Memorial Sloan Kettering
Cancer Center

Liver perfusion imaging for cirrhosis, HCC, and colorectal cancer liver metastases

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Dual blood supply

	Portal vein	Hepatic artery
Normal liver	80%	20%
HCC	37%	63%

Li et al. (2011) *Hepatobiliary Pancreatic Dis. Int*. 10(1): 43-9

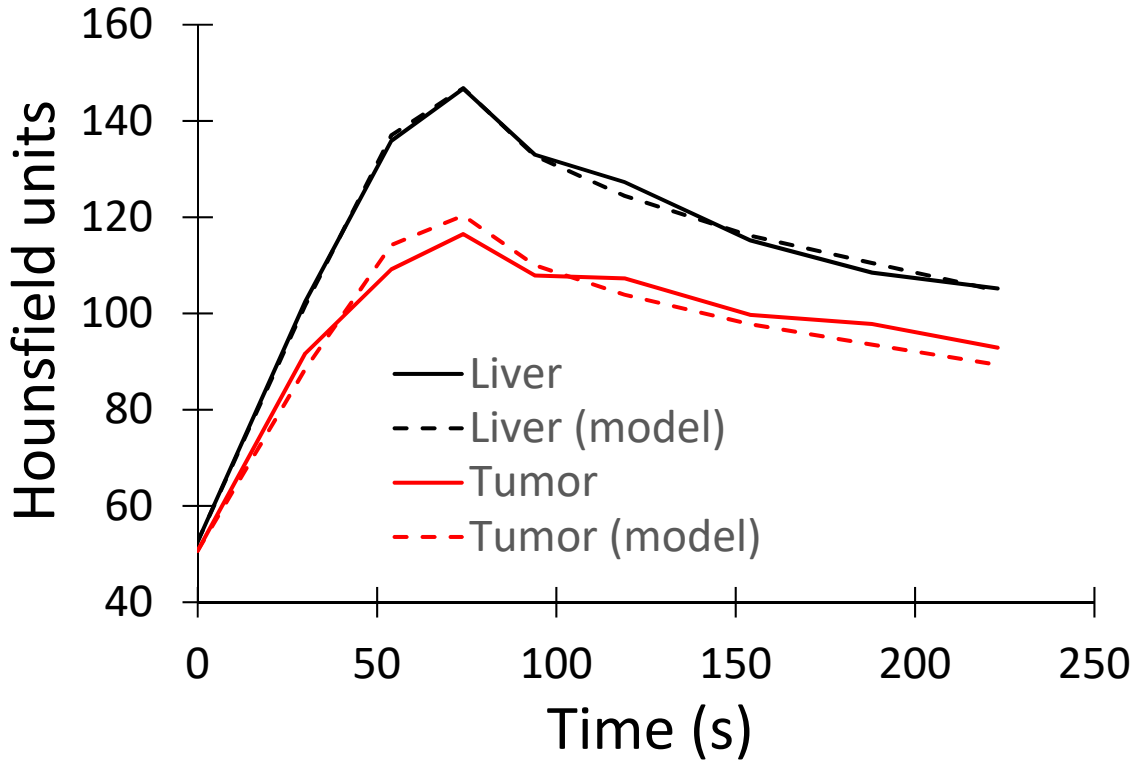
Liver perfusion imaging

- Determine hepatic artery versus portal vein supply to liver and liver tumors.
- **Cirrhosis**: Shift from portal vein to hepatic artery supply.
- **Tumor vascularity**: HCC recruits arterial blood supply.
- **Response to arterially directed therapies**: TAE, TACE, Y90

How many phases are needed to get perfusion parameters?

- Traditionally, liver perfusion involves scanning at ~ 20 time points.
- How much information can we get from just 3 time points?

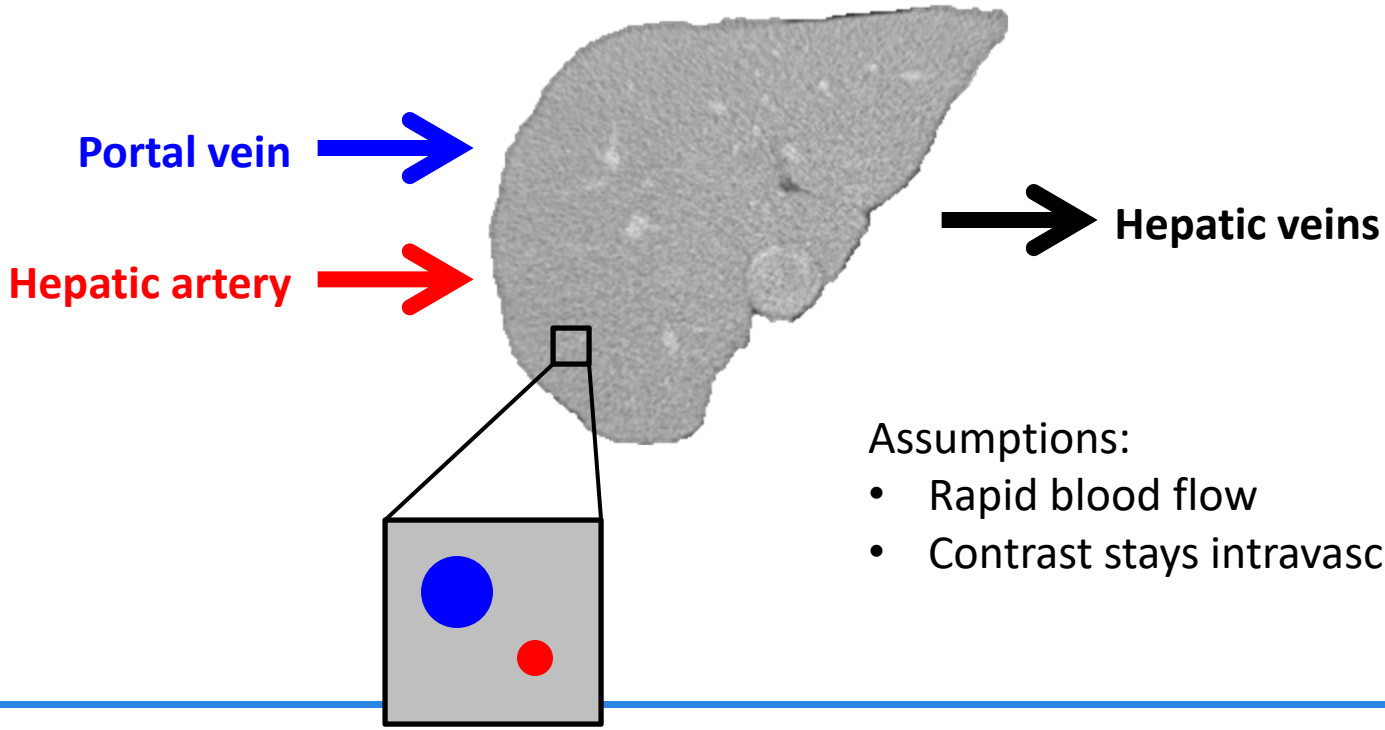
Three phases is sufficient for liver perfusion



Enhancement of liver tumor in a pig (9 phases).

Simple perfusion model (3 phases, 2 parameters) fits actual enhancement curves.

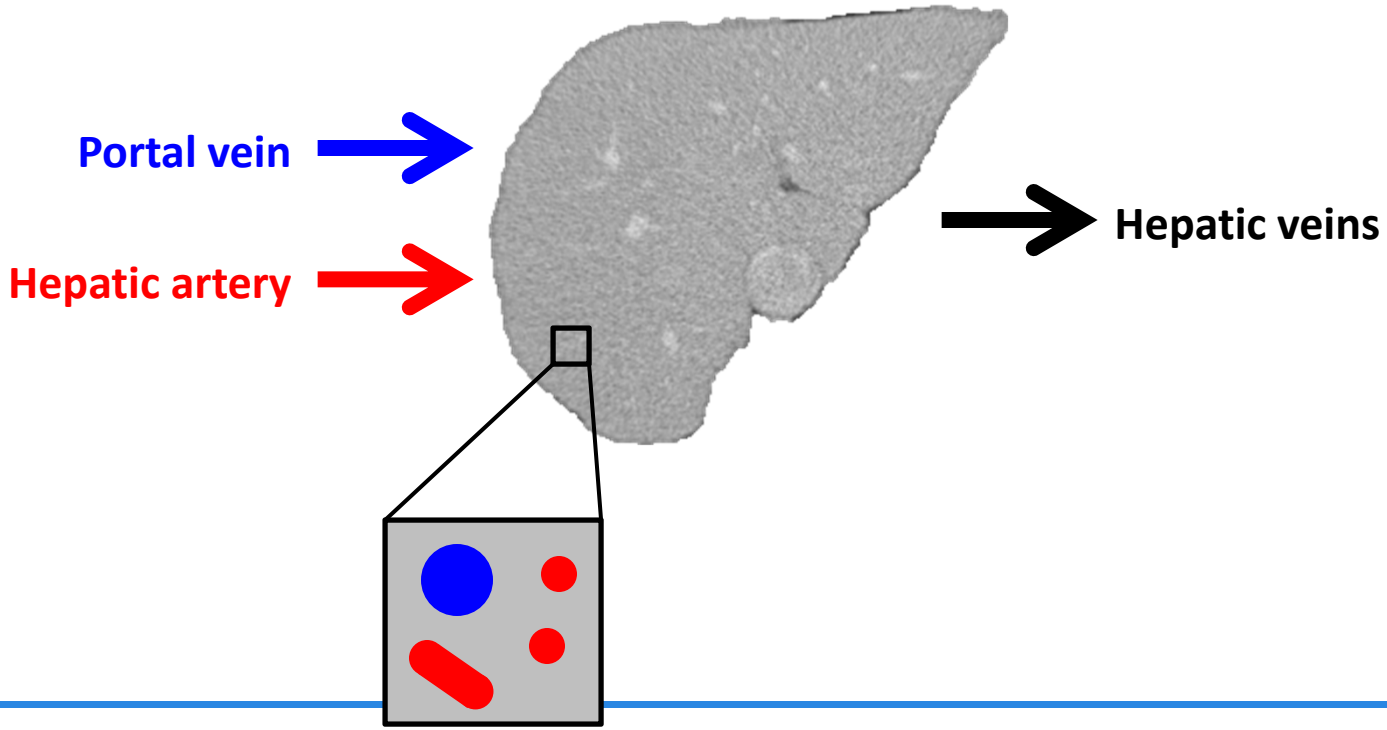
Color liver perfusion imaging



Assumptions:

- Rapid blood flow
- Contrast stays intravascular

Color liver perfusion imaging

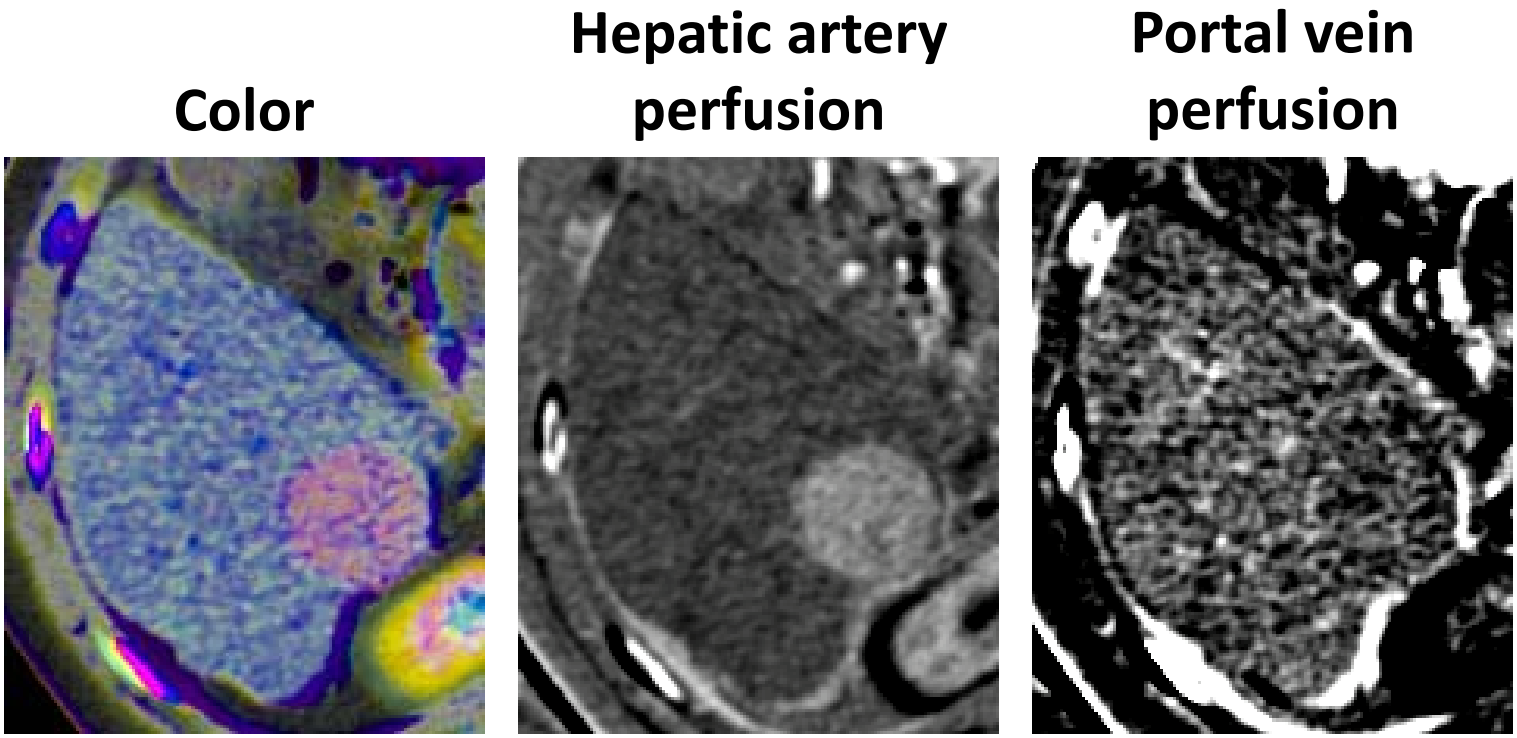


Perfusion measurements from triphasic CT

Parameter	Interpretation	Formula
Hepatic artery coefficient	Hepatic artery perfusion	$\frac{v_1(x_3-x_2)+v_2(x_1-x_3)+v_3(x_2-x_1)}{a_1(v_2-v_3)+a_2(v_3-v_1)+a_3(v_1-v_2)}$
Portal vein coefficient	Portal vein perfusion	$\frac{a_1(x_3-x_2)+a_2(x_1-x_3)+a_3(x_2-x_1)}{a_1(v_3-v_2)+a_2(v_1-v_3)+a_3(v_2-v_1)}$
Arterial enhancement fraction	$\frac{\text{Hepatic artery perfusion}}{\text{Total perfusion}}$	$\frac{x_2-x_1}{x_3-x_1}$

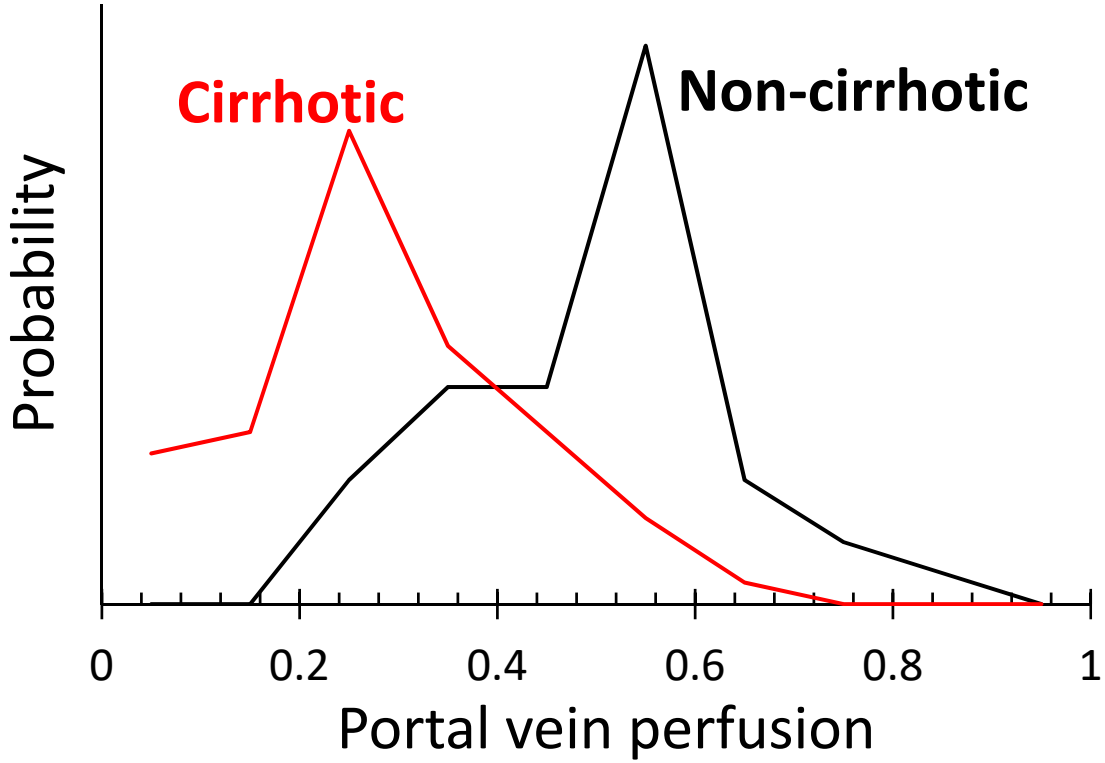
a_1, a_2, and a_3: hepatic artery Hounsfield units in the non-contrast, arterial, and portal venous phases
v_1, v_2, and v_3: portal vein Hounsfield units in the non-contrast, arterial, and portal venous phases
x_1, x_2, and x_3: liver lesion Hounsfield units in the non-contrast, arterial, and portal venous phases.

HCC: Increased hepatic artery perfusion



Boas FE et al (2015) *Journal of Digital Imaging*. 28: 213-23.

Cirrhosis: Decreased portal perfusion

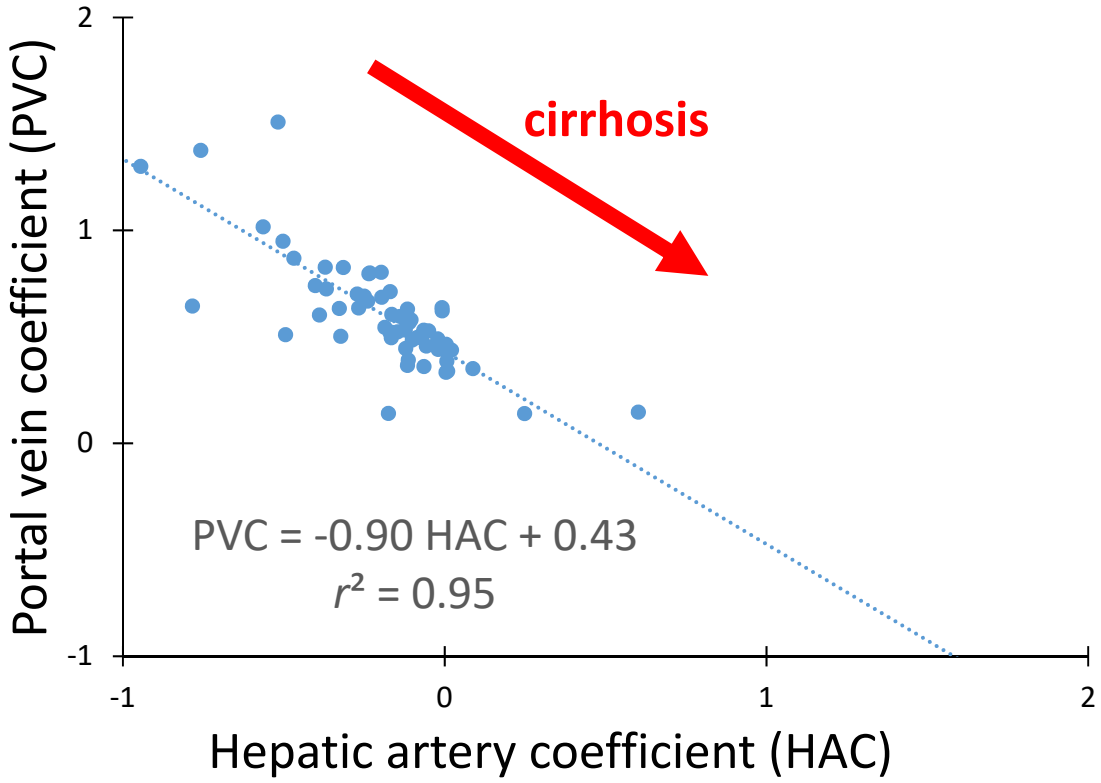


105 patients

$p = 4 \times 10^{-12}$

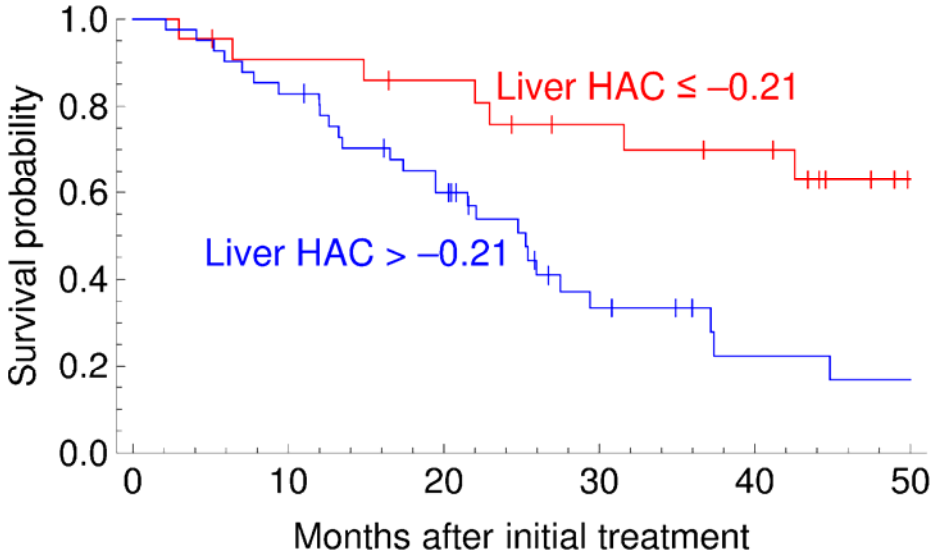
Boas FE et al (2015) *Journal of Digital Imaging*. 28: 213-23.

Hepatic arterial buffer response



PVC versus HAC of background liver in 63 HCC patients

Background liver perfusion predicts survival



- Liver HAC predicts survival after embolization of HCC (p=0.015).
- In our patient population (mostly Child Pugh A5 or A6), Child Pugh score did not predict survival (p=0.83).

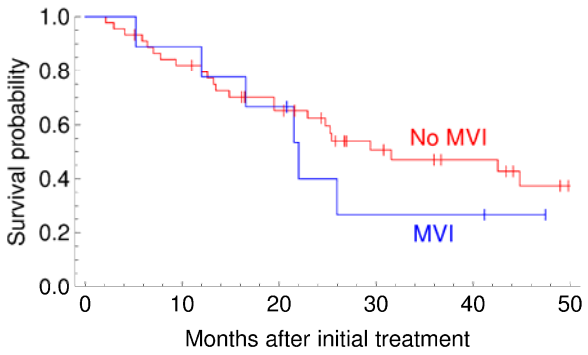
Normal bilirubin ≠ Normal liver.

Liver perfusion detects early cirrhotic changes that predict survival.

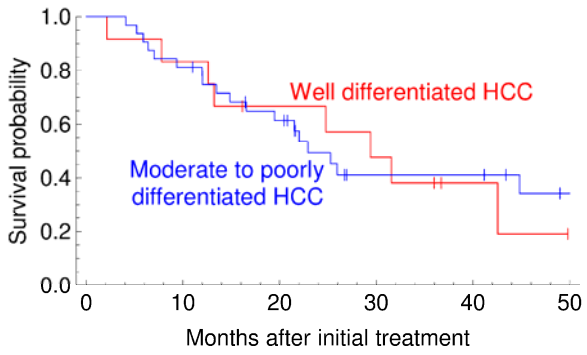
HCC tumor perfusion predicts survival

Overall survival after embolization of HCC:

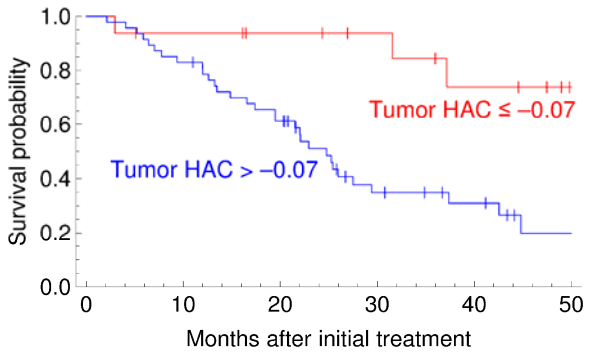
Microvascular invasion
(*p*=0.45)



Degree of differentiation
(*p*=0.87)



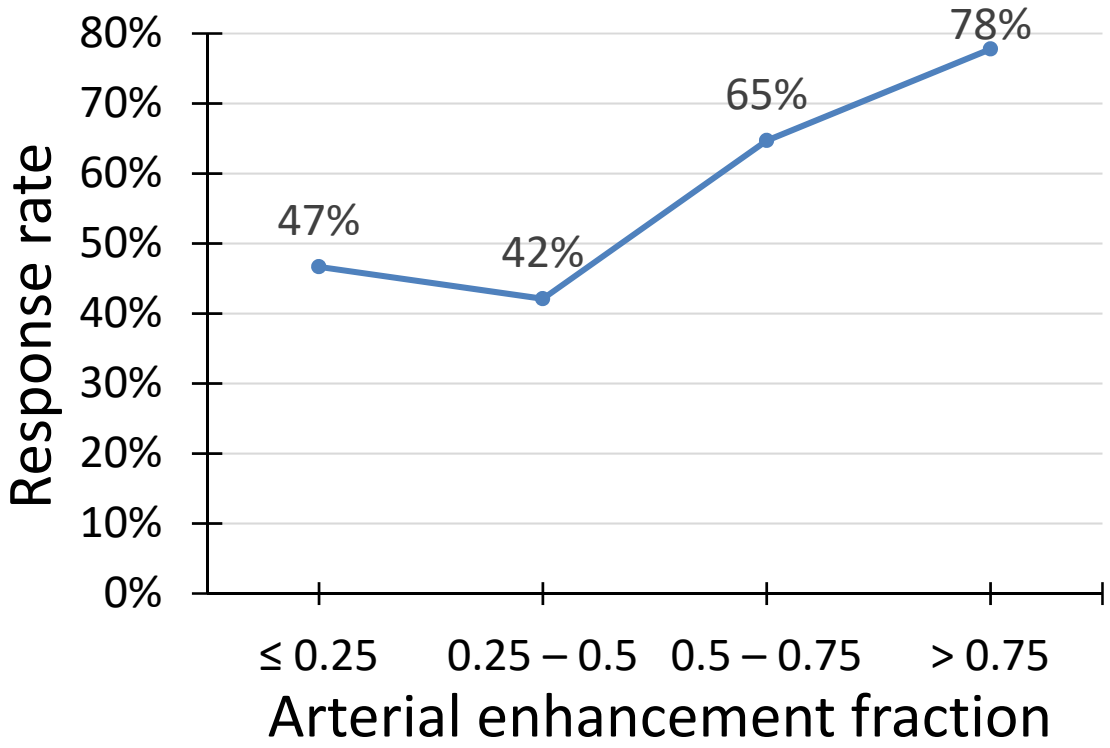
Hepatic artery coefficient
(*p*=0.011)



Colorectal liver mets: Response to Y-90

Parameter	Non-responders	Responders	p
Arterial phase enhancement (HU)	11 ± 11	14 ± 14	0.32
Portal venous phase enhancement (HU)	29 ± 17	26 ± 19	0.64
Hepatic artery coefficient (HAC)	–0.025 ± 0.039	–0.018 ± 0.069	0.62
Portal vein coefficient (PVC)	0.24 ± 0.15	0.22 ± 0.14	0.66
Arterial enhancement fraction (AEF)	0.29 ± 0.59	0.74 ± 1.02	0.038 *

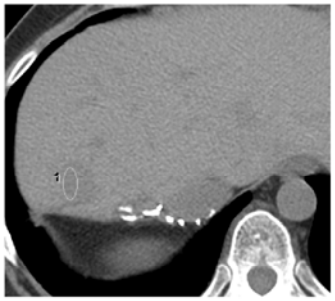
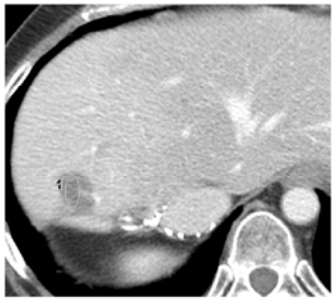
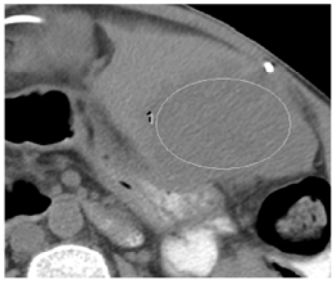
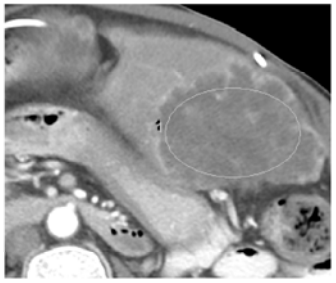
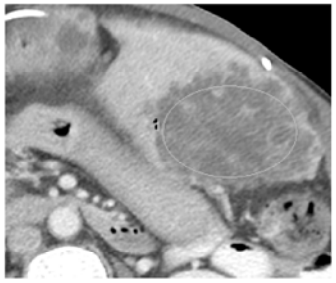
Colorectal liver mets: Response to Y-90



60 tumors

$p = 0.038$

Colorectal liver mets: Response to Y-90

Non-contrast	Arterial phase	Portal venous phase	AEF	Response
 46 HU	 47 HU	 59 HU	0.08	progression
 30 HU	 47 HU	 53 HU	0.74	partial response

Summary

Liver perfusion imaging detects:

- **Early cirrhotic changes** that are not reflected in Child Pugh score, and that predict survival.
- **Aggressiveness of HCC** that is not detected on core biopsy, and that predicts survival.
- **Response to radioembolization** of colorectal liver metastases.

References

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