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H.U.B HÔPITAL UNIVERSITAIRE DE BRUXELLES ACADEMISCH ZIEKENHUIS BRUSSEL

Hôpital Erasme ULB

CT Liver Perfusion « State of the Art »

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

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Disclosures

- *Consultance fee for the present presentation*
- *No other disclosure to declare*

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SUMMARY

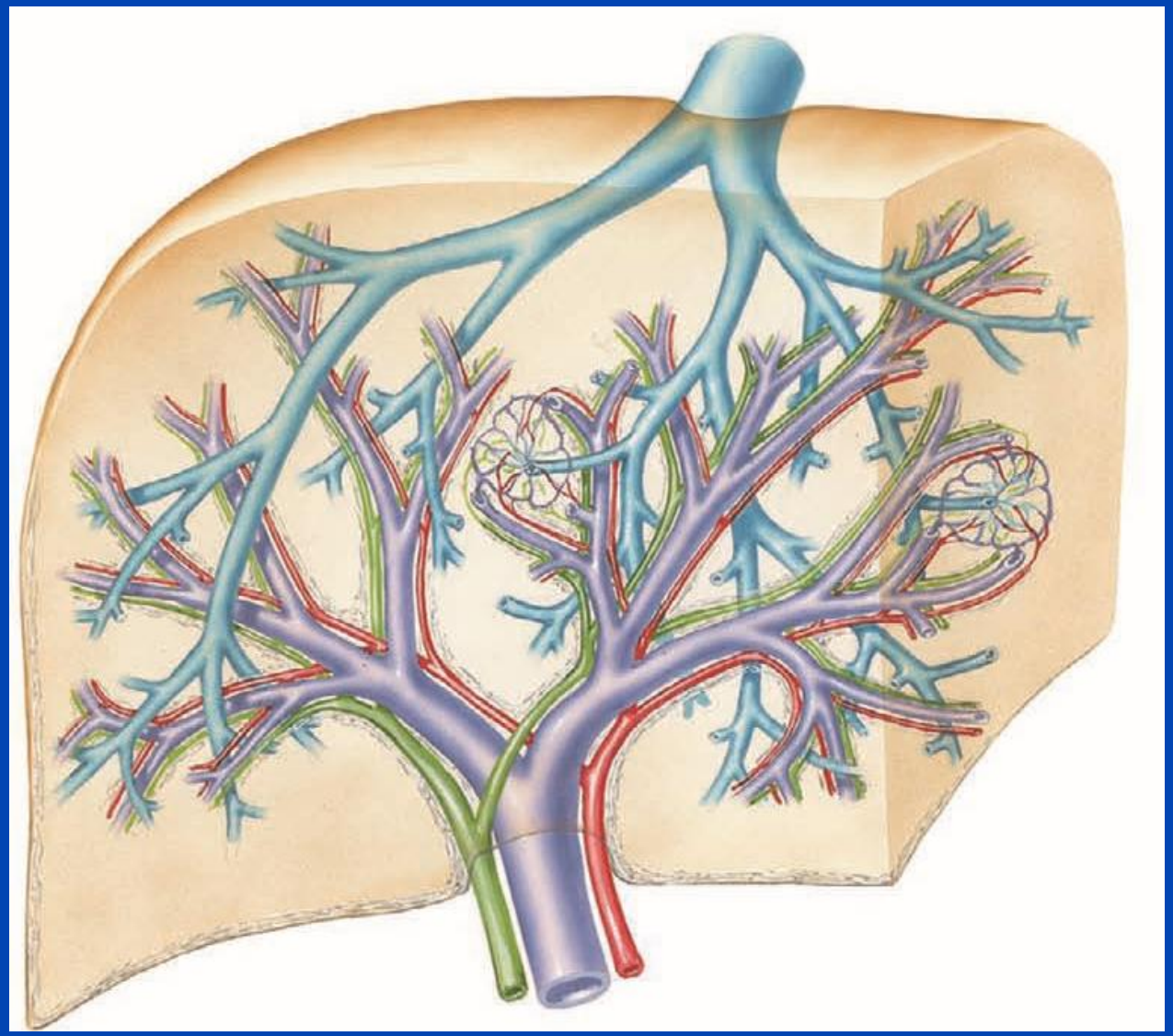
- Introduction and Concepts
- Technique
- Potential applications
- Dose reduction : results from a monocentric study

INTRODUCTION AND CONCEPTS

- Perfusion = blood transport/tissue volume/time
- CT : local differences of tissue attenuation (HU) ⟶ proportional to [iodine] inside tissues
- Perfusion CT ⟶ [iodine] variation/tissue volume /time
- Perfusion CT ≠ multiphasic CT

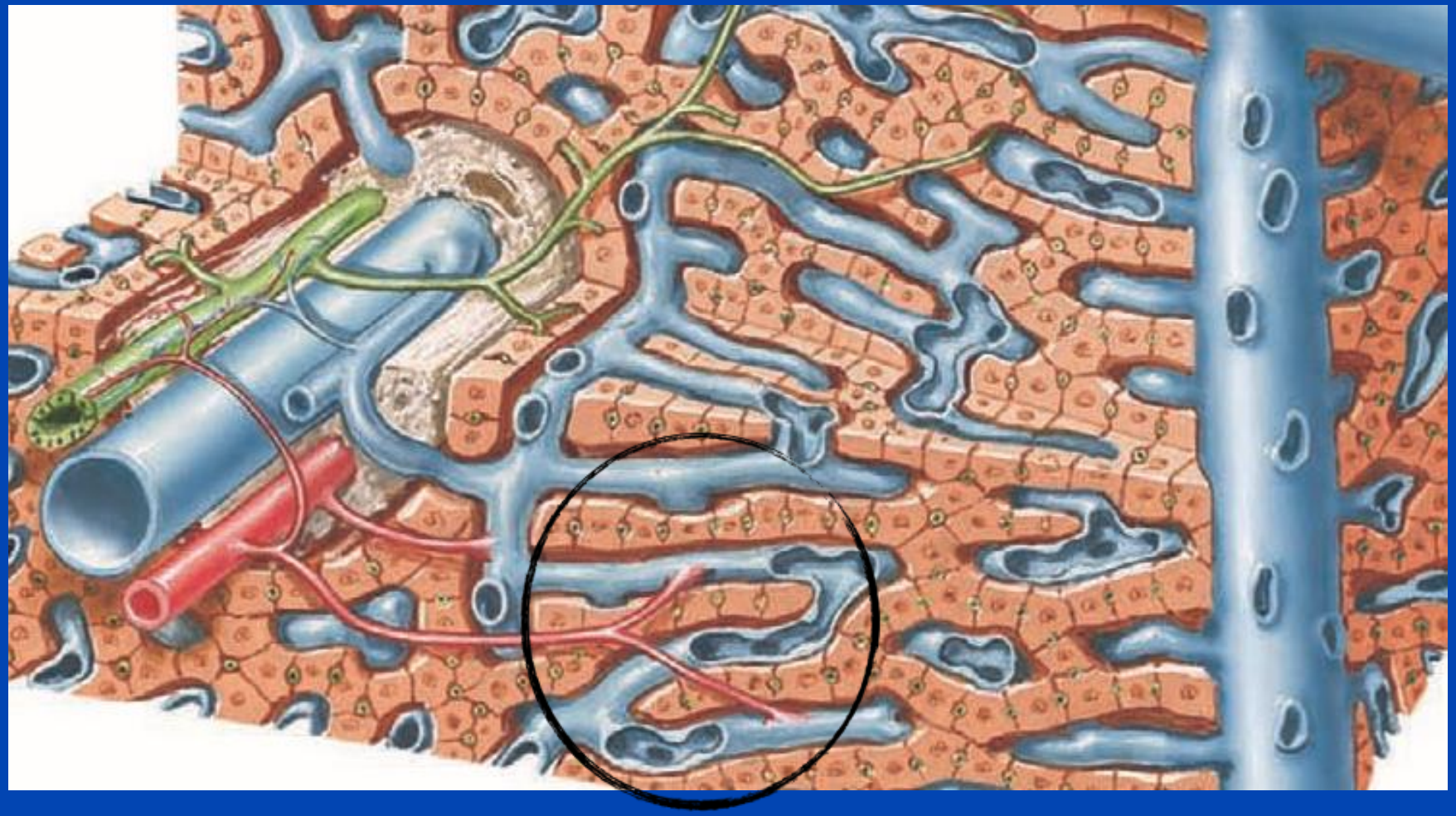
Kim SH et al. Radiology. 2014;272(2):322-44

INTRODUCTION AND CONCEPTS



Netter FH. Atlas d'anatomie humaine. 5e Ed. Elsevier. 2011

INTRODUCTION AND CONCEPTS



Netter FH. Atlas d'anatomie humaine. 5e Ed. Elsevier. 2011

TECHNIQUE

- Liver Perfusion is complex
- Volumic multiphasic acquisition of the same volume through time (before, during and after IV contrast medium injection)
  - Early phase : 40 to 60 s
  - (Late phase : 2 to 10 min)
- Calcuations and analyses differ between mathematic algorithms

Radiology. 2014;272:322-344

TECHNIQUE

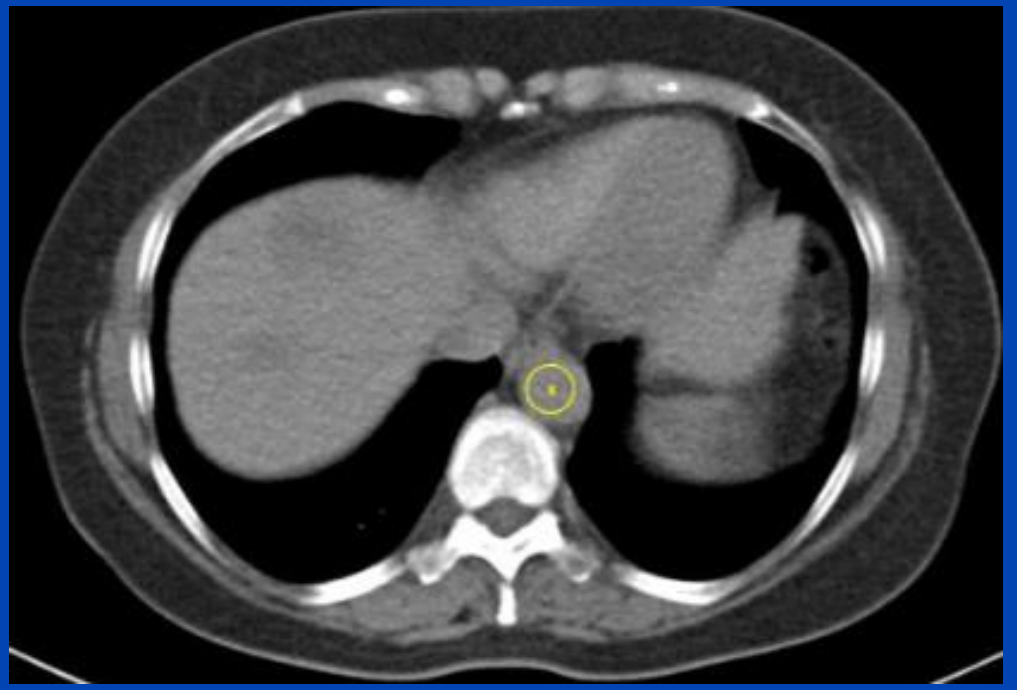
- Acquisition protocols depend on CT model, mathematical model and used software (frequency, tube rotation speed, duration, mAs, kV, number of acquisitions, …)

- Tube parameters: 80-100 kV, 50-120 mAs
- Number of acquisitions:
  - 1/s during 40-60 seconds (intravascular space)
  - 1/10s or more during 2 to 10 min (extravascular space)
- Contrast injection : 40-70 ml, 4-10ml/s, > 300 mg/ml iode (750 mgI/kg)

Eur J Radiol. 2017;97:101-109

Radiology. 2014;272:322-344

PRACTICALLY
(STANDARD PERFUSION ACQUISITION ON FORCE SIEMENS CT SCANS)

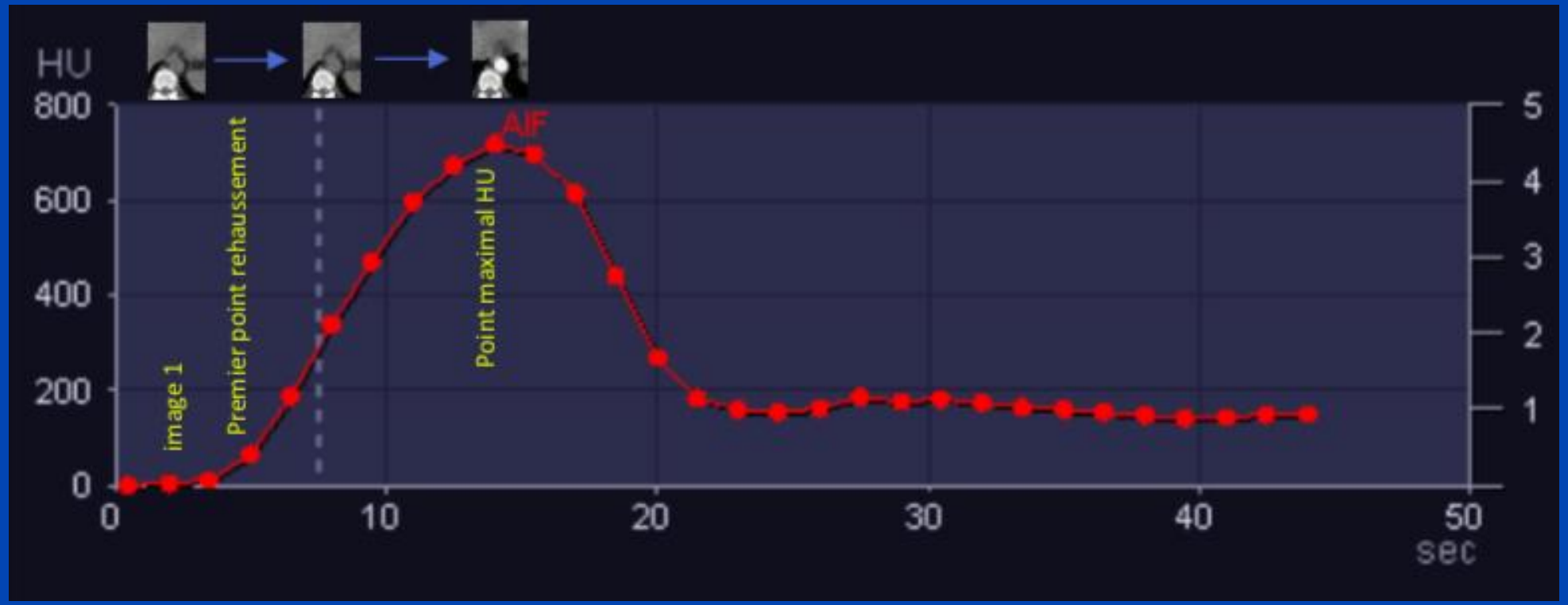


PRACTICALLY

TEST PHASE

Iomeron 400 - 12 cc - 4,5 cc/s

15 slices - 1/2 sec - 40 mAs - 100 kV



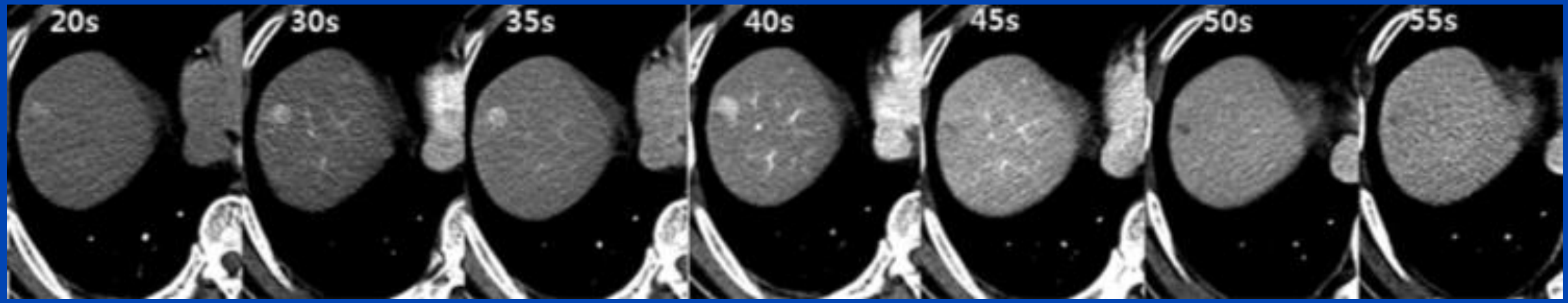
PRACTICALLY

PERFUSION ACQUISITION

Iomeron 400 - 50 cc - 4,5 cc/s

30 acquisitions (24 cm height volume) - 1/1.5 s (45s) - 100 mAs - 80 kV

Quiet and free-breathing

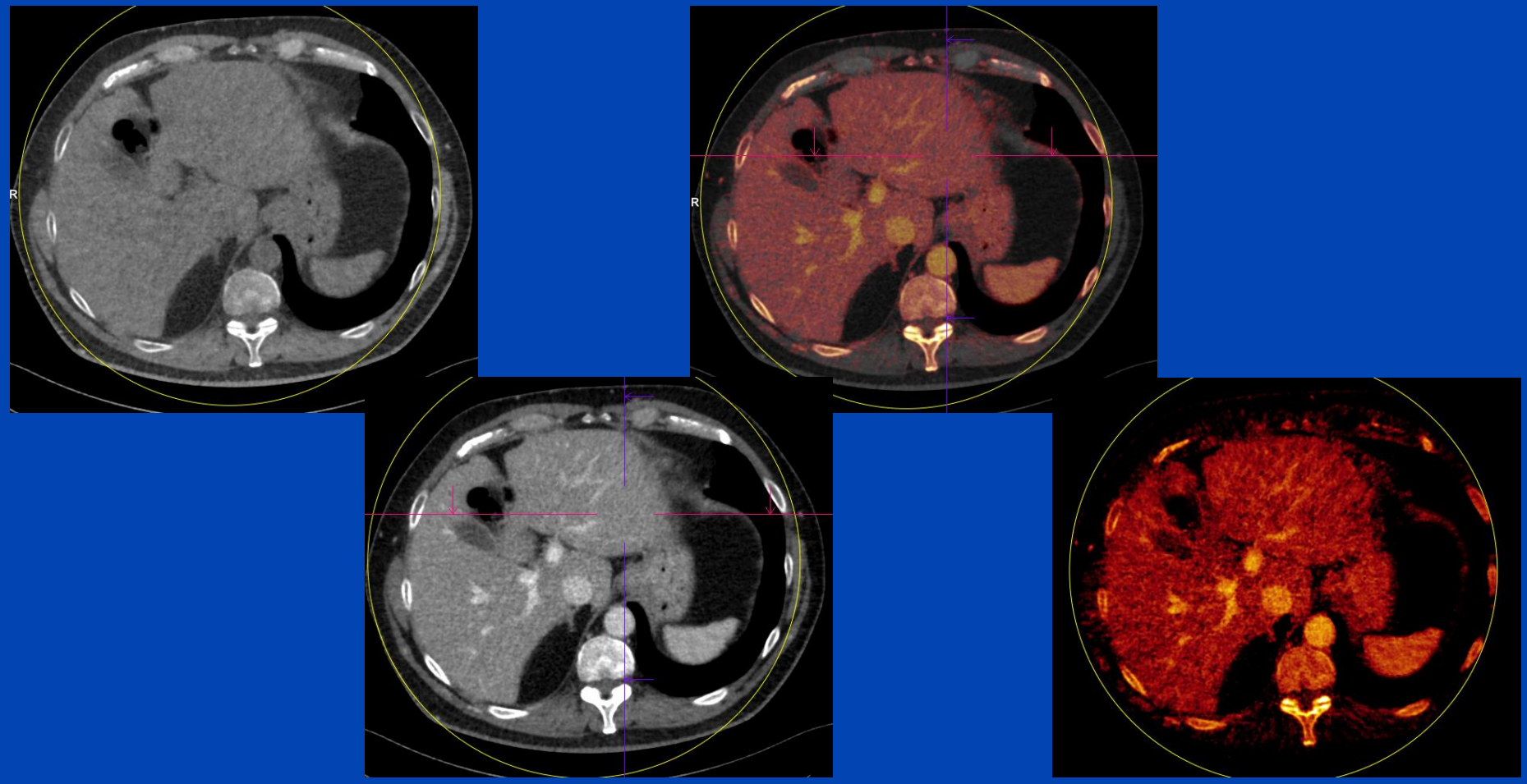


PRACTICALLY

PORTAL PHASE ACQUISITION

Iomeron 400 - 50 cc - 4,5 cc/s

Whole abdomen - 90/150 kV - 90/50 mAs



PRACTICALLY

POST-PROCESSSING

- Model-Free
- Model-Based
  - Single vs dual-input
  - Single vs dual-compartment
  - Conventional compartment vs distributed parameter

Radiology. 2014;272:322-344
World J Gastroenterol. 2010;16:1598-1609

MODEL-FREE

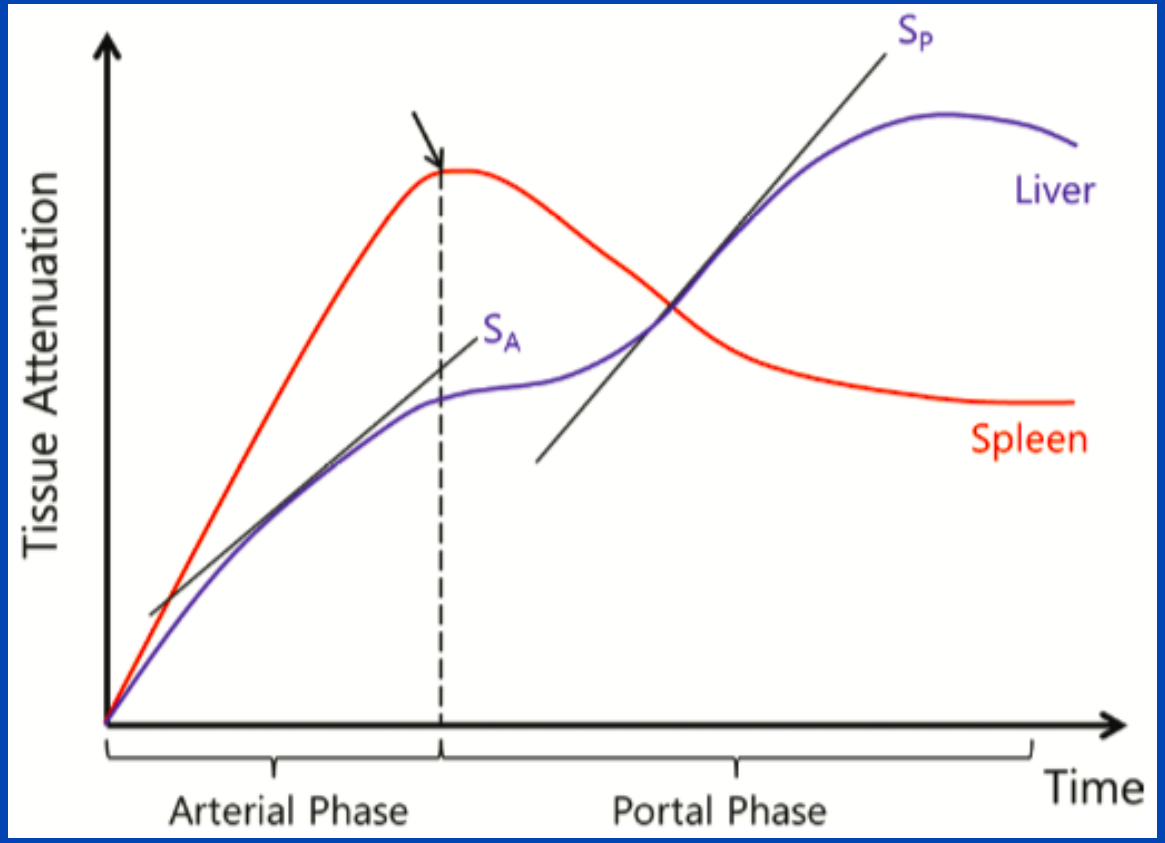
- = simple observation of attenuation change in liver parenchyma depending on contrast flow
- Perfusion based on the rate of enhancement (ml/100ml/min)

- Advantages :

rapid, low informatic ressources requested

- Disadvantages :

basic parameters calculation



Radiology. 2014;272:322-344
World J Gastroenterol. 2010;16:1598-1609

MODEL-BASED — SINGLE VS DUAL-INPUT

- Arterial vs. Arterio-portal vascularization
- Some tumors have an exclusively arterial vascularization (HCC, NET, …)
- Dual input model: Higher computer performance ressources requested, more physiological approach, some histologies more adapted, reporducibility, better response assessment/characterization

Radiology. 2014;272:322-344
World J Gastroenterol. 2010;16:1598-1609

SINGLE VS DUAL-COMPARTMENT

- Vascular vs Vascular-interstitial compartments
- Disse’s spaces communicate largely with sinusoids in healty liver parenchyma.
- Dual compartment : higher computer ressources, investigates microcirculation in healthy and tumor tissues

Radiology. 2014;272:322-344
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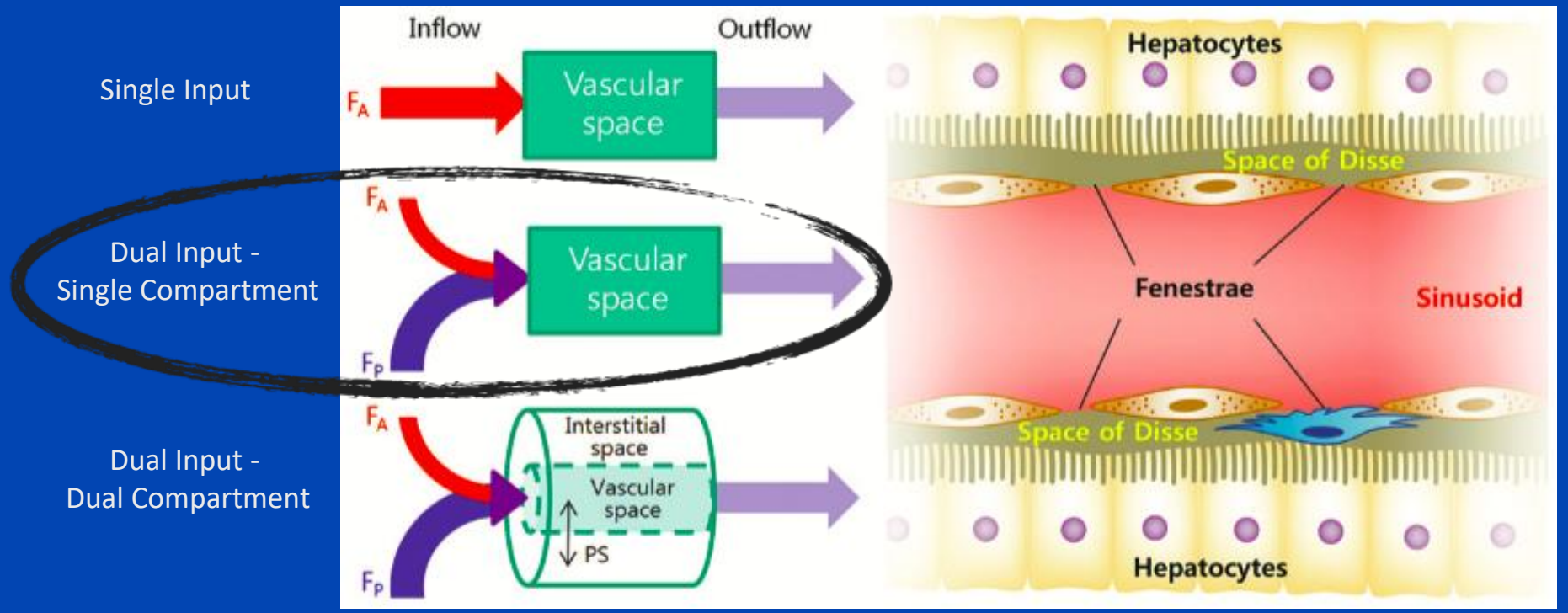
SINGLE VS DUAL-COMPARTMENT



Radiology. 2014;272:322-344

PARAMETERS

- Qualitative : attenuation curves / time and parametric color maps
- Semi-quantitative : time-to-peak and peak value
- Quantitative : through placement of « ROI » in target lesions and use of mathematical models

Eur J Radiol. 2017;97:101-109

QUANTITATIVE PARAMETERS

- Blood Flow(BF) (ml/min/100gr)
- Total Liver Perfusion (TLP) (ml/min/100gr)
- Arterial Liver Perfusion (ALP) (ml/min/100gr)
- Portal Liver Perfusion (PLP) (ml/min/100gr)
- Hepatic Perfusion Index (HPI) (%)

Model-Free or
Maximum Slope Method

- Time to Peak (TTP) (s)
- Blood Volume (BV) (ml/100gr)
- Mean Transit Time (MTT) (s)
- Permeability – Surface product (PS) (ml/min/100gr)

Dual-compartment
or Distributed

Eur J Radiol. 2017;97:101-109

QUANTITATIVE PARAMETERS

- Blood Flow (BF) (ml/min/100gr)
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- Time to Peak (TTP) (s)
- Blood Volume (BV) (ml/100gr)
- Mean Transit Time (MTT) (s)
- Permeability – Surface product (PS) (ml/min/100gr)

Liver Perfusion

Lesions Arterialization

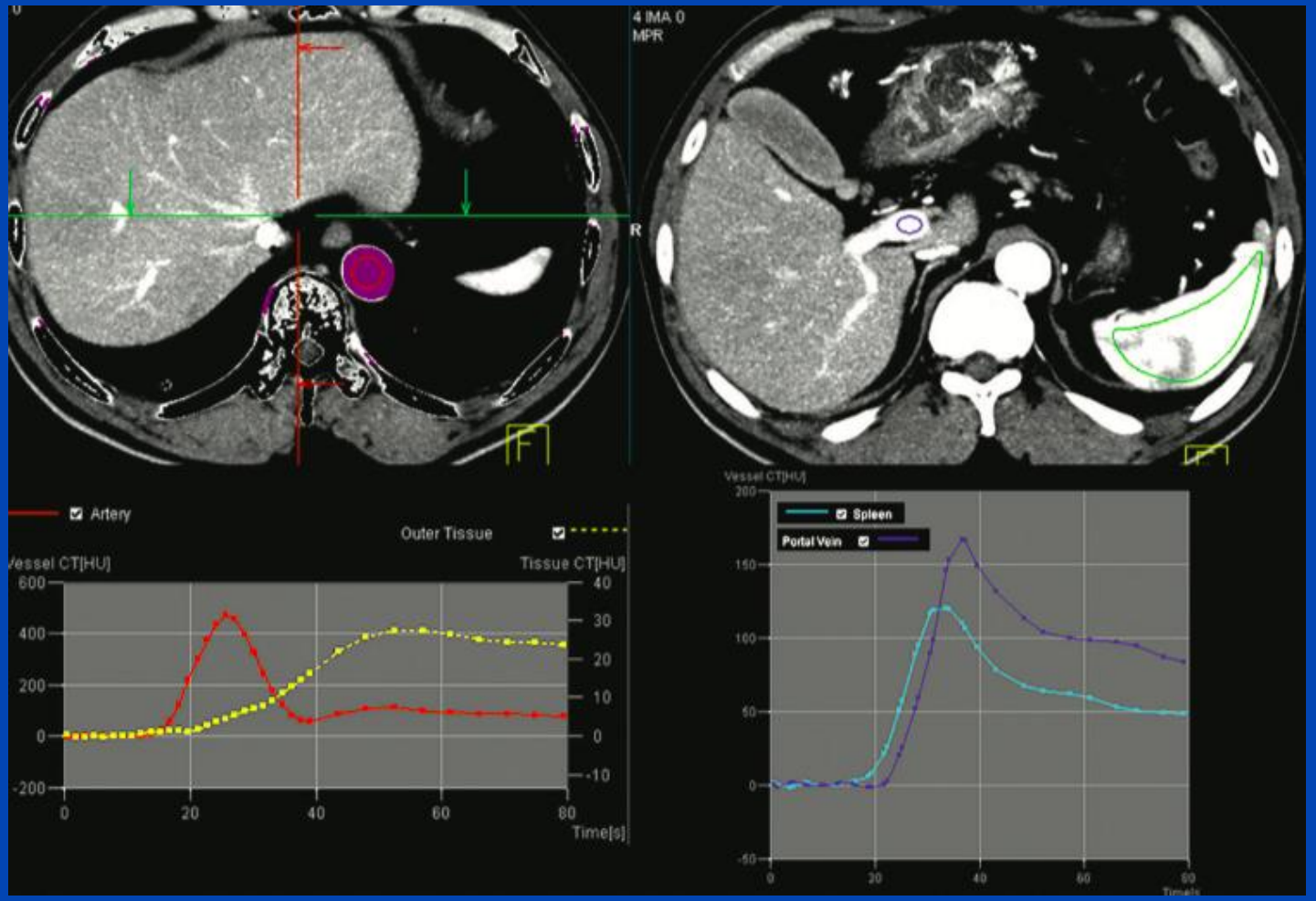
Vascular Density

Vascular-capillary permeability

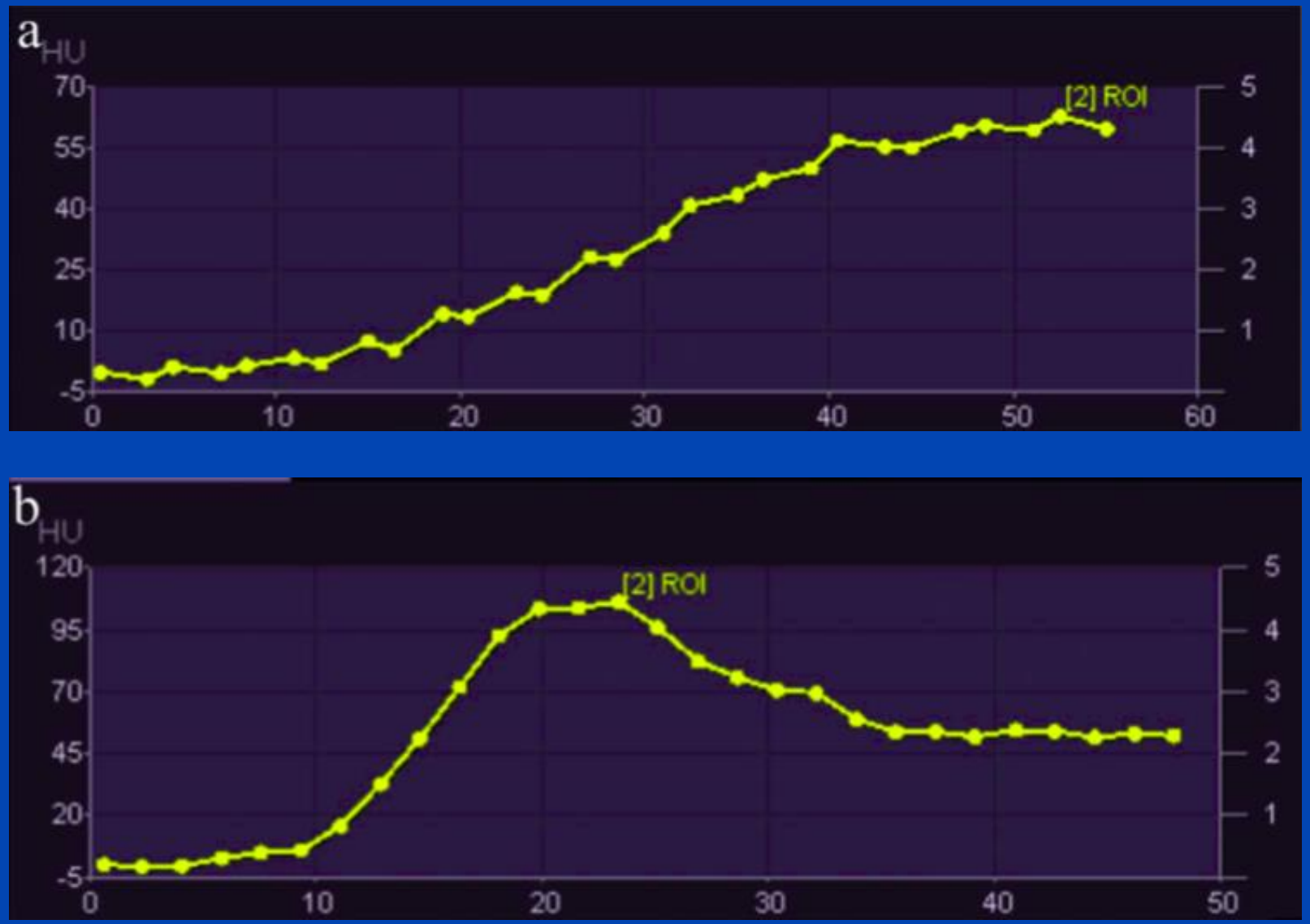
Eur J Radiol. 2017;97:101-109

POST-PROCESSING

- Movement correction
- Positionning of « ROI »



POST-PROCESSING



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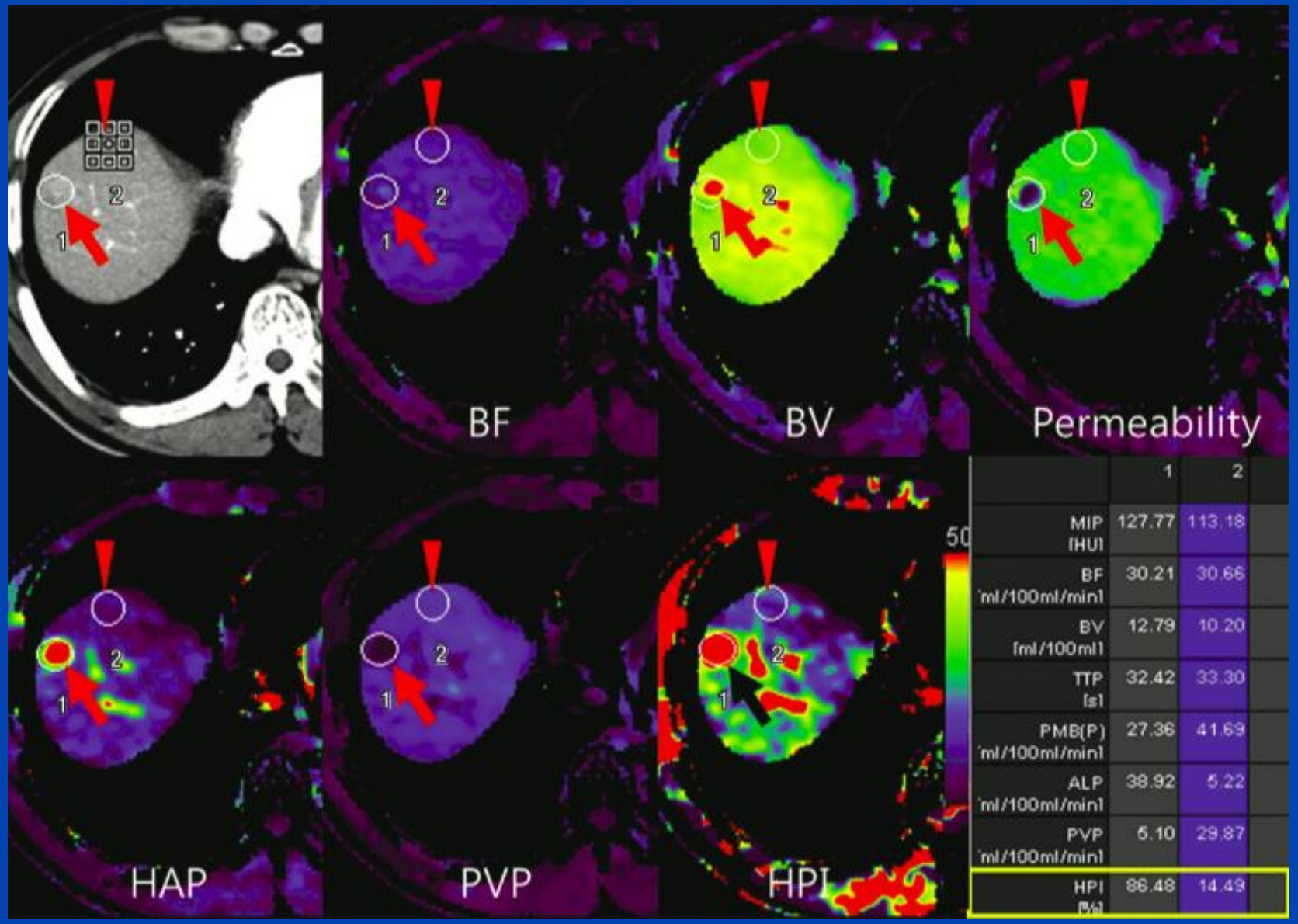
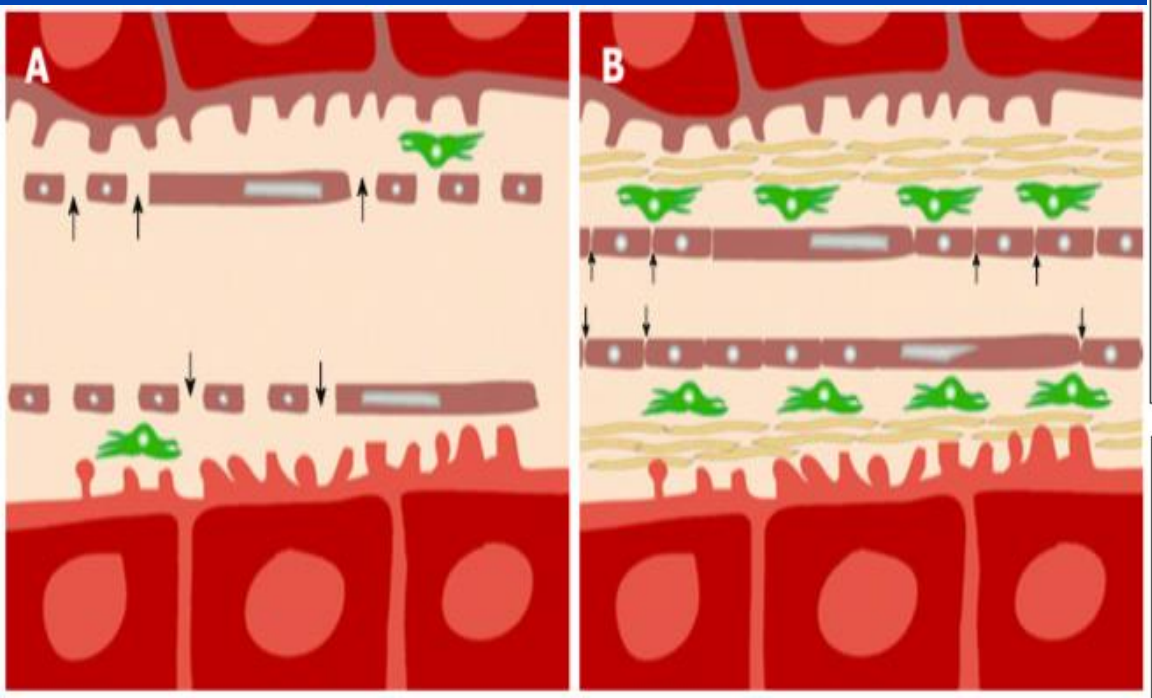
POST-PROCESSING



Radiology. 2014;272:322-344

POTENTIAL APPLICATIONS

GRADING FIBROSIS/ CIRRHOSIS



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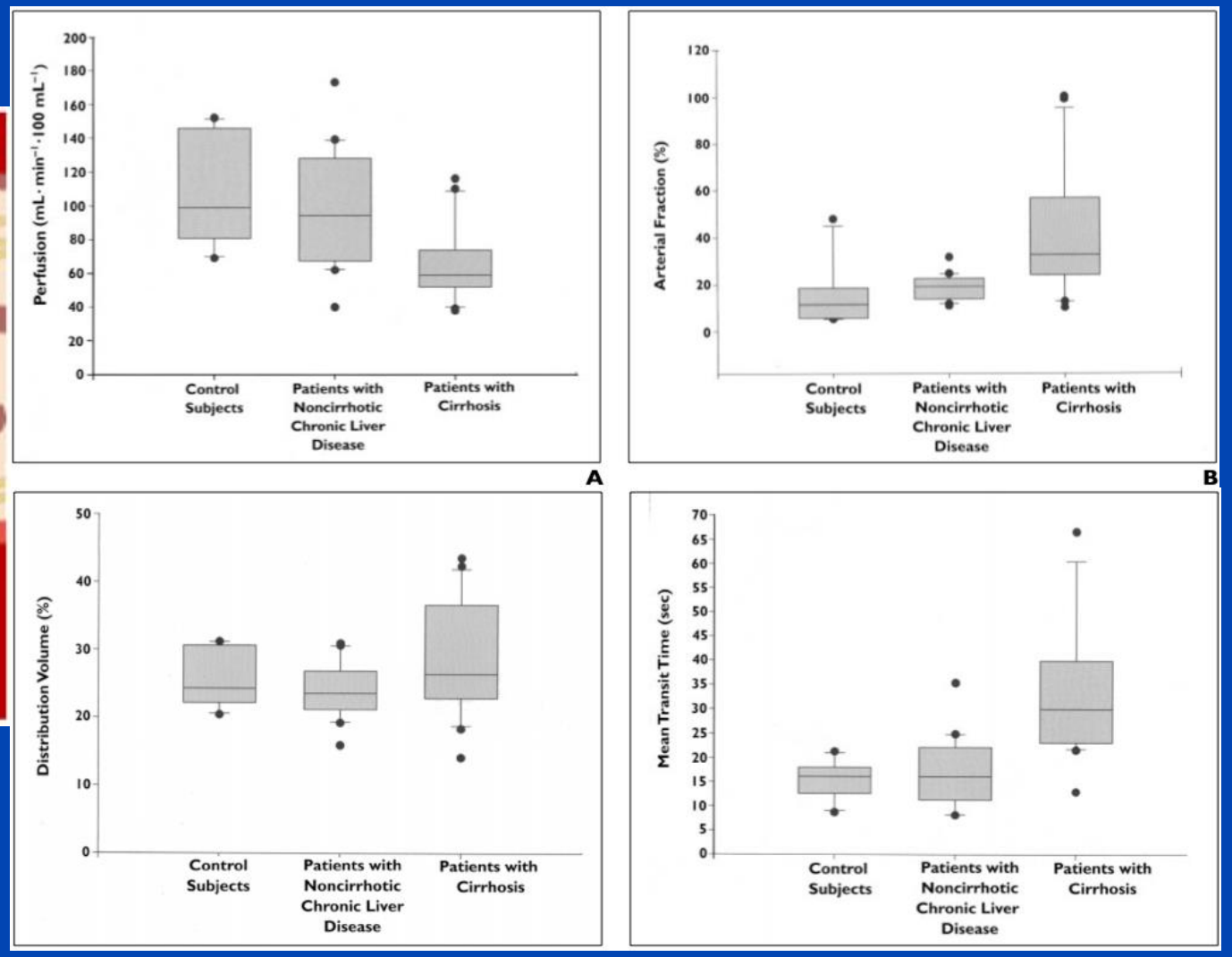
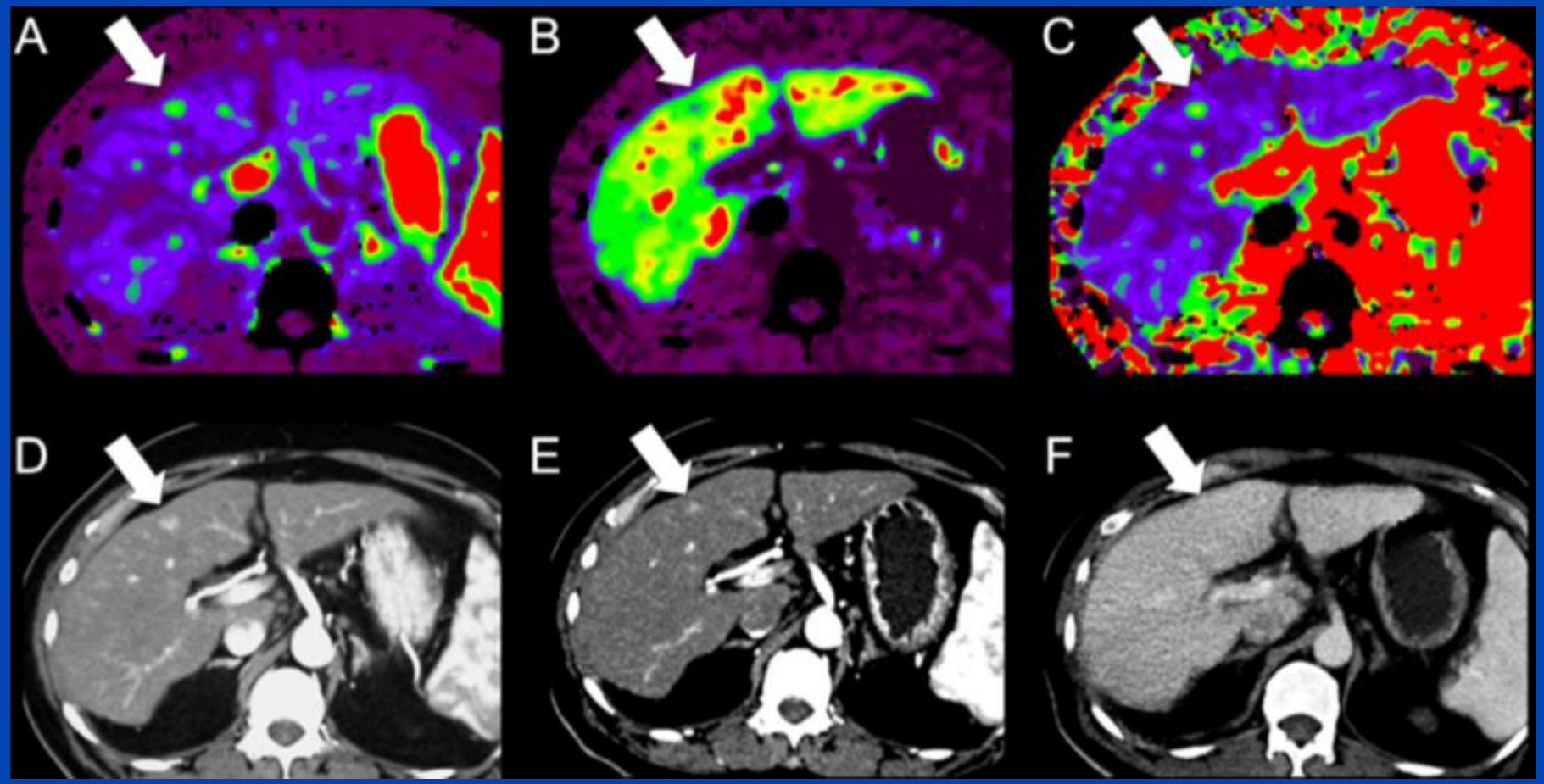


AJR. 2001;176:667-673

POTENTIAL APPLICATIONS

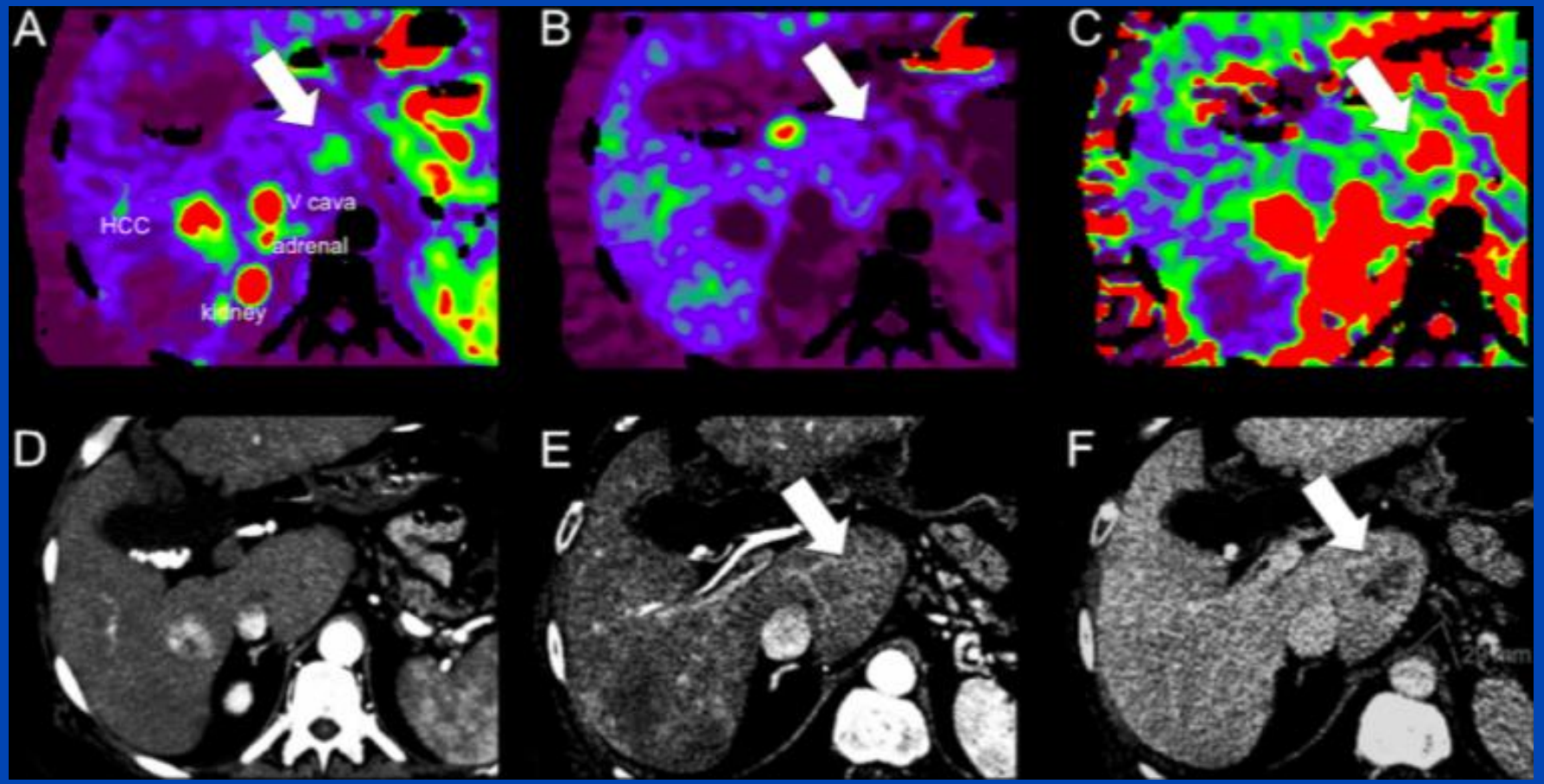
HCC DETECTION / CHARACTERIZATION



Eur Radiol. 2015;25:3123-3132

POTENTIAL APPLICATIONS

HCC DETECTION / CHARACTERIZATION



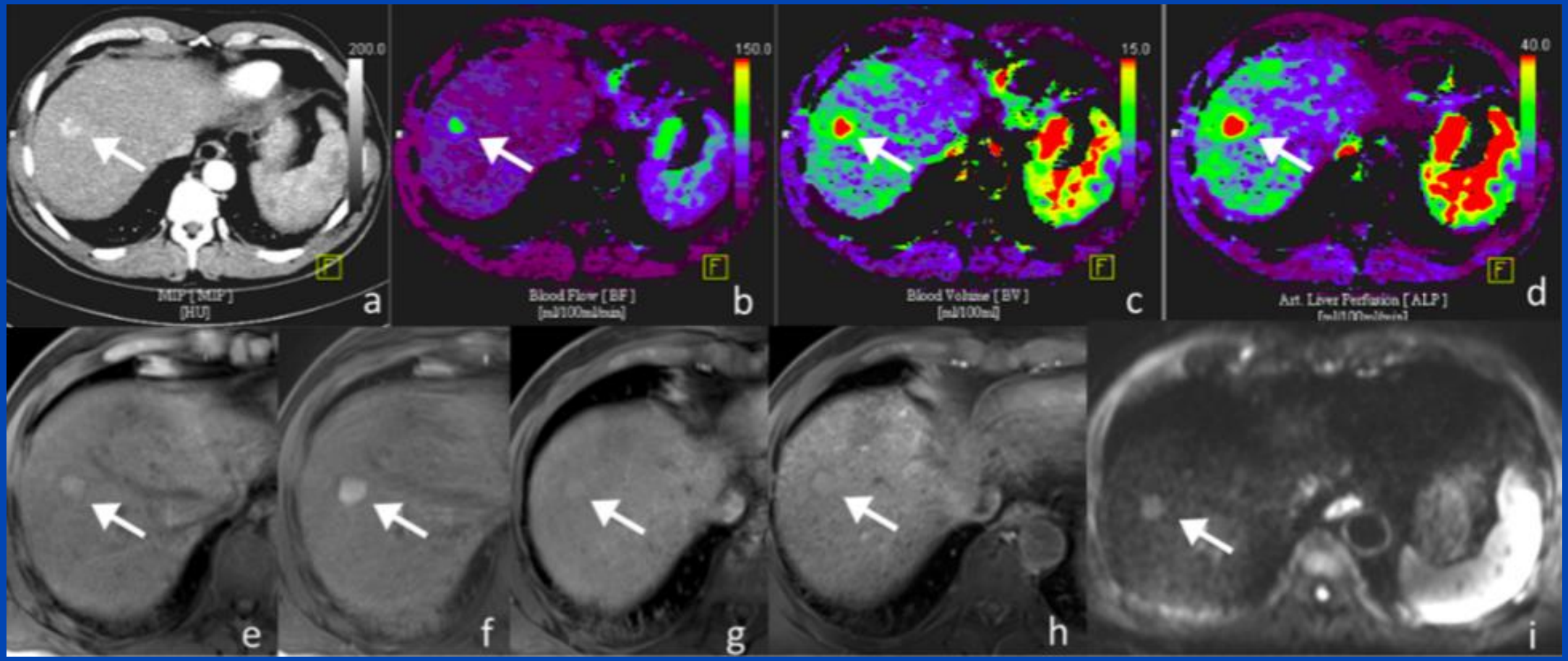
Eur Radiol. 2015;25:3123-3132

DISCUSSION - SCREENING - HEPATOCELLULAR CARCINOMA

	Detection rate	Positive predictive value
Perfusion maps alone		
Reader 1	91.6 % (CI, 82–100; N, 44/48)	62.8 % (CI, 50–74; N, 44/70)
Reader 2	87.5 % (CI, 77–97; N, 42/48)	62.6 % (CI, 50–75; N, 42/67)
Side-by-side analysis		
Reader 1	97.9 % (CI, 92–102; N, 47/48)	68.1 % (CI, 56–79; N, 47/69)
Reader 2	95.8 % (CI, 89–102; N, 46/48)	70.7 % (CI, 58–82; N, 46/65)

Fischer MA et al. Eur Radiol. 2015;25:3123-32

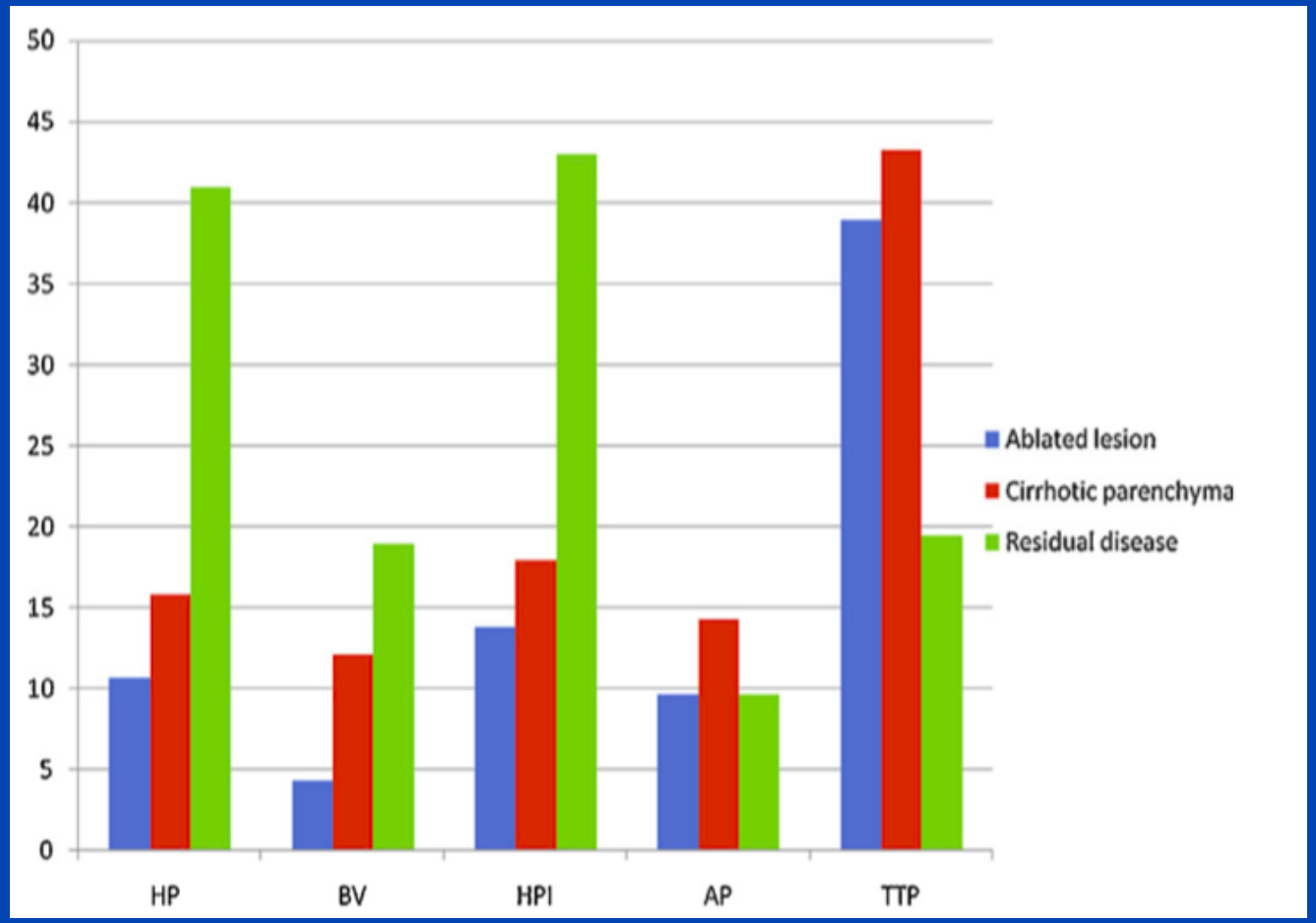
COMPARISON TO MRI



Cancer Imaging. 2017;17:18

POTENTIAL APPLICATIONS

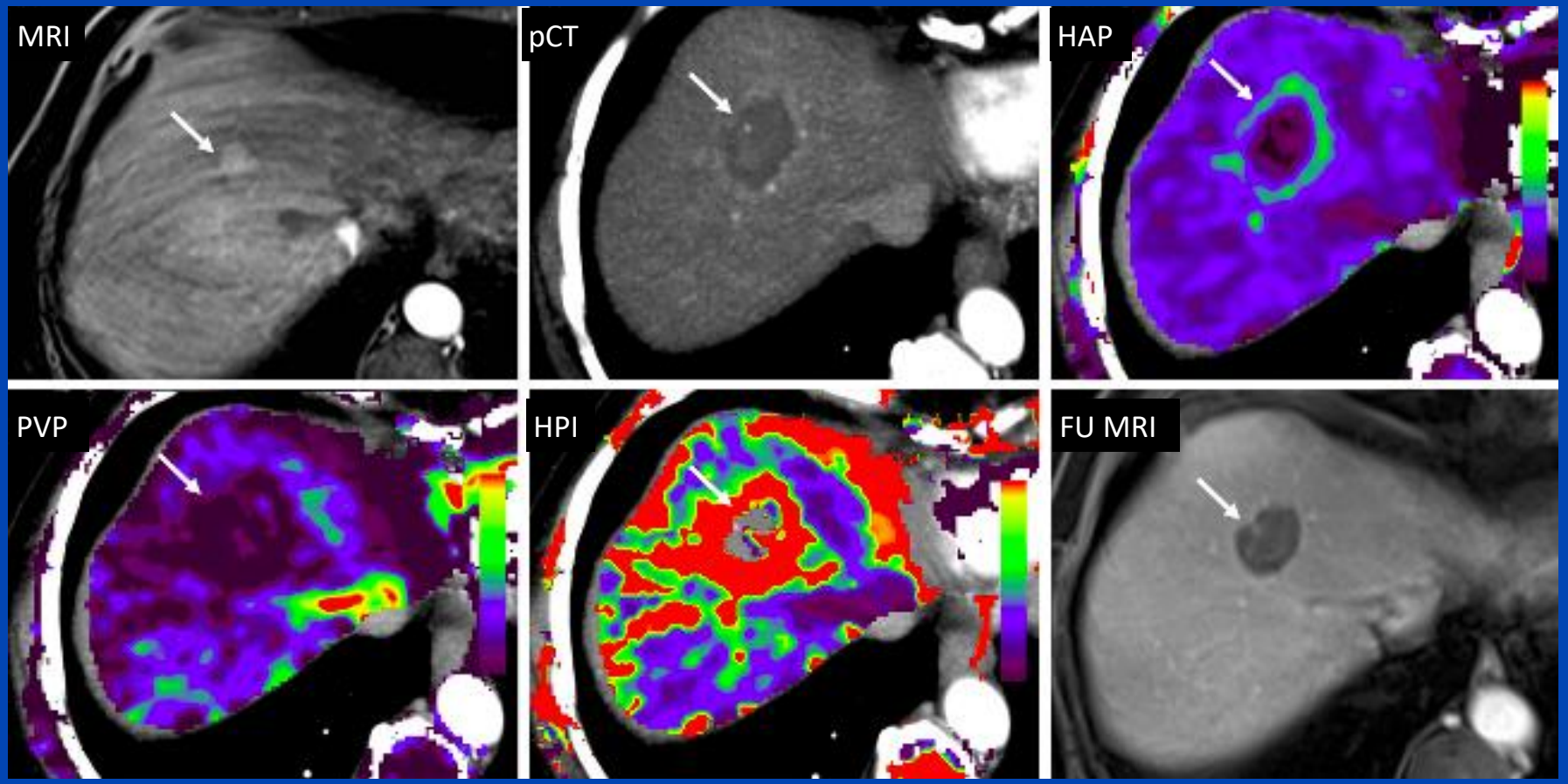
RESPONSE TO TREATMENT : RFA



Eur J Radiol. 2014;83:1665-1671

POTENTIAL APPLICATIONS

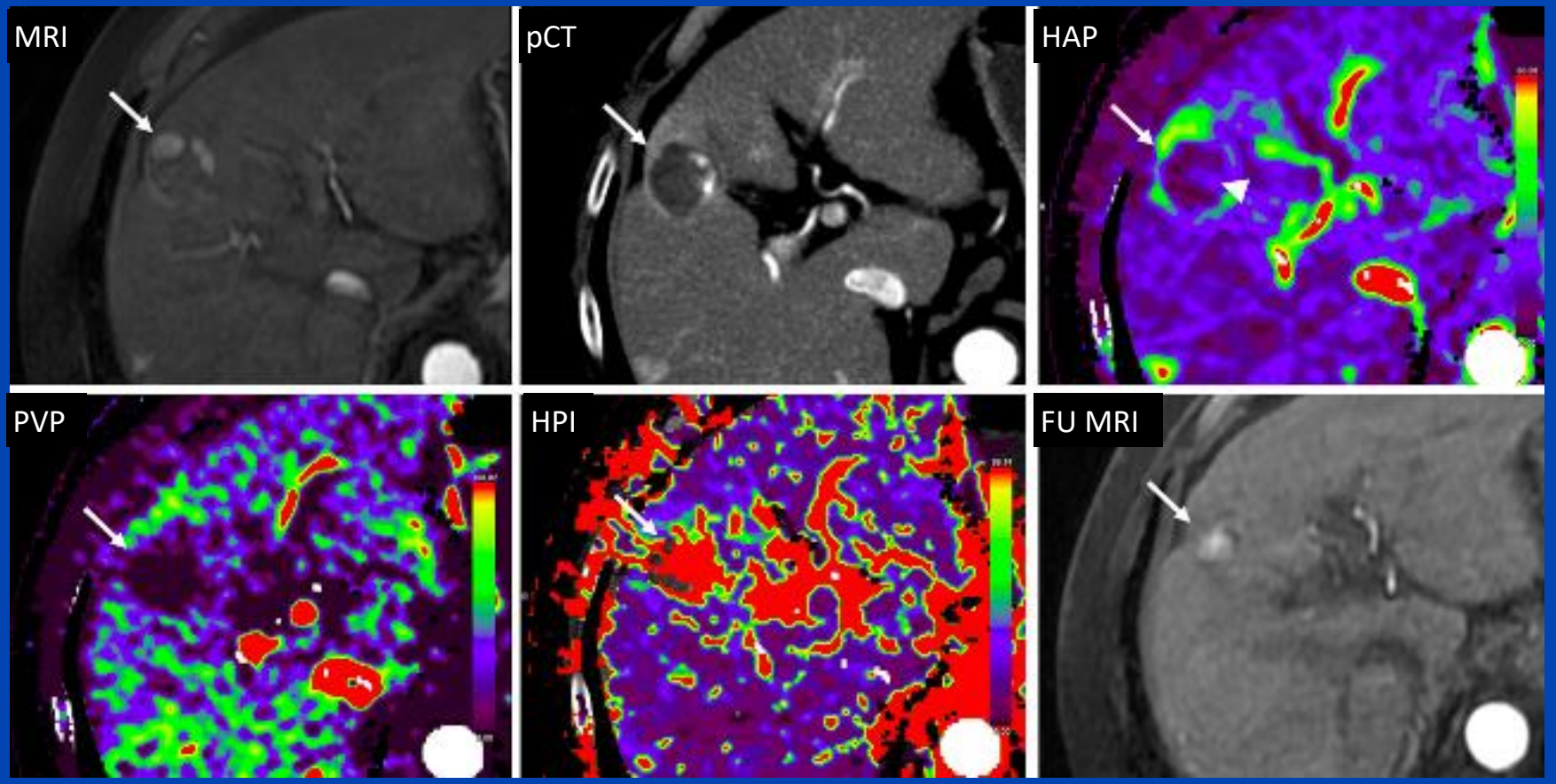
RESPONSE TO TREATMENT : RFA



Cardiovasc Intervent Radiol. 2017;40:90-98

POTENTIAL APPLICATIONS

RESPONSE TO TREATMENT : RFA



Cardiovasc Intervent Radiol. 2017;40:90-98

POTENTIAL APPLICATIONS

RESPONSE TO TREATMENT : SORAFENIB

Responders

Perfusion Parameters	Baseline	1 °Follow-up	*p*-value
HP	54.3 ± 15.9	28.7 ± 21.5	0.001
TTP	16.6 ± 2.5	22.4 ± 8.4	0.026
AP	52.0 ± 15.8	28.7 ± 21.8	0.018
HPI	84.0 ± 24.4	51.3 ± 36.8	0.013

Progressors

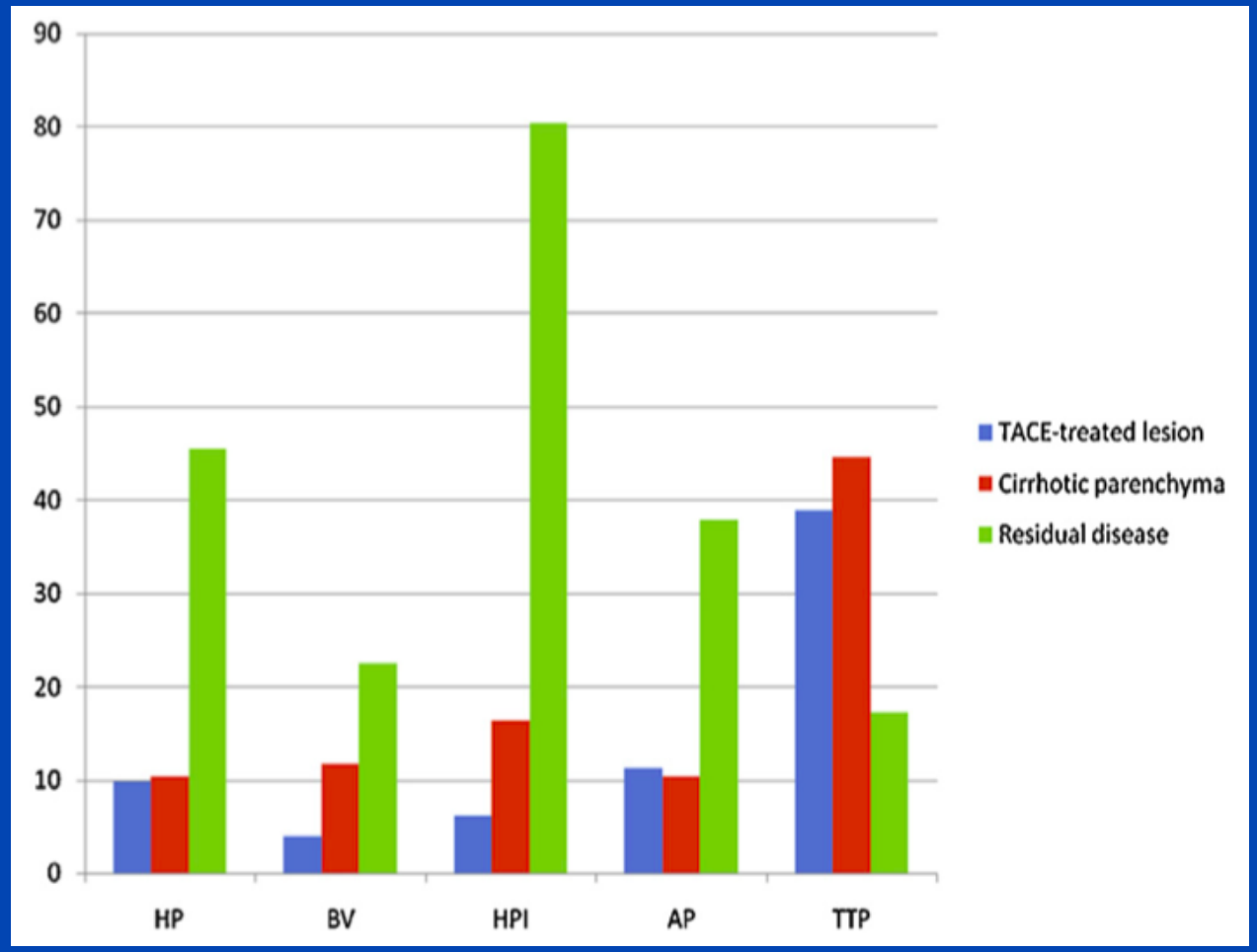
Perfusion Parameters	Baseline	1 °Follow-up	*p*-value
HP	38.2 ± 25.8	45.8 ± 23.8	0.050
TTP	18.9 ± 2.9	17.2 ± 2.7	0.148
AP	36.4 ± 22.0	44.0 ± 24.2	0.032
HPI	89.3 ± 28.3	87.0 ± 22.5	NA

HP: hepatic perfusion (ml/s/100 g); TTP: time-to-peak (s); AP: arterial perfusion (ml/s); HPI: hepatic perfusion index (%).

Eur J Radiol. 2018;106:62-68

POTENTIAL APPLICATIONS

RESPONSE TO TREATMENT : TACE



Eur J Radiol. 2014;83:1665-1671

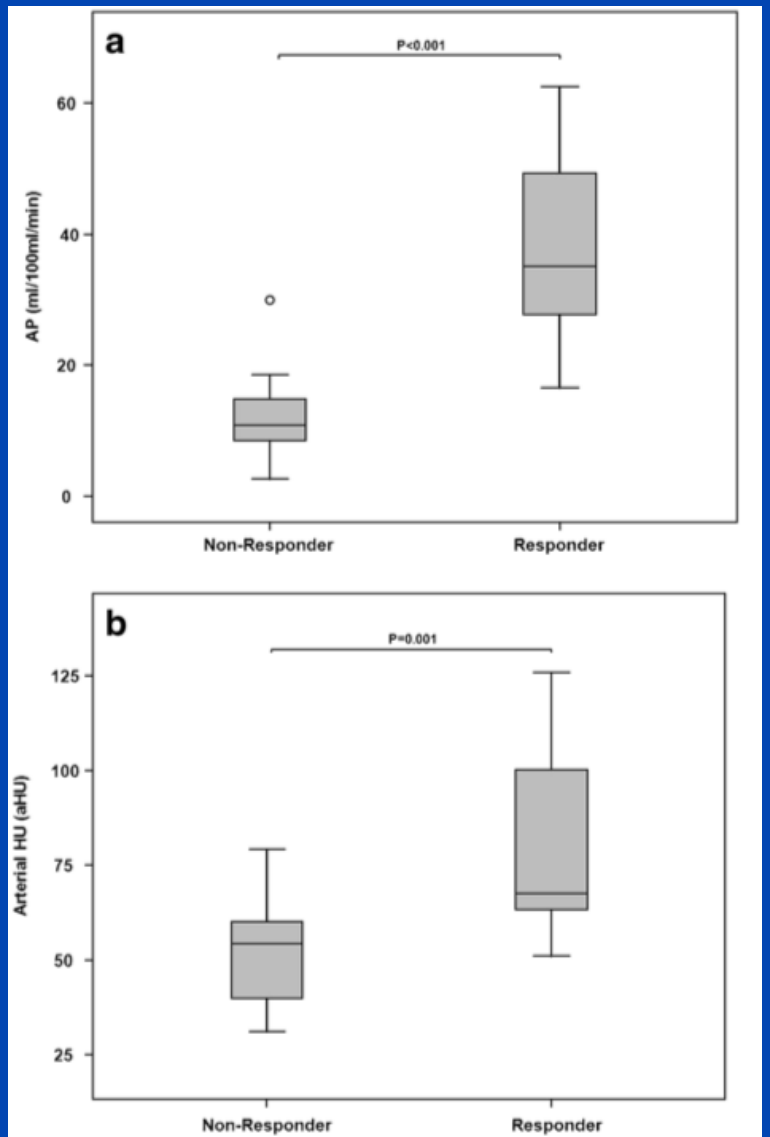
DISCUSSION - TREATMENT FOLLOW-UP HCC

		Before treatment	After treatment	
Ippolito et al. (2017) Sorafenib	ALP	49.2	29.4	-40 %
	HPI	76.5	47.9	-37 %
Tamandl et al. (2017) TACE	ALP	29.2	4.3	-85 %
	HPI	67	17.2	-74 %
Marquez et al. (2017) TACE	ALP	41.4	12.6	-70 %
	HPI	77.5	46.1	-40 %
Ippolito et al. (2018) Sorafenib	ALP	51	28.7	-44 %
	HPI	84	51.3	-39 %

Ippolito D et al. Eur J Radiol. 2017;90:34-41
Tamandl D et al. Eur J Radiol. 2017;90:73-80
Marquez HP et al. Eur J Radiol. 2017;91:160-7
Ippolito D et al. Eur J Radiol. 2018;106:62-8

POTENTIAL APPLICATIONS

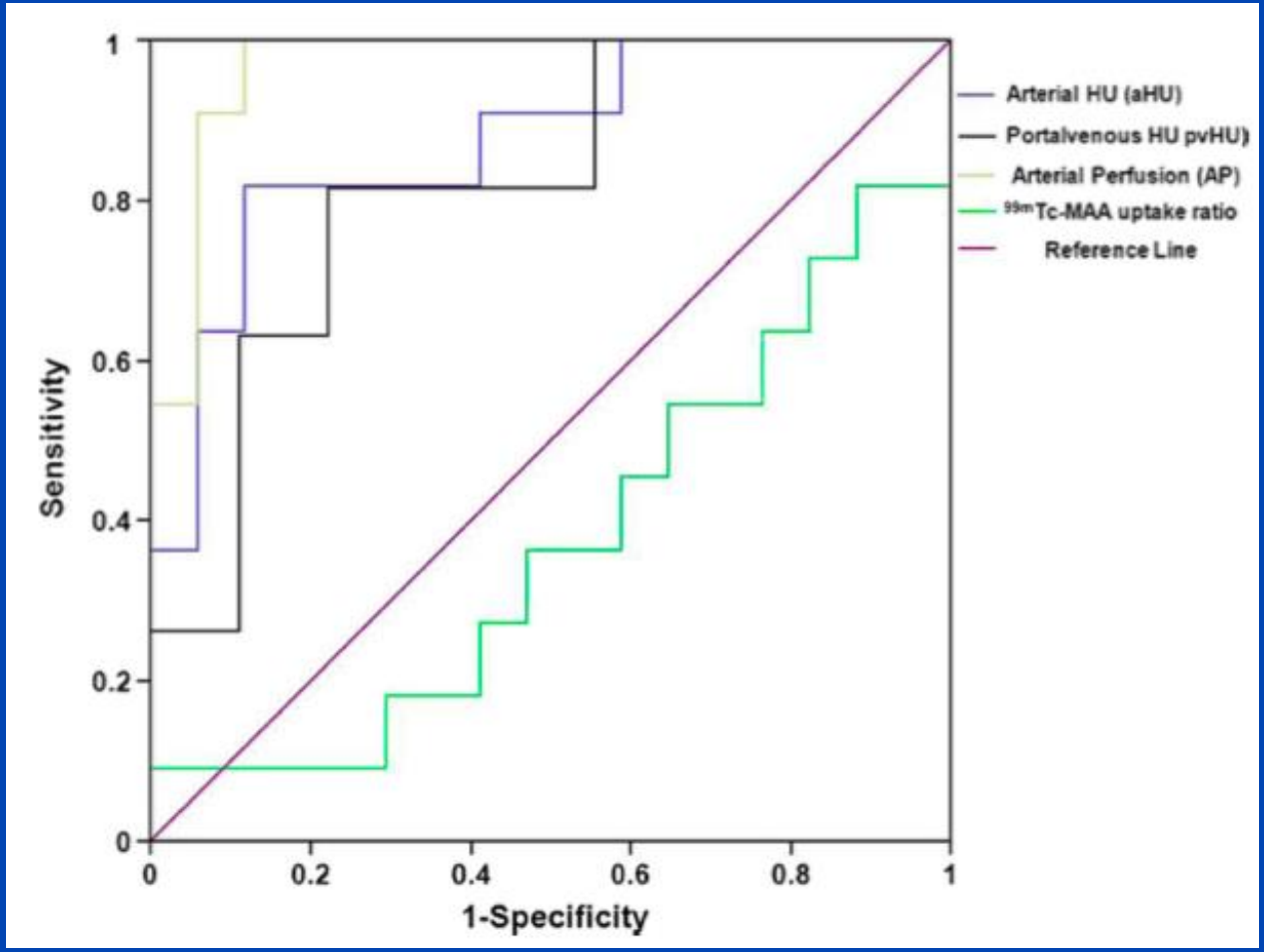
RESPONSE TO TREATMENT : TARE



Invest Radiol. 2013;48:787-794.
Eur Radiol 2014;24:1455-1465.

POTENTIAL APPLICATIONS

RESPONSE TO TREATMENT : TARE



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POTENTIAL APPLICATIONS

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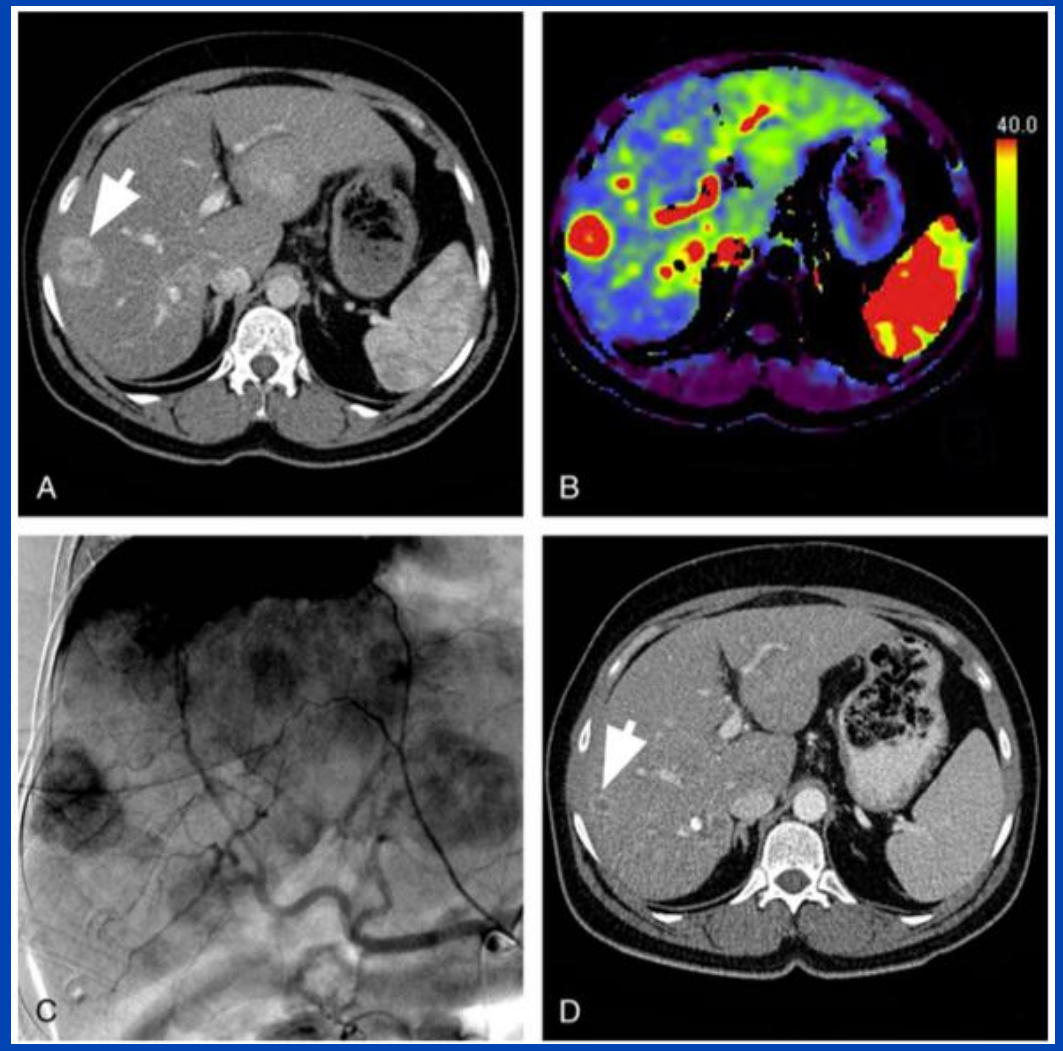
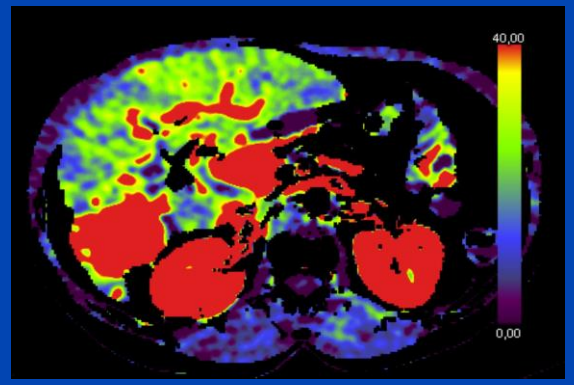
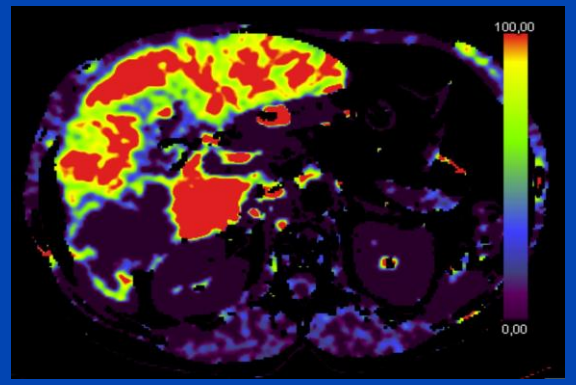


Invest Radiol. 2013;48:787-794.

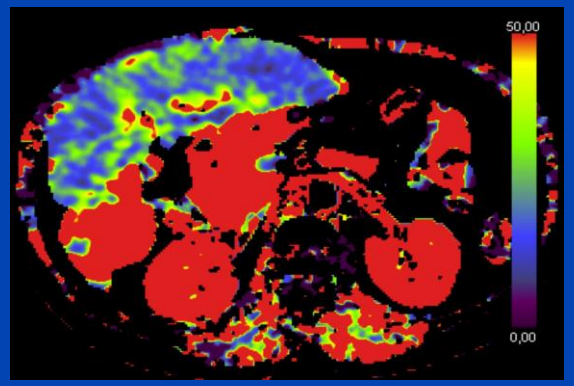
ESTIMATION OF ARTERIAL ENHANCEMENT BEFORE TRANSARTERIAL THERAPIES



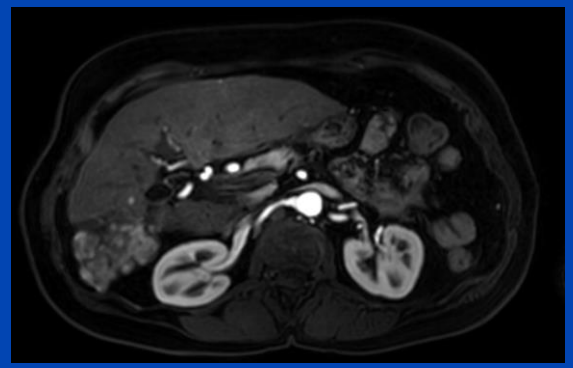
ALP



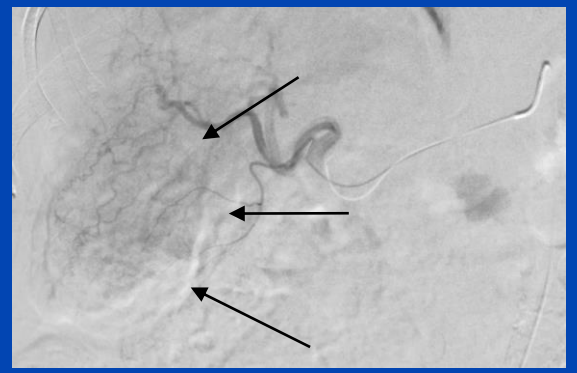
PVP



HPI



DIXON-W Arterial Phase MRI



TARE procedure

HCC

ESTIMATION OF ARTERIAL ENHANCEMENT BEFORE TRANSARTERIAL THERAPIES

COLORECTAL CANCER

- 75 y.o. male

- 04/2022: Rectal adenocarcinoma with synchronous bilobar liver metastases

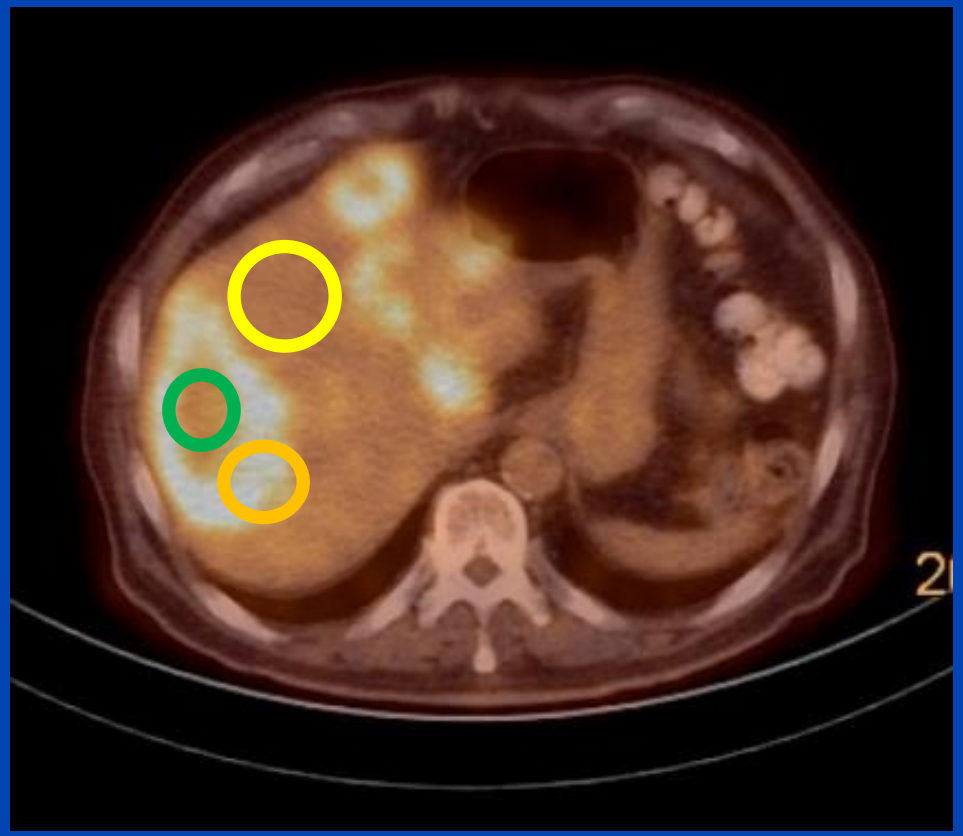
- Contra-indication to systemic chemo

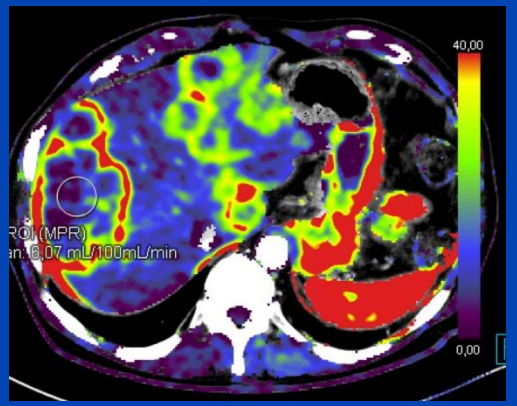
  (heavy cardiovascular comorbidities)

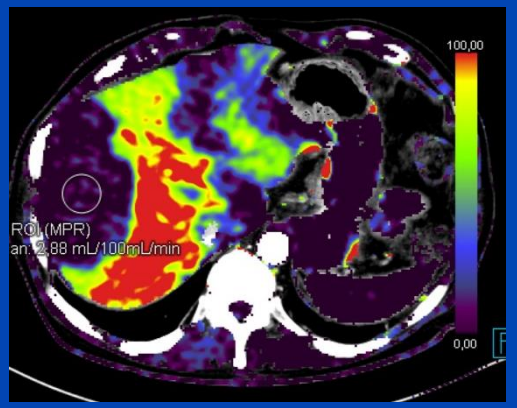
- CMO decision:

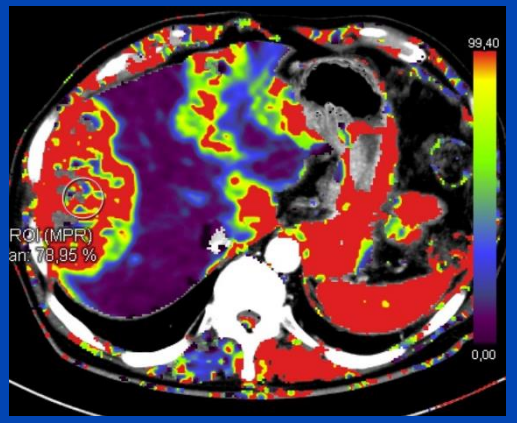
radioembolisation + short course radiothérapie + TME (rectum)

ESTIMATION OF ARTERIAL ENHANCEMENT BEFORE TRANSARTERIAL THERAPIES



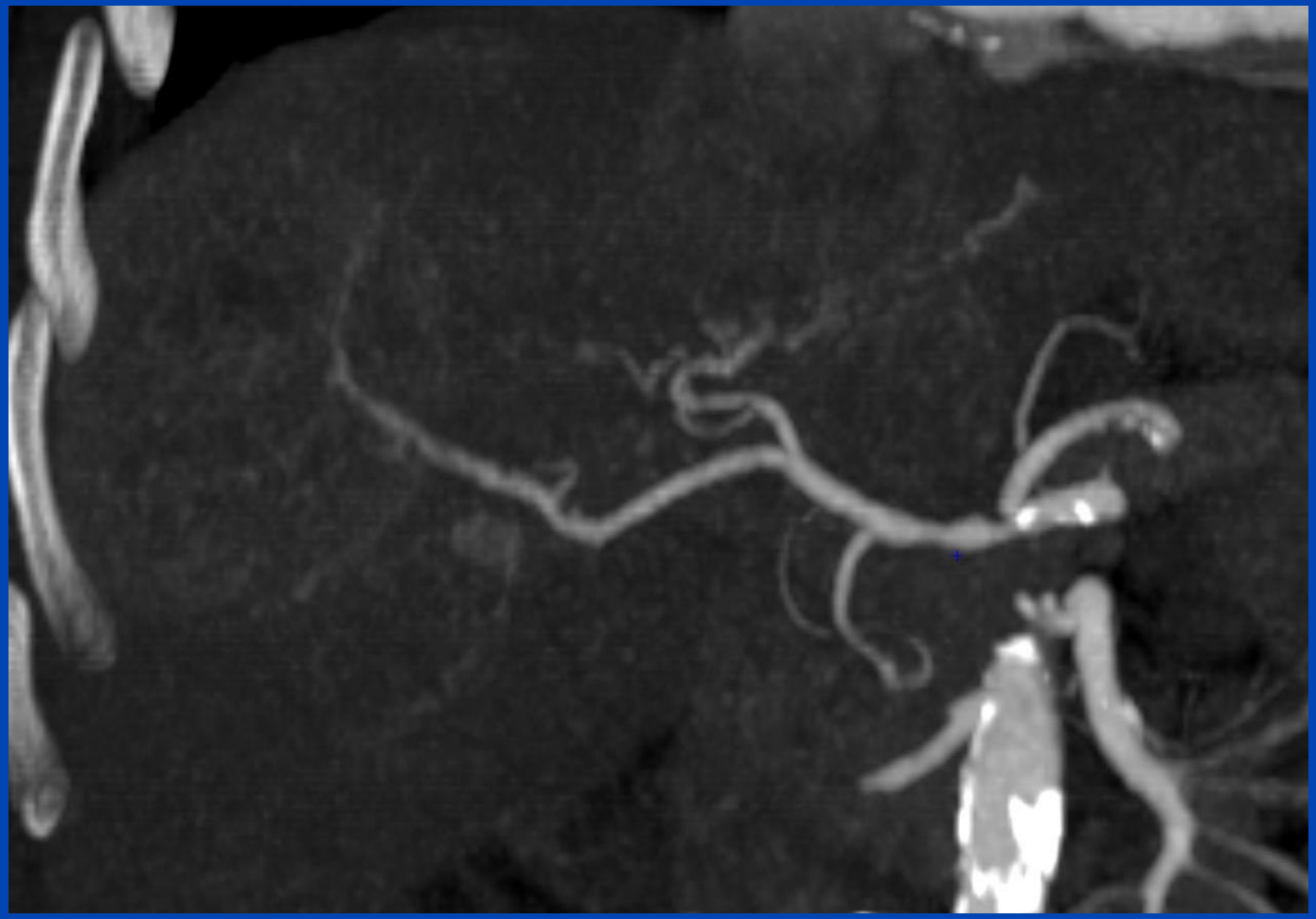


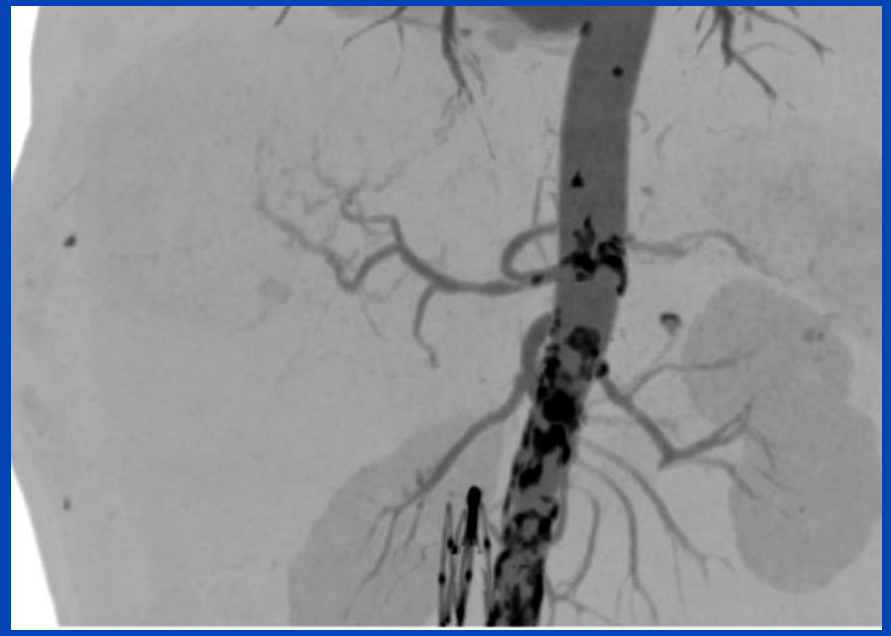




ROI/VOI	Legend	MIP	ALP	PVP	HPI	
[1] ROI		156,32	4,83	93,07	4,96	
[2] ROI		87,15	6,07	2,88	78,95	
[3] ROI		198,95	42,76	10,51	84,70	

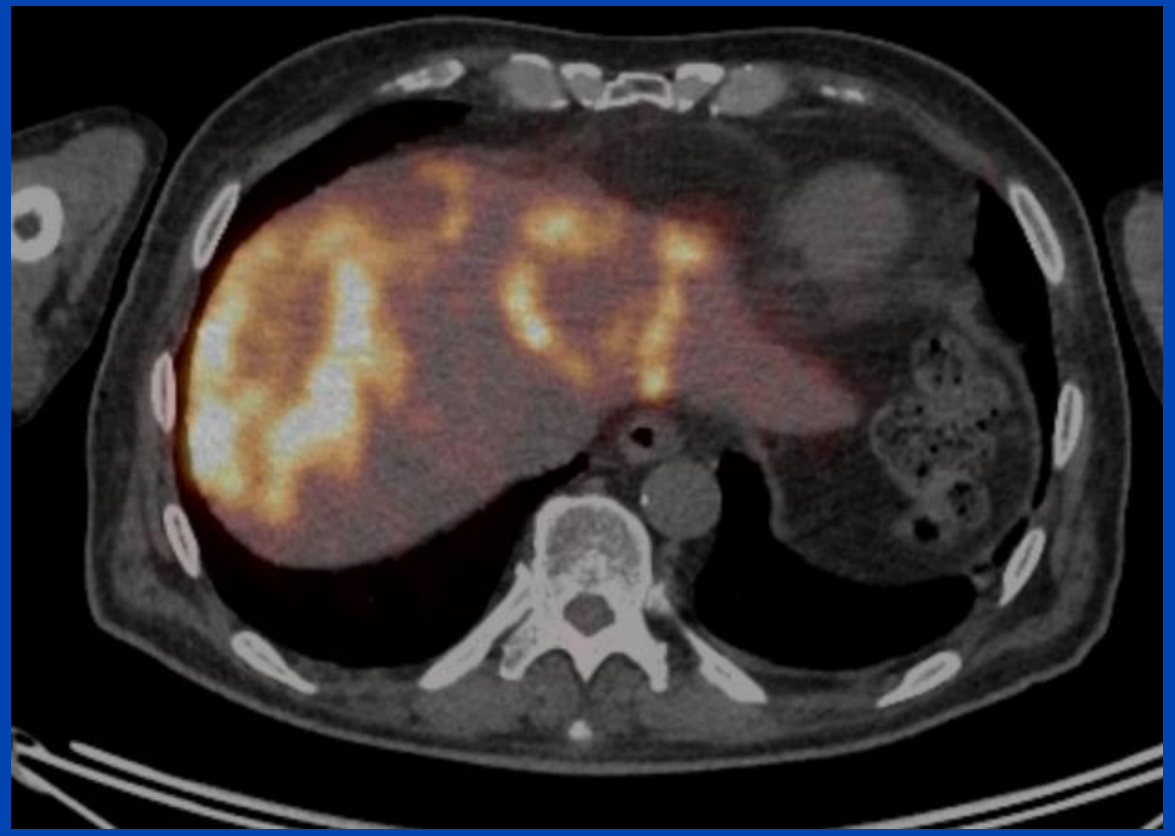
ESTIMATION OF ARTERIAL ENHANCEMENT BEFORE TRANSARTERIAL THERAPIES





ESTIMATION OF ARTERIAL ENHANCEMENT BEFORE TRANSARTERIAL THERAPIES

FDG PET-CT

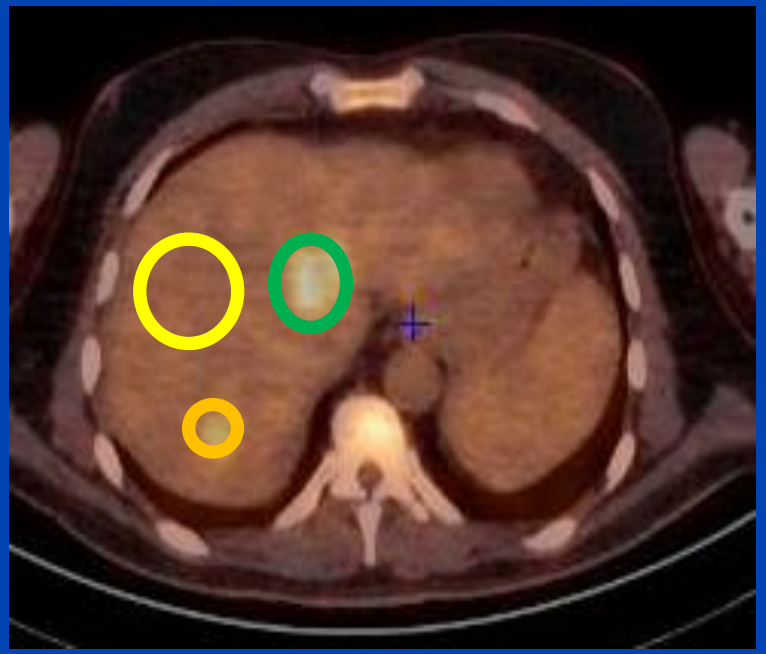


Yttrium 90 PET-CT

ESTIMATION OF ARTERIAL ENHANCEMENT BEFORE TRANSARTERIAL THERAPIES

- 2015: diagnosis of colon adenocarcinoma MSS of transverse colon (pT3N0)
- 2021: metachronous liver metastases
- Folfirinox converted to Folfox + Bevacizumab (digestive toxicity)
- 10/2022: progressive disease ➔ Folfiri + Bevacizumab
- Progressive disease in the liver ➔ radioembolization

ESTIMATION OF ARTERIAL ENHANCEMENT BEFORE TRANSARTERIAL THERAPIES



PERFUSION CT : MANY APPLICATIONS

- Early detection of liver tumors
- Prognosis assessment
- Monitoring therapeutic effects
- Prediction of response to treatment

…. but very radiating (7.3 to 30.6 mSv).

Kim SH et al. Radiology. 2014;272(2):322-44.
Kartalis N et al. Eur J Radiol. 2017;97:101-9.
Zhong L et al. World J Gastroenterol. 2009;15(8):907-11

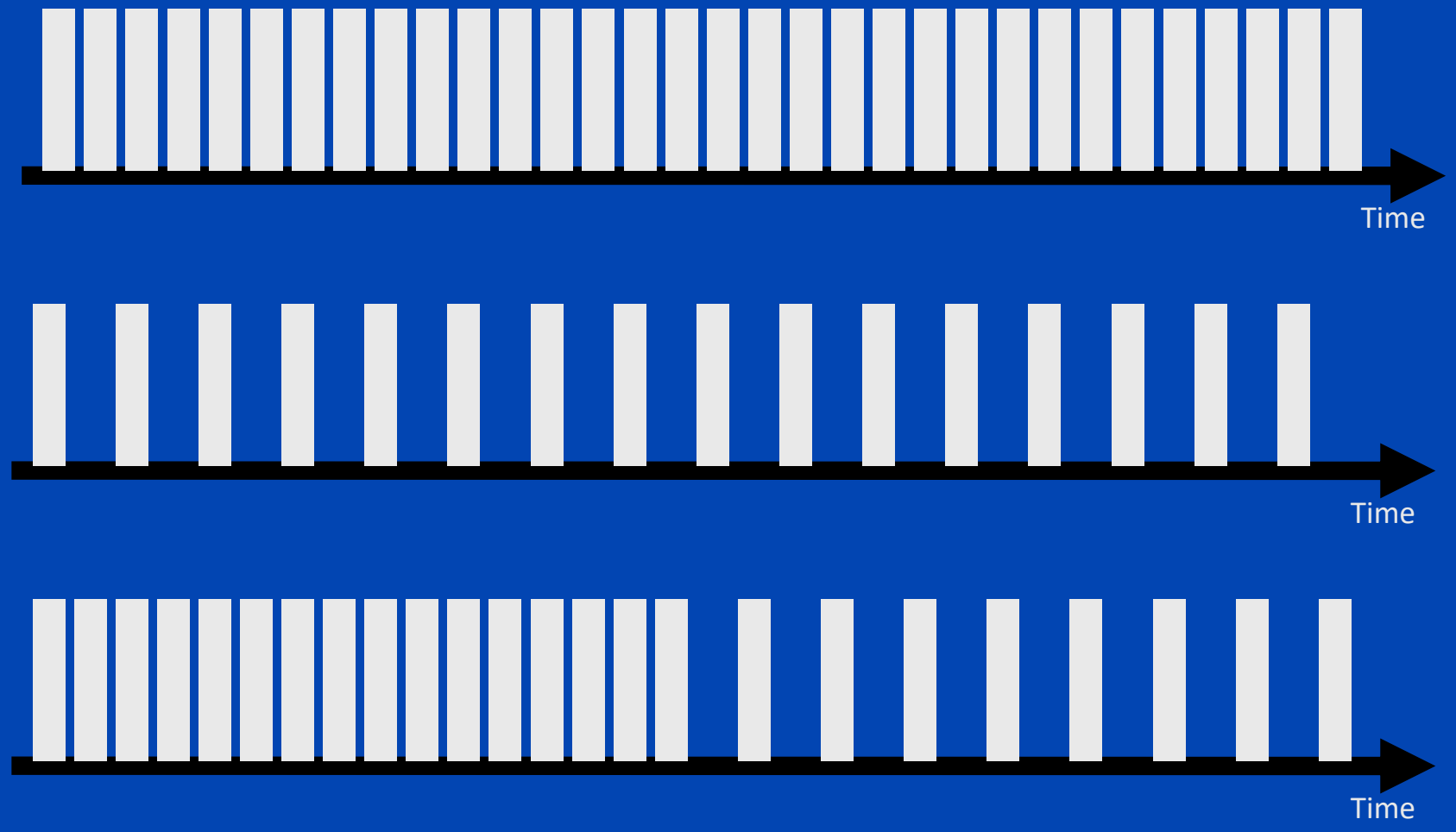
DOSE REDUCTION

- Reduction kV or mAs ➞ increase of noise
- Iterative reconstruction algorithms
- « Whole-liver quantitative color mapping displays »

$$AEF = ((HUa - HUu)/(HUp - HUu))x100$$

Radiology. 2014;272:322-344

DOSE REDUCTION



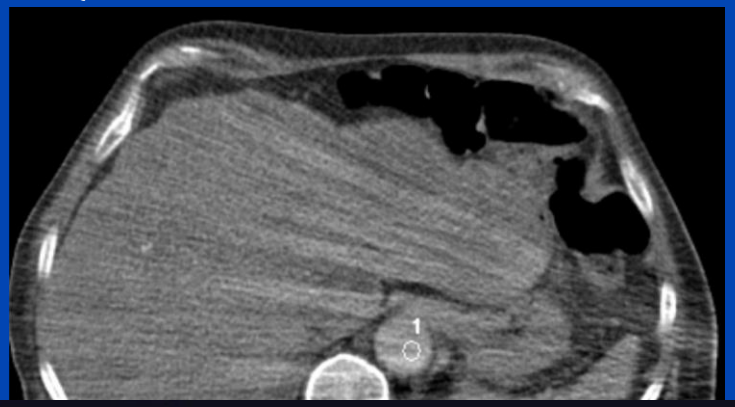
EVALUATION OF VIRTUAL REDUCTION DOSE PROTOCOLS OF PERFUSION LIVER CT

AUTHOR: DELHAYE CORENTIN, M.D.
PROMOTOR: VOUCHE MICHAËL, M.D., PHD.

- Monocentric retrospective study (Jules Bordet Institute)
- Including all patients undergoing a liver perfusion CT performed on CT Siemens Somatom Force between 08/2015-12/2018
- Purpose: to evaluate the variation of quantitative vascular parameters of whole-liver pCT when virtually increasing the sampling interval between acquisitions.

- Benefit : theoretical dose reduction up to 66%.

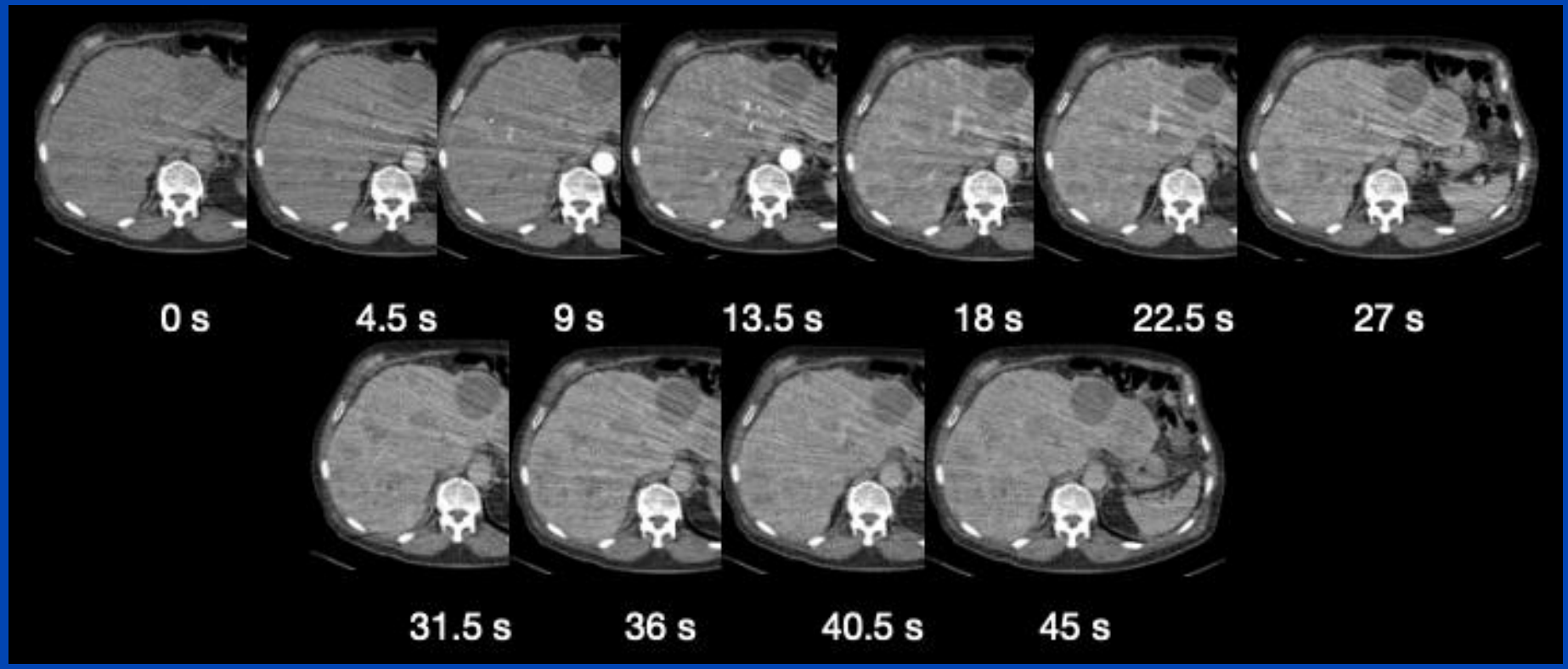
TEST-BOLUS ACQUISITION



100 kV, 40 mAs, 15 slides of 10 mm thickness every 2 seconds immediately after intravenous

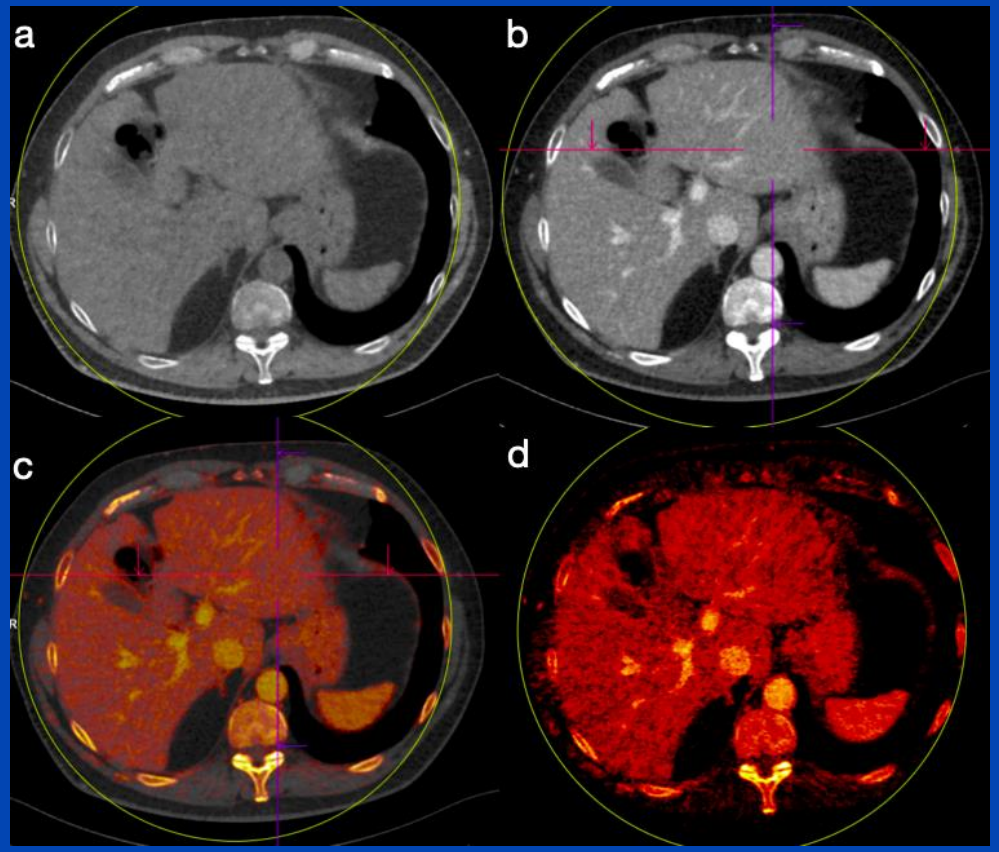
injection of 12 ml of iomeprol 400 mg Iodine/ml (Iomeron 400) at an injection rate of 4.5

PERFUSION ACQUISITION



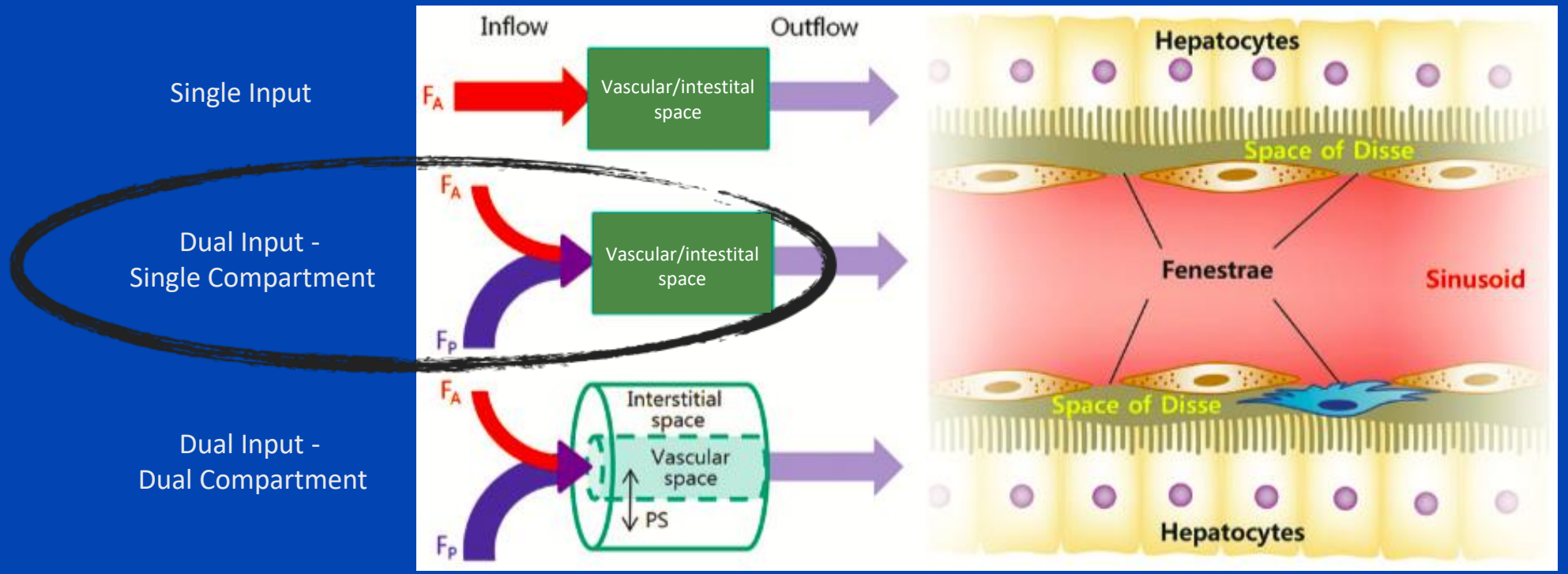
80 kV, 100 mAs, 30 helical acquisitions of 240 mm length every 1.5 second immediately after intravenous injection of 50 ml of iomeprol 400 mg Iodine/ml (Iomeron 400) at an injection rate

PORTO-VENOUS ACQUISITION



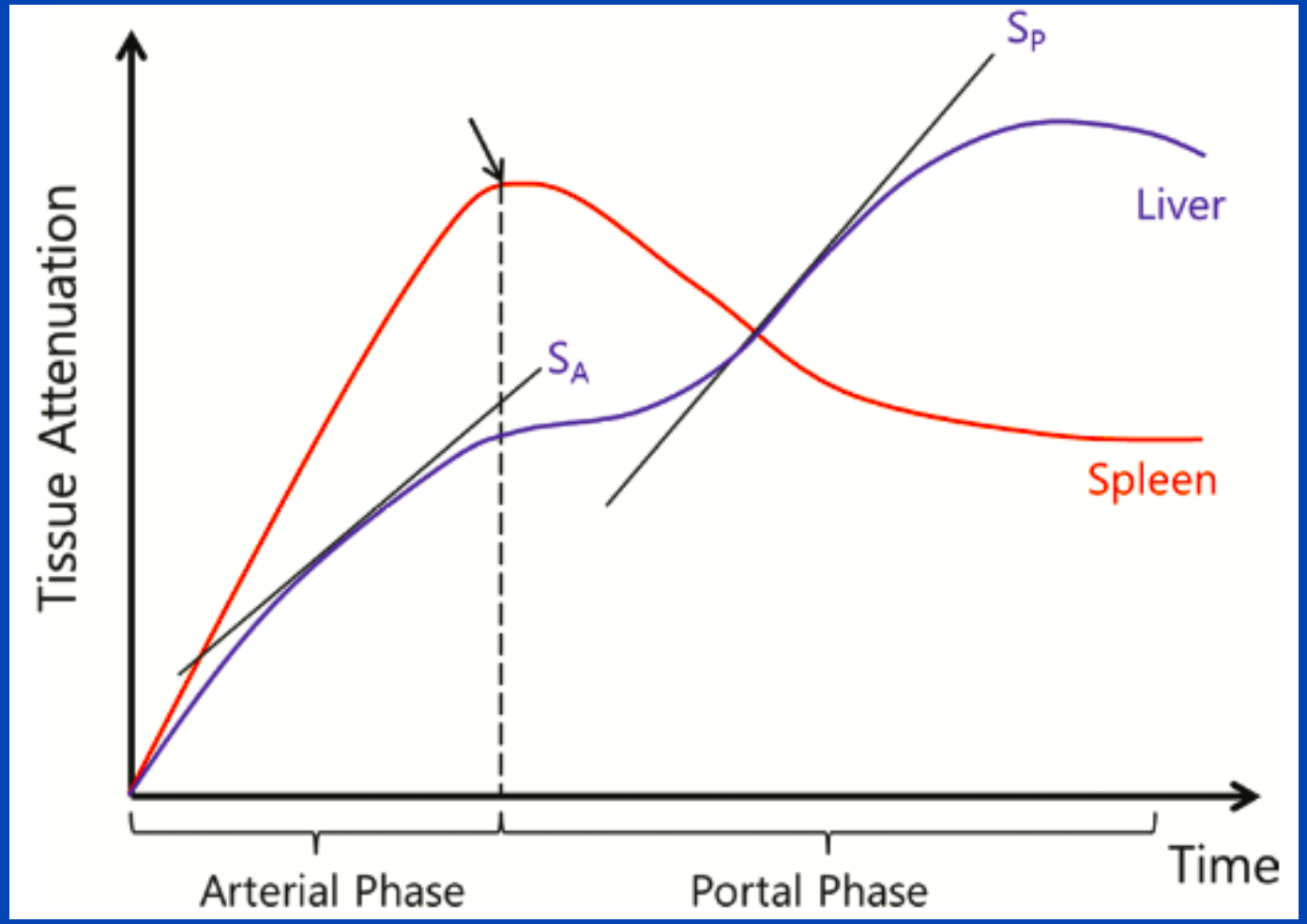
90/150 kV, 90/50 mAs, breath-hold

MATERIAL AND METHODS - IMAGE ANALYSIS



Adapated from Kim SH et al. Radiology. 2014;272(2):322-44

MATERIAL AND METHODS - IMAGE ANALYSIS

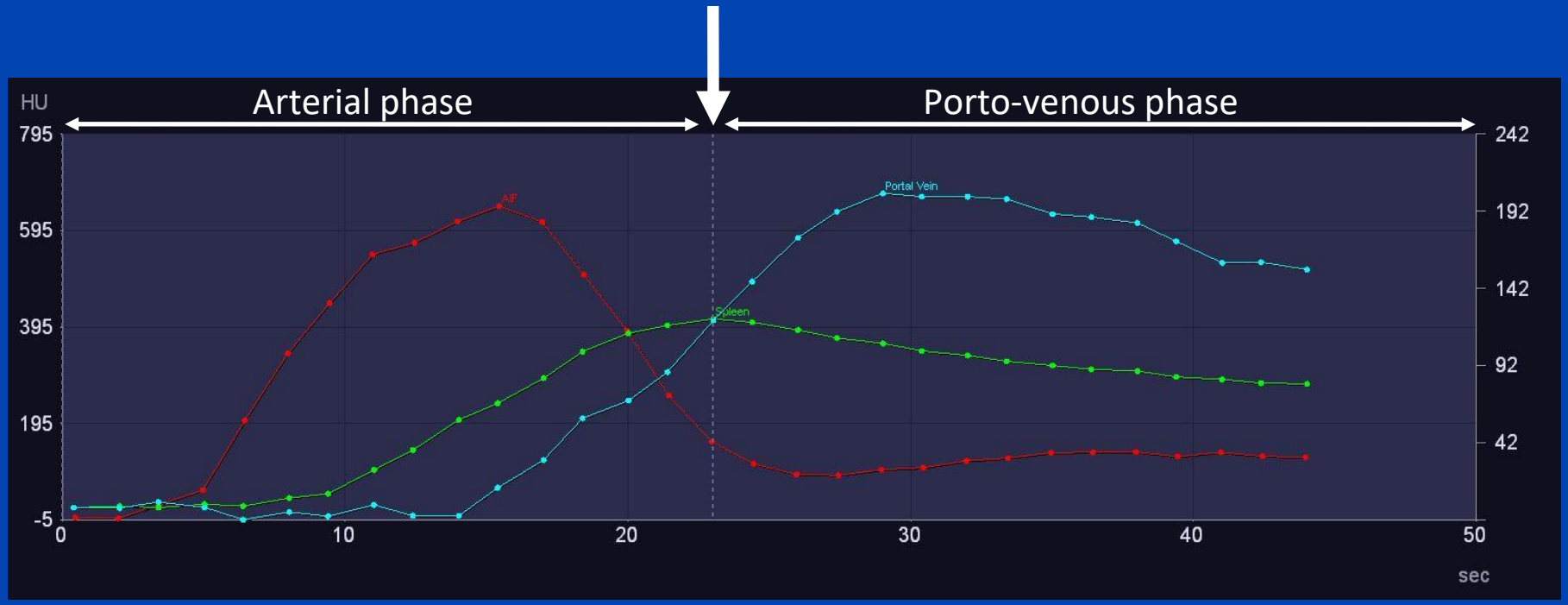


Kim SH et al. Radiology. 2014;272(2):322-44

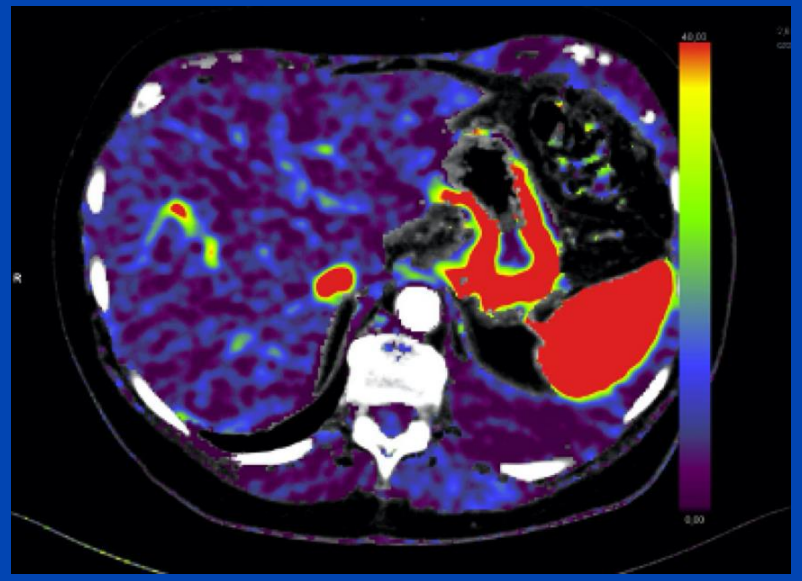
MATERIAL AND METHODS - IMAGE ANALYSIS

- Imported in Syngo.Via software - Perfusion Body CT
  - Respiratory motion correction, noise reduction, segmentation
  - ROI placement into upper abdominal aorta, spleen, and portal vein
  - ROI placement into liver parenchyma (no tumor, unique or multiple tumor)

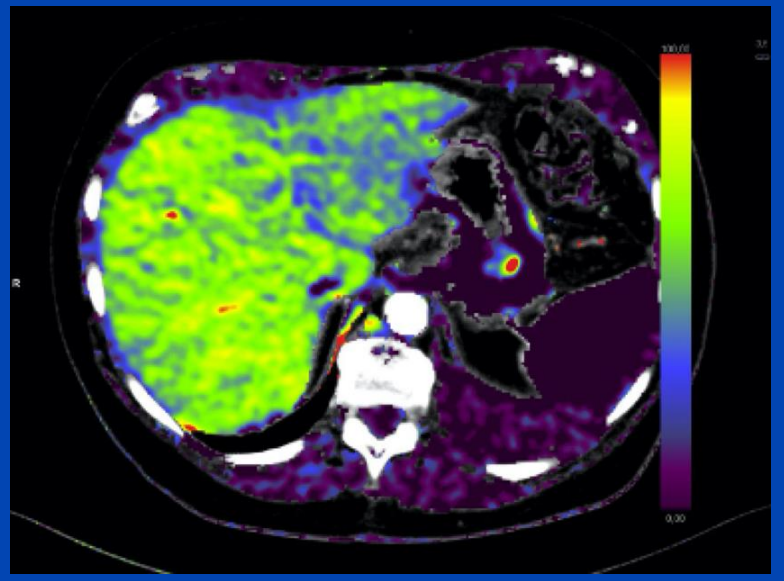
MATERIAL AND METHODS - IMAGE ANALYSIS



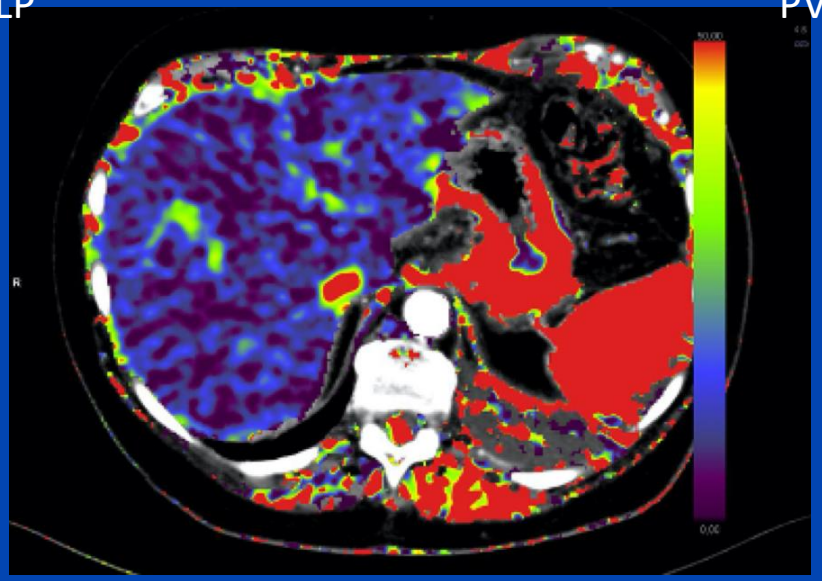
MATERIAL AND METHODS - IMAGE ANALYSIS



ALP



PVP



HPI

MATERIAL AND METHODS - IMAGE ANALYSIS

- Data collected
  - Vascular ROI: time to peak (TTP) (s)
  - Parenchymal ROI:
    - Arterial liver perfusion (ALP) (ml/100ml/min)
    - Portal venous perfusion (PVP) (ml/100ml/min)
    - Hepatic perfusion index (HPI) (%)

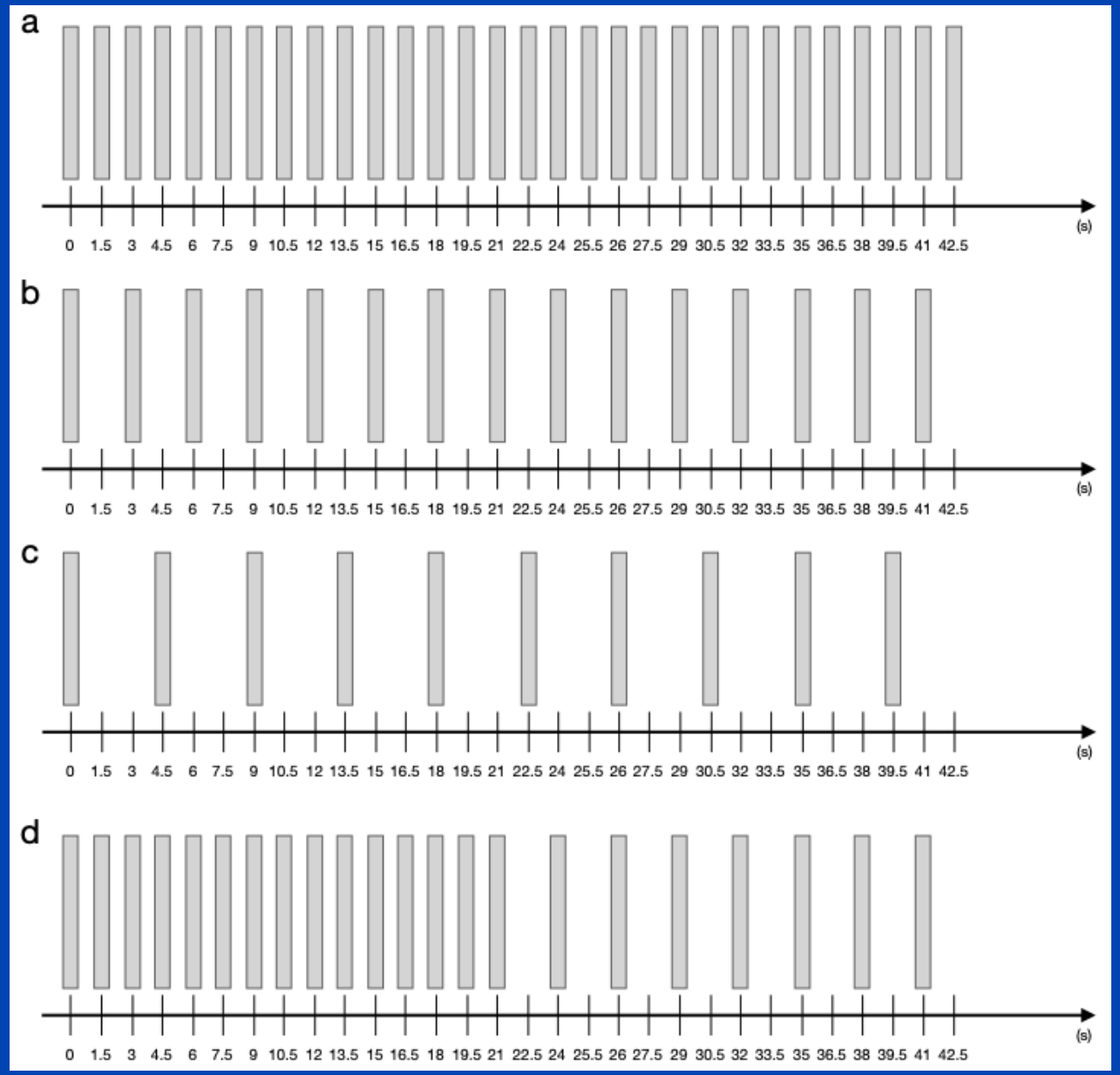
MATERIAL AND METHODS – VIRTUAL TEMPORAL SPACING

Full-dose

Half-dose

Third-dose

Portal-half-dose



RESULTS - PATIENTS

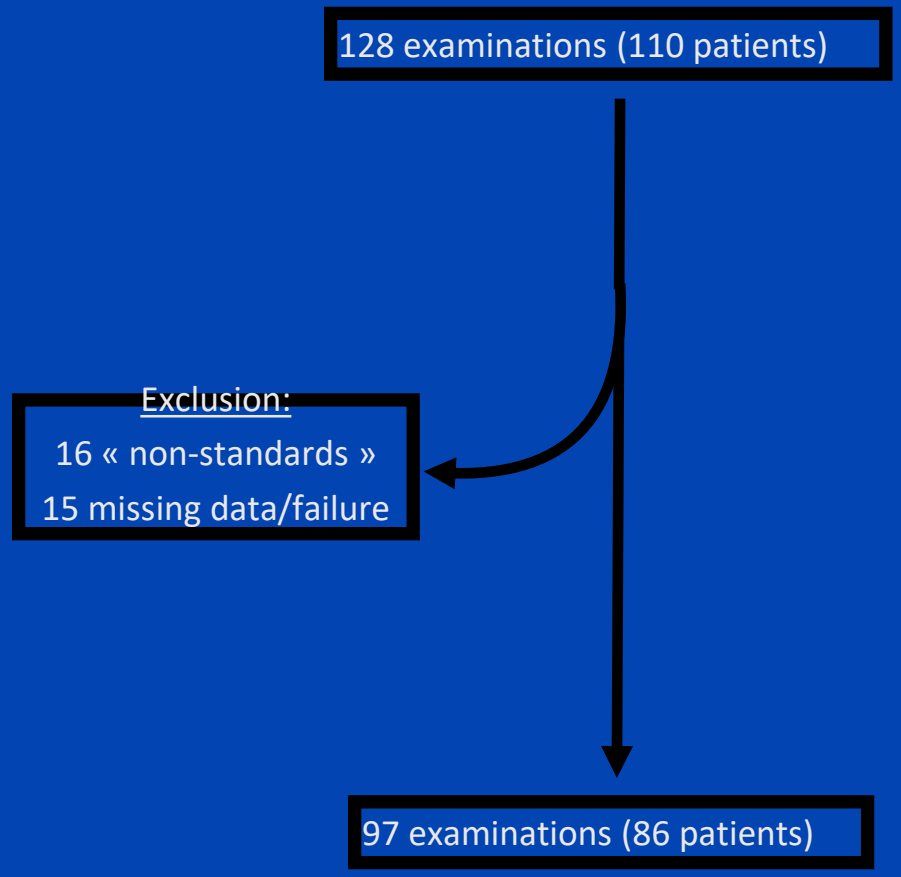
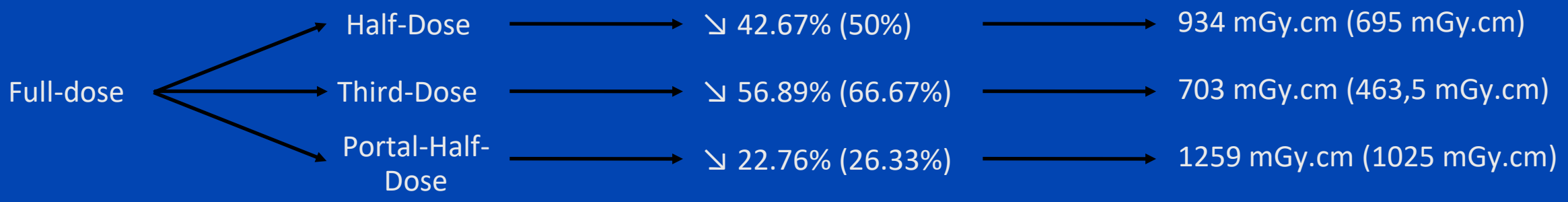


Table 1. Population characteristics	
No. of examination (No. of patients)	97 (86)
Gender	
Male	52
Female	45
Age at examination (mean ± SD)	65 ± 12
Hepatic Lesion	
None	18
Unique	39
Multiple	40
Primary Neoplasm	
Hepatocellular carcinoma	22
Intrahepatic cholangiocarcinoma	10
Colorectal cancer	30
Breast cancer	16
Neuroendocrine tumor	10
Other	9
Vascular infiltration/thrombosis	
Yes	17
No	80
Previous hepatic treatment	
None	64
Yes	33
Surgery	13
Transarterial chemoembolization	3
Transarterial radioembolization	9
Radiofrequency ablation	11
Peptide receptor nucleide therapy	2
Portal embolization	1
Bland embolization	1

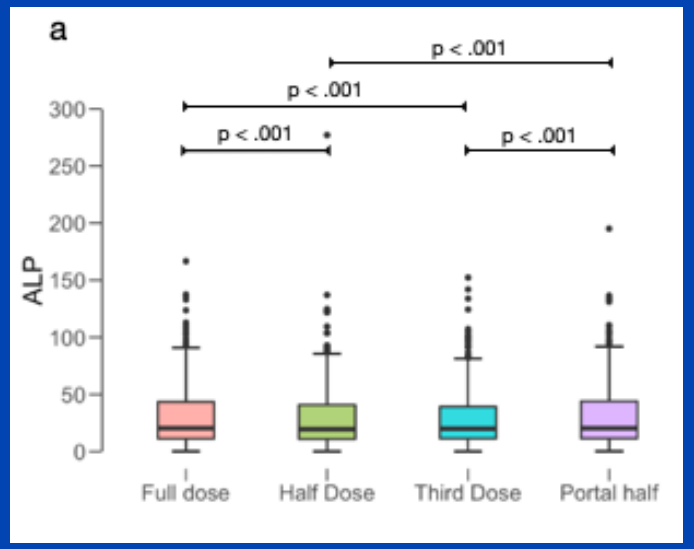
RESULTS - DOSE

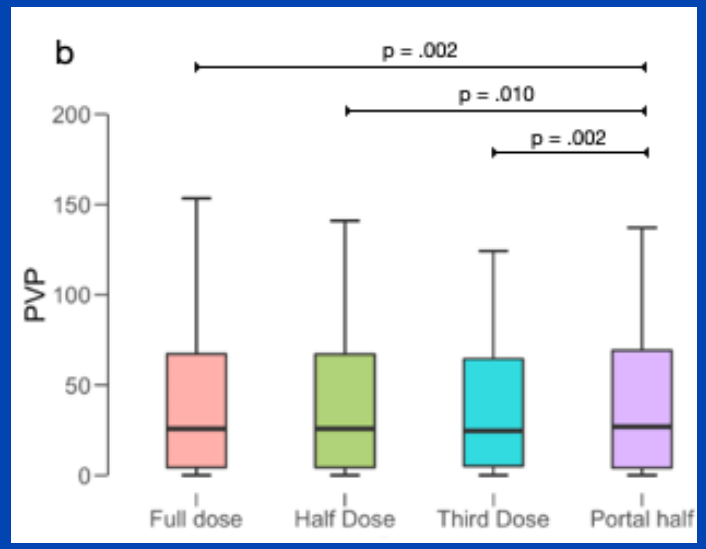
- Entire examination
  - DLP: 1629.75 ± 110.87 mGy.cm
  - EED: 24.25 ± 1.66 mSv
- Liver pCT solely
  - DLP: 1390.77 ± 0.42 mGy.cm
  - EED: 20.86 ± 0.01 mSv

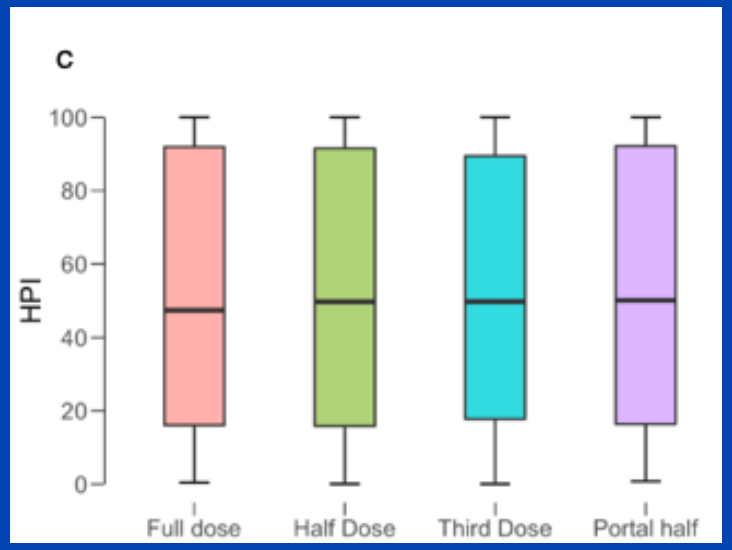
ADULTES	$CTDI_{vol}$ (mGy)		DLP (mGy.cm)	
	DRL	Valeur cible	DRL	Valeur cible
Abdomen	**10**	8	**490**	380
Abdomen – complet	**-**	-	**570**	420
Thorax-abdomen	**8,5**	7	**550**	450
Thorax-abdomen – complet	-	-	**800**	600



RESULTS - QVP - INTER-GROUP VARIABILITY - ENTIRE POPULATION

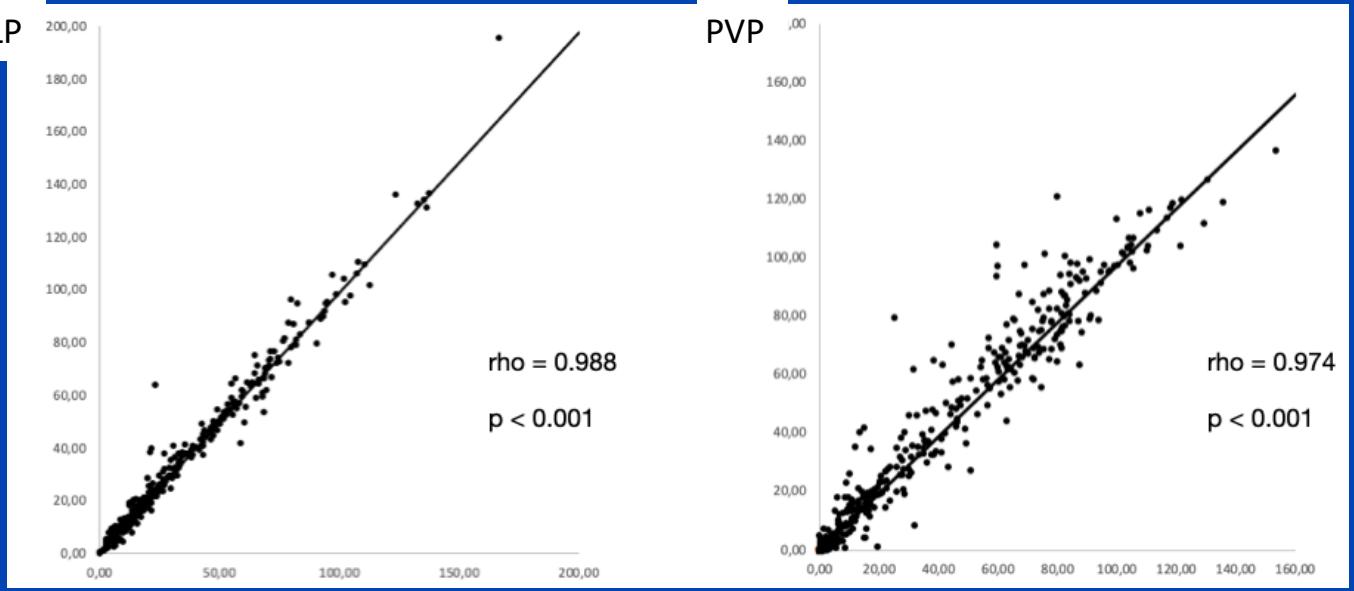






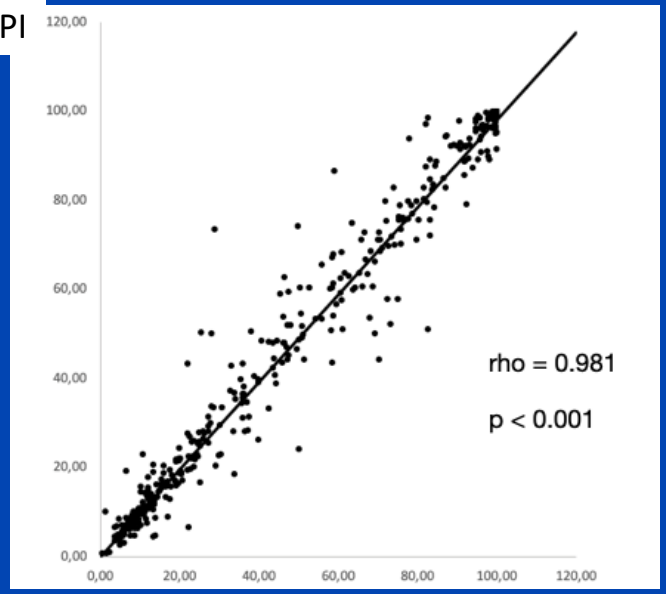
RESULTS - QVP - CORRELATION AND AGREEMENT- ENTIRE POPULATION - FD/PHD

ALP

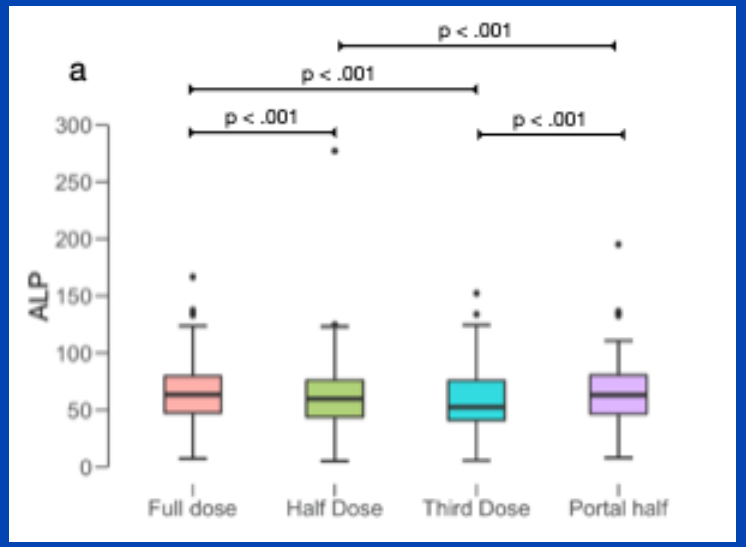


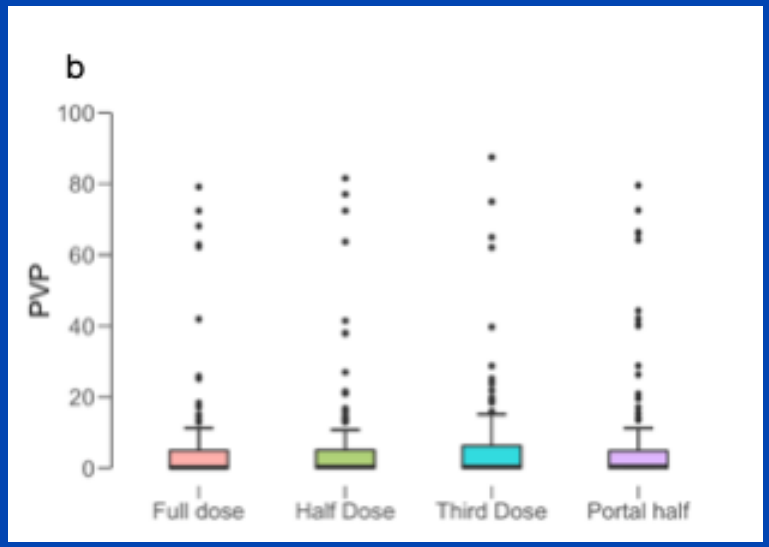
PVP

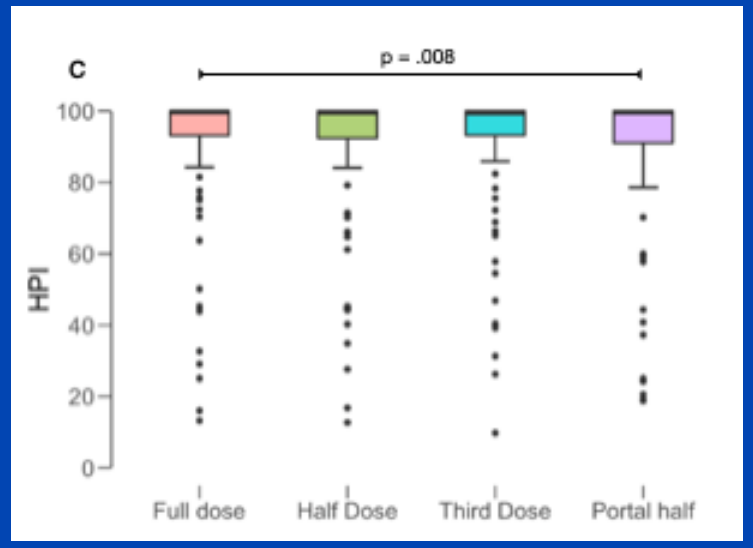
HPI



RESULTS - QVP - INTER-GROUP VARIABILITY - HYPERVASCULAR

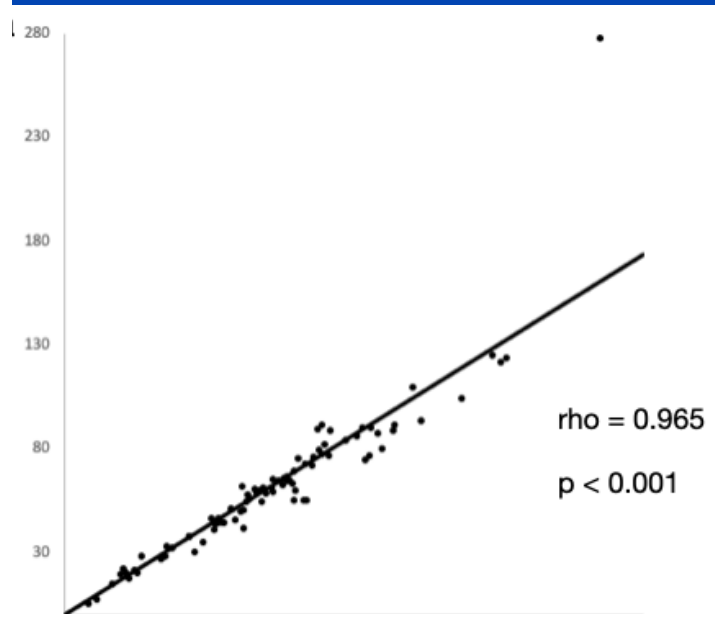




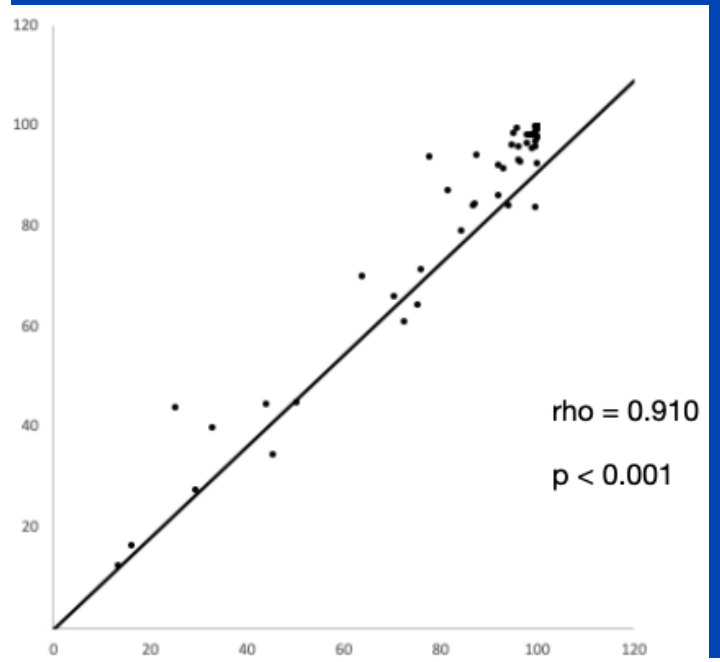


RESULTS - QVP - CORRELATION AND AGREEMENT- HYPERVASCULAR - FD/HD

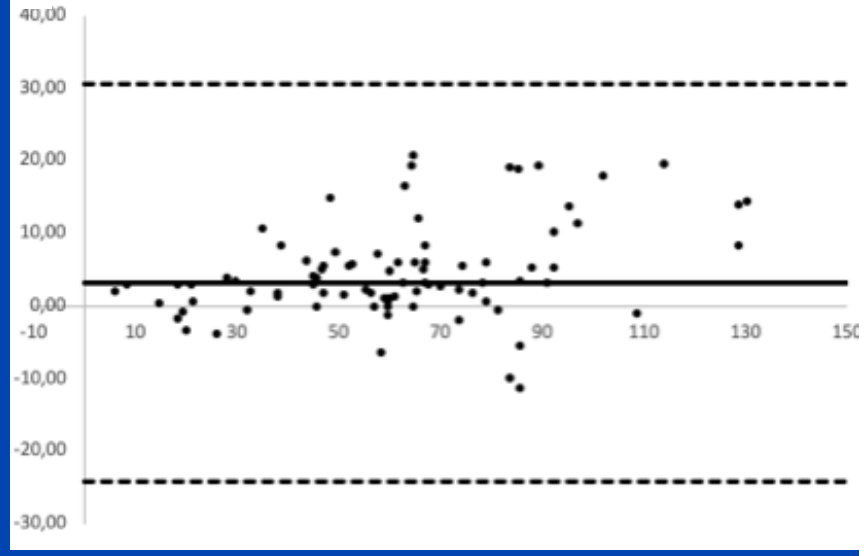
ALP

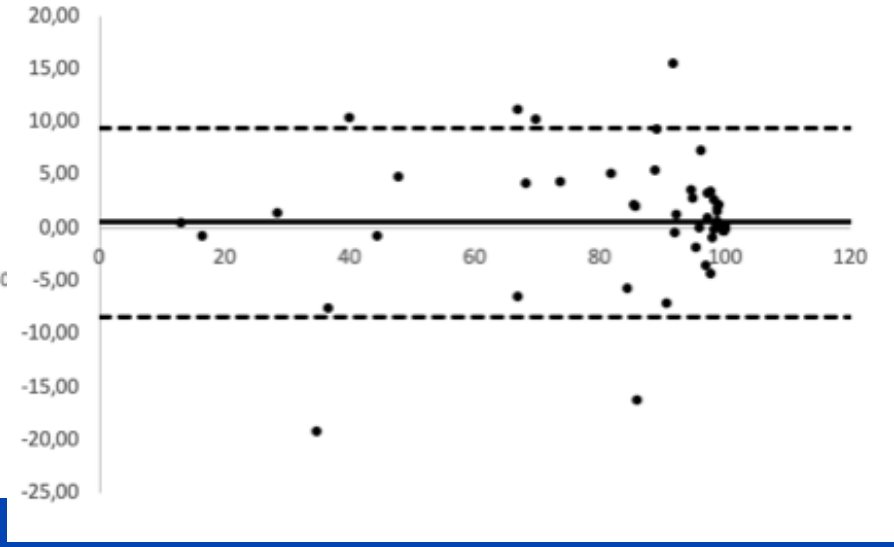


HPI



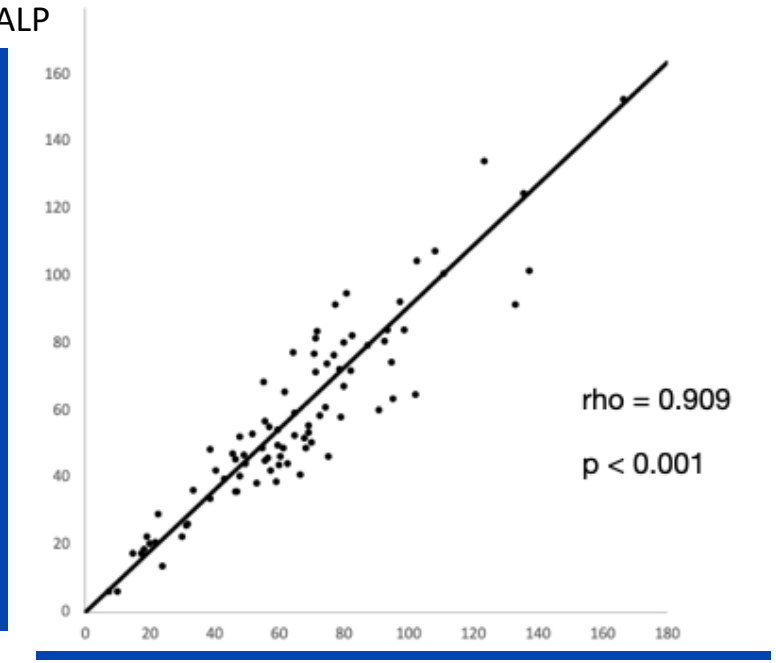
C



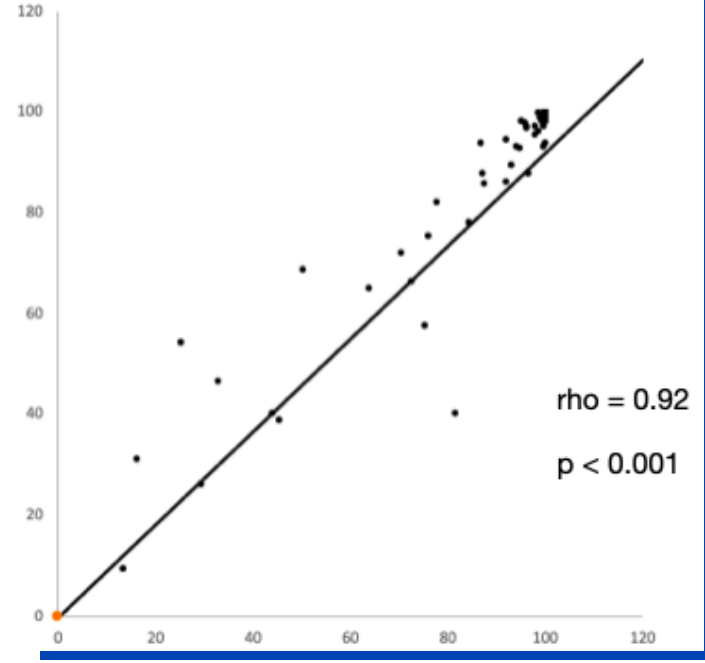


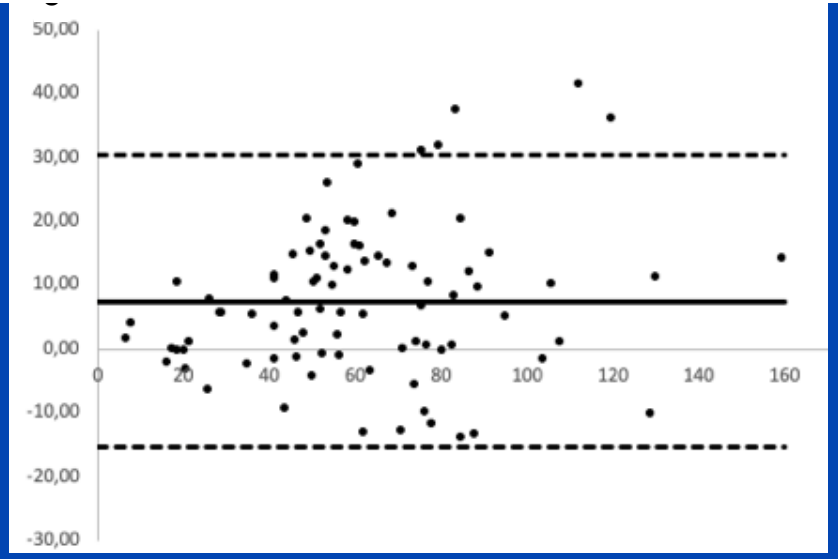
RESULTS - QVP - CORRELATION AND AGREEMENT- HYPERVASCULAR - FD/TD

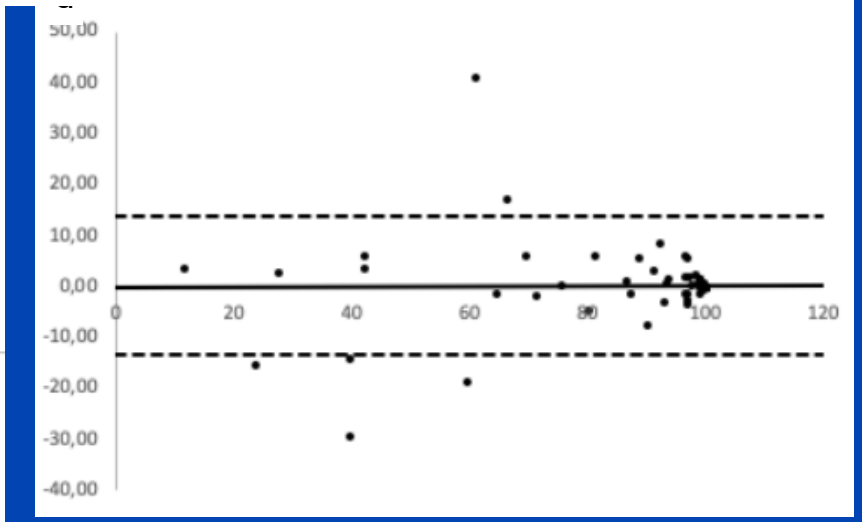
ALP



HPI







CONCLUSIONS

- Sampling interval could be extended up to 3 seconds during the second part of the perfusion CT.
- Caution should be taken in a general population in which we don’t recommend increased sampling interval.
- For follow-up, sampling interval can be extended up to 3 seconds during the entire perfusion CT.

PERFUSION LIVER CT

- ***Non-invasive methods for screening, imaging and treatment? YES***
- ***Valuable alternative to MRI in case of contraindication or low availability***
- ***But…***
- ***Should be limited to selected cases***
- ***Refinement in acquisition procotols and radiation dose reduction are requested***

THANK YOU FOR YOUR ATTENTION

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ULB
iris