  - S. Dymarkowski
  - L. Konijn
  - B. Miseur
  - K. Op de beeck
  - R. Symons
  - D. Vanbeckevoort
  - R. Vanslembrouck
  - V. Vandecaveye
- Medical physics
  - J. Binst
  - H. Bosmans
  - W. Coudyzer
  - H. Verhoeven

Thank you !!!

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