Optimizing Y90 Treatment for HCC: Update on Data, Dosimetry and Advanced Techniques: CME Symposium at CIO 2025.

Sponsored by an educational grant from Sirtex

Faculty

- **Zach Berman, MD**
  Associate Professor, Clinical Radiology
  UC San Diego
- **Jacob Core, DO**
  Vascular and Interventional Radiology, Assistant Professor
  Mayo Clinic Florida
- **Ripal T. Gandhi, MD, FSIR, FSVM**
  Miami Cardiac & Vascular Institute
  Miami Cancer Institute
  Clinical Professor, FIU Herbert Wertheim College of Medicine
- **Nima Kokabi, MD, FRCPC**
  Associate Professor of Radiology, Hepatology, Medical Oncology
  Vice Chair of Clinical Research
  Director of Interventional Oncology

Faculty Disclosures

- **Zach Berman, MD-** Consultant: AstraZeneca, Boston Scientific, Sirtex, Trisalus Life Sciences; Speakers Bureau: Trisalus Life Sciences. Guerbet, Varian
- **Jacob Core, DO-** has nothing to disclose in relation to this activity
- **Ripal T. Gandhi, MD-** Advisory Board- Trisalus Life Sciences; Consultant- ABK Biomedical, Argon, BD Life Sciences, Cook, Medtronic, Quantum surgical, RenovoRx, Sirtex, Teilx; Speaker's Bureau- Genentech, Quantum surgical, Sirtex, Trisalus Life Sciences
- **Nima Kokabi, MD-** Consultant: Boston Scientific, Sirtex Medical Ltd, Terumo Medical, Okami Medical, Trisalus Life Sciences

Disclosures

- The faculty have been informed of their responsibility to disclose to the audience if they will be discussing off-label or investigational use(s) of drugs, products, and/or devices (any use not approved by the U.S. Food and Drug Administration).
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  - This activity has been independently reviewed for balance
  - This continuing medical education activity may include device or medicine brand names for participant clarity purposes only; no product promotions or recommendations should be inferred

Learning Objectives

- Analyze recent clinical trial data and real-world studies supporting the efficacy and safety of transarterial radioembolization (TARE) with Yttrium-90 for hepatocellular carcinoma, including its role in early, intermediate, and advanced-stage disease management.
- Integrate advanced dosimetric planning and emerging interventional techniques to optimize treatment delivery, improve therapeutic outcomes, and minimize toxicity in patients undergoing Y90 radioembolization.
- Identify key patient selection criteria and collaborate across oncology, hepatology, and interventional radiology disciplines to determine the optimal timing and integration of Y90 treatment within the broader hepatocellular carcinoma care continuum.

Update on Y90 Data for HCC

Zach Berman, MD

Associate Professor of Clinical Radiology
UC San Diego

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We live in a great time for interventional oncology – and more specifically, Y90 radioembolization.

I think it's worth a brief (actually, very rapid) history

Radioembolization is older than you think

It's even older than this guy

The initial concept was with another Y: Yb169

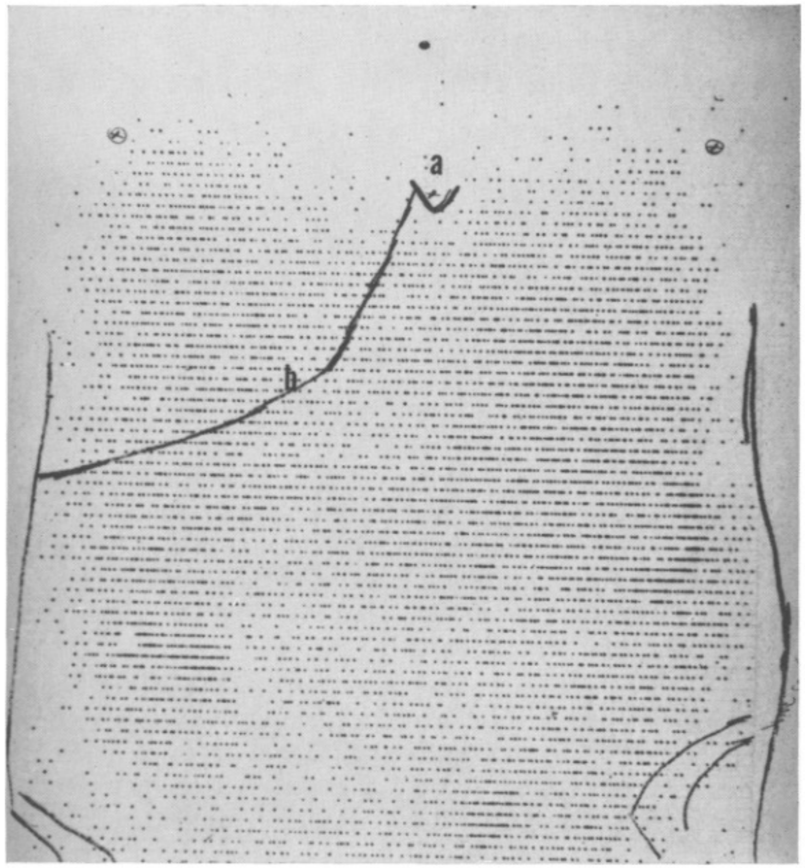
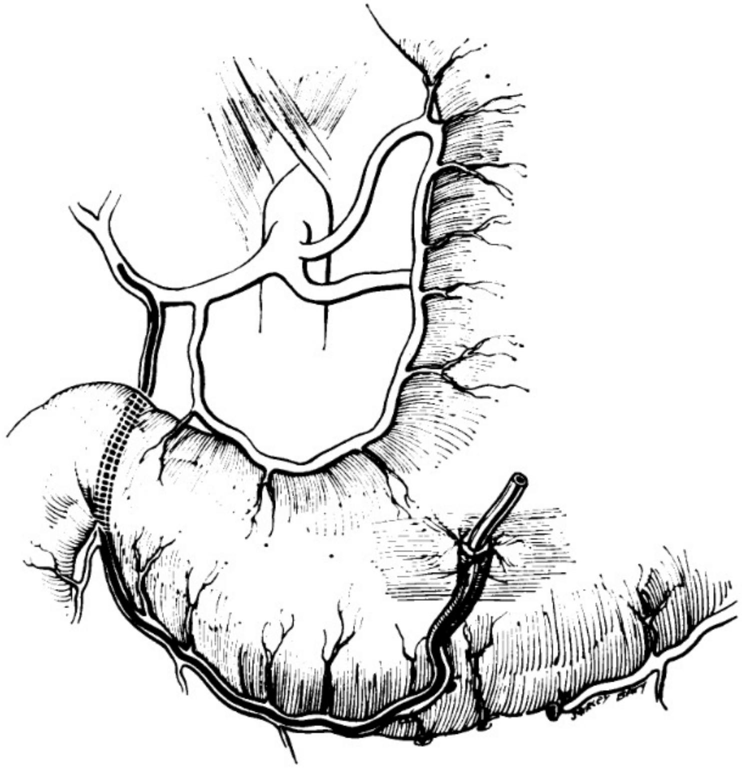


FIG. 1. Photoscan of abdomen in patient who received radiating microspheres to which are attached Yb^{169}. Catheter was inserted into aorta at level of celiac axis. Note uniform distribution of radiation source. Entire abdomen, including liver and spleen, has retained administered microspheres. (a) xiphoid process. (b) right costal margin.

Results were as bad as one would imagine

Maybe it wasn’t the best idea to infuse the entire abdominal aorta – selective infusion is better



Catheter surgically placed into the right gastroepiploic, through GDA to hepatic artery

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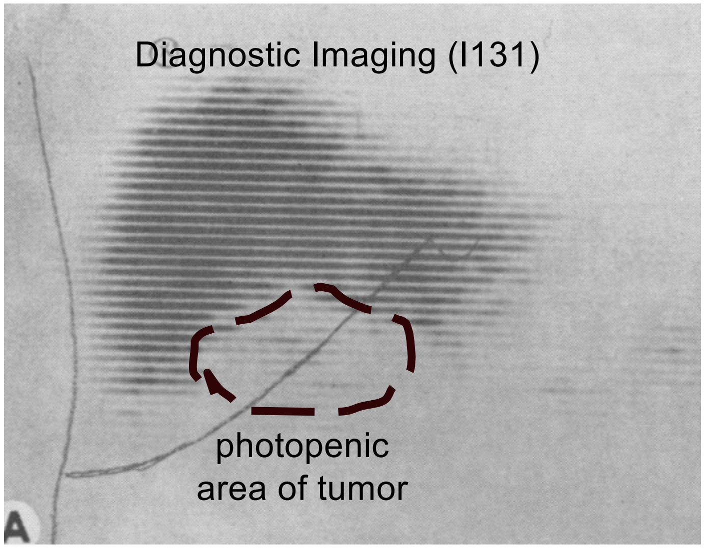
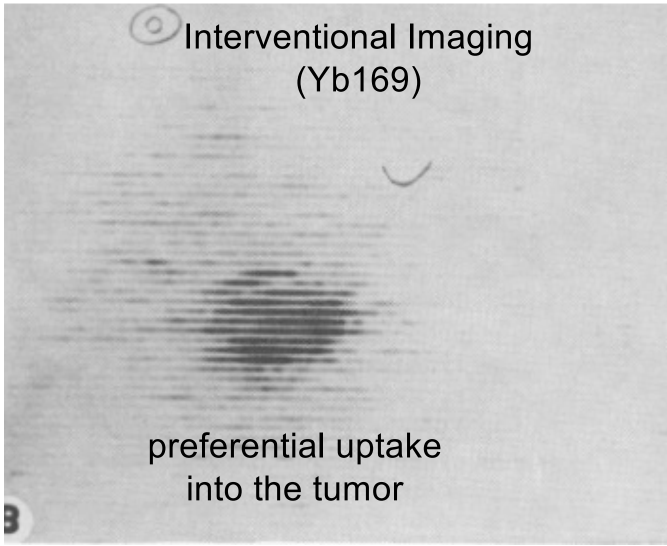
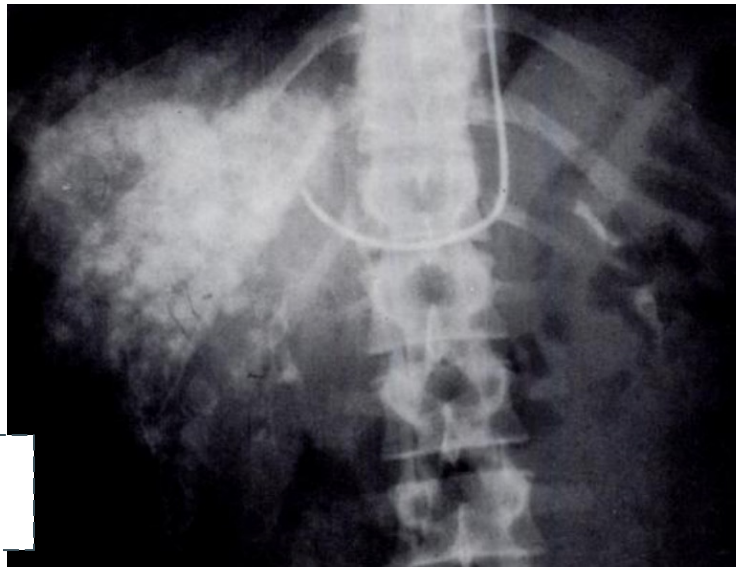
The future is standardized and customized and in combination





Catheter-based techniques were coming into fashion

– as was the concept of dosimetry

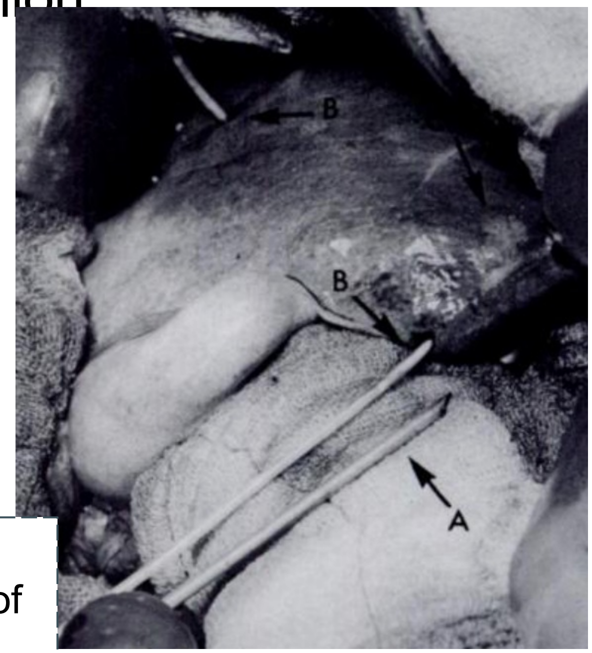


proto-
MIRD

DOSIMETRY

For practical purposes, we assume that the intra-arterially injected beta emitter is distributed evenly throughout the liver and estimate the dose by the formula:

$$D_B = 73.8CE_BT,$$



The
origins of
T:N

athed dosimeters (B) is shown. Dosimeters within tumor nodules (C) received about twice the dose received by dosimeters within normal liver tissue. The dosimeters remained in the tissue for almost 1 hour after the Y^{90} had been injected into the hepatic artery.

The next big advancement came about 10 years later

Establishment of MIRD

The Society of Nuclear Medicine's Committee on Radiation Dosimetry gave us method of dose calculation.[3] The summary of these MIRD formulas gives us a formula generally applicable for dosimetry of rads

Further refinement of T:N

tumors in rats and found that all moderate sized tumors (3–7 mm) had well-developed arterial circulation. Blanchard *et al.*[5] demonstrated that intra-arterial administration of ^{90}Y microspheres gave four times as much radiation in the tumor of V-2 cancers in rabbit livers as accumulated in the normal liver. Blanchard[4] recently described autoradiographs in a patient who

The origins of the microsphere activity debate!

of tissue to deliver a desired radiation dose will be correspondingly higher. It is clear that variations in dosage per individual microsphere will not be a factor influencing therapeutic effectiveness.

Modulating T:N

zation. Our own studies in recent cases indicated that administration of adrenalin along with ^{90}Y may direct the microspheres preferentially to tumor by selectively constricting arterioles leading to normal liver tissue. Because of the fact that the duration of the

Something that we would also recognize today!

Thera Sphere (Theragenics, Atlanta, GA)

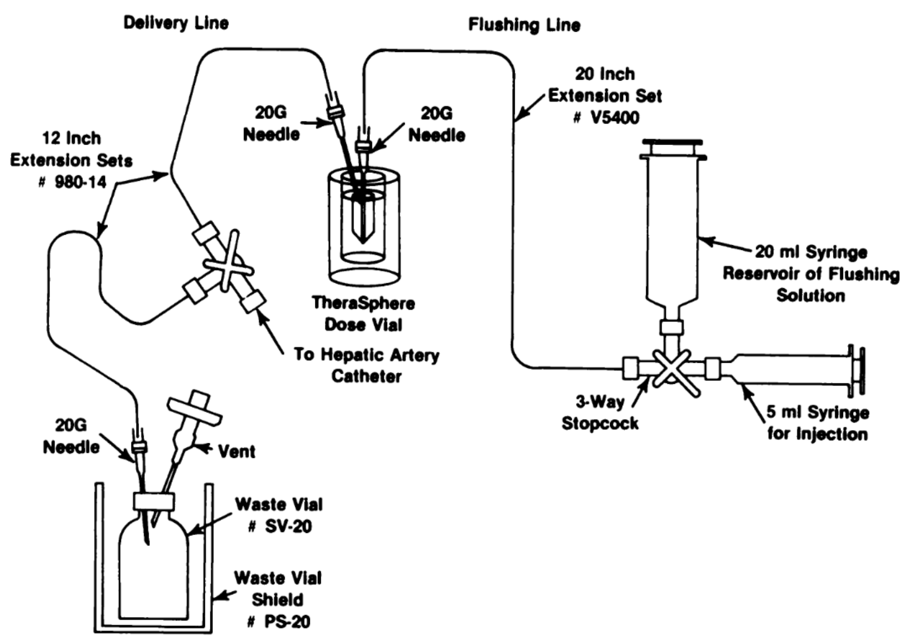


Figure 1. Diagram of the Y-90 glass microspheres delivery apparatus.

Something that we would also recognize today!

Dose escalation trial v
our starting point of d

Fifteen patients (12 m
mean age 62 years [rang
were included in the stu
metastatic colorectal can
cinoid (n = 1), islet cell t
hepatoma (n = 1) treated
levels of 5,000, 7,500, an
(5,000, 7,500, and 10,000

Though partition dosing suggested

With the technologic improvements that we incorporated, we have shown that this form of internal radiation therapy is practical and feasible and will allow further response studies to be done in an attempt at achieving an optimal therapeutic dose depending on size, morphologic characteristics, and vascularity of malignant hepatic lesions. GI tract side effects might be a limiting factor, although perhaps prophylactic measures to protect the GI mucosa might be beneficial. ■

Further dose escalation in dogs gave us our current on-label dosing todav

TABLE 1. Doses of Nonradioactive and Radioactive TheraSphere Received by 12 Dogs

Dog	Estimated liver weight (g)	Sphere dose (mg)*	Sphere dose (mCi)	Actual cGy to liver
1	925	143.0	—	—
2	812	148.0	—	—
3	850	558.0	—	—
4	665	562.0	—	—
5	700	145.0	52.5	13,650
6	700	154.0	53.9	14,000
7	650	147.0	54.5	15,260
8	700	147.9	49.0	12,740
9	700	150.0	73.0	18,980
10	650	145.5	69.5	19,460
11	650	148.0	112.2	31,420
12	575	147.0	112.1	35,480

* There are approximately 7.5 million TheraSphere in 140 mg.

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Further dose escalation done in humans

Dos
Rel

shunt fraction was calculated as the ra
of the lung counts to the total counts.
contrast scintigraphic views of the sto
ach (10) were obtained when indicate
confirm shunting of microspheres to
stomach.
The administered amount of Y-90 w
based on the volume of the patient's l
and the desired total radiation absorb
dose to the liver (5,000 cGy for the fir
four patients, 7,500 cGy for the next t
and 10,000 cGy for the last patient) as
suming a uniform distribution of the
crospheres within the hepatic parenc
ma. Under this assumption, each meg
becquerel of Y-90 per kilogram of live
tissue gives a total absorbed dose of 4
cGy over the complete decay of the Y
(11). The required activity *A* (in mega
querels) for a given hepatic radiation

How ahead of their time

ternal radiation (4).
Further work needs to be done in the area of dosimetry. We expected to see a better response to the internal radiation in tumors that received high doses of absorbed radiation. A possible explanation for this lesser

Further T:N evidence

The tumor-to-liver perfusion ra-
varied from unity to 10: 1.0, 1.0,
2.3, 2.4, 6.0, and 10.0. These val-
are similar to the perfusion ratios

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Sirspheres were being developed simultaneously

MIRD was initial dosimetry

The protocol for SIR therapy has developed over several years. As radiation hepatitis has been observed in several patients receiving high radiation doses, it is now our policy to deliver an amount of Yttrium-90 activity that will result in an inferred radiation dose to the normal liver of approximately 80 Gy.[13] Because the radiation from SIR therapy is delivered as a series of discrete point sources, the dose of 80 Gy is an average dose with many normal

Continued attempts to alter T:N

SELECTIVE INTERNAL RADIATION THERAPY

The technique of SIR therapy has been described in detail elsewhere.[7,12] It involves a laparotomy to expose the hepatic arterial circulation and infusion of Angiotensin-2 into the hepatic artery to redirect arterial blood to flow into the metastatic tumour component of the liver and away from the normal parenchyma. This is followed by embolization of Yttrium-90 containing microspheres (SIR spheres)

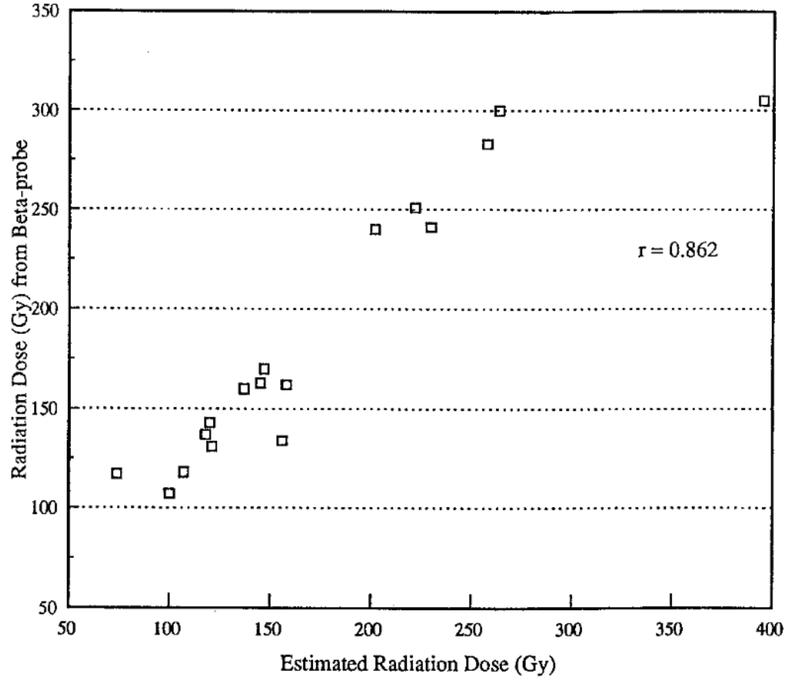
Further dose escalation studies confirm that doses up to 140 Gy safe with glass

Patient dose (cGy)	Calculated nominal absorbed radiation dose (cGy)*
1	5500
2	5700
3	7400
4	8600
5	8700
6	8100
7	8500
8	8300
9	12700
10	11100
11	13800
12	14000
13	10300
14	10700
15	10700
16	12500
17	12500
18	12500
19	13600
20	14200
21	11100
22	15000
23	15300
24	13700

80-150 is posited as the safe threshold MIRD dosimetry for glass microspheres

People were even debating the use of MAA as a surrogate for Y90 in 1996

$$\frac{A_T / M_T}{A_N / M_N} = r.$$



2004 was a big year for Y90 therapy dosimetry

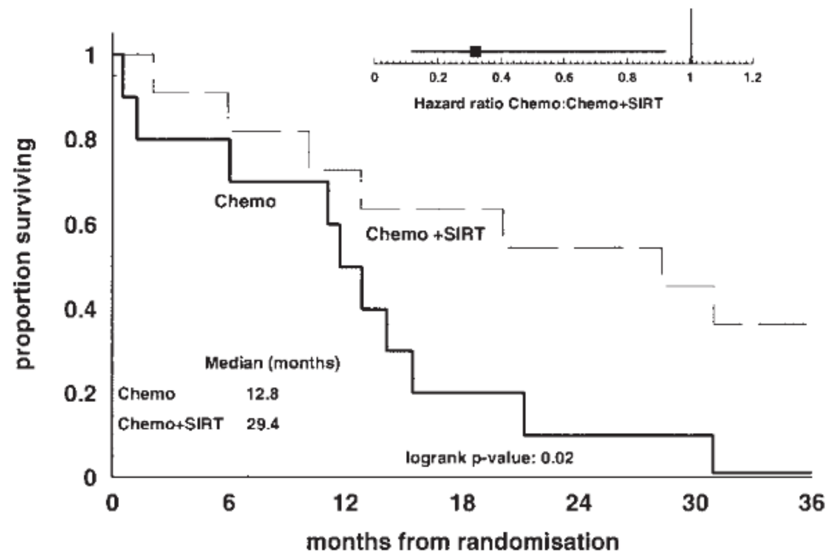
BSA is born

The first five patients treated with SIRT received a standard dose of 2.5 GBq of yttrium-90 activity. As one very small patient developed evidence of radiation hepatitis at this radiation dose, the subsequent six patients were treated with a dose of SIR-Spheres that was calculated from the patient's body surface area and the size of the tumour within the liver according to the following equation:

Dose of SIR-Spheres in GBq

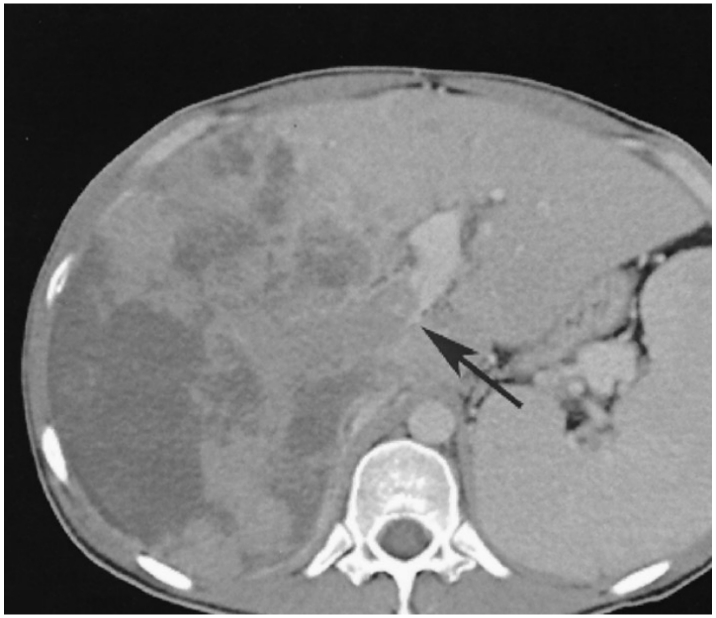
$$= (BSA^{*} - 0.2) + \left(\frac{\%\ \text{tumor involvement}}{100}\right)$$

* BSA = body surface area measured in square metres.



2004 also confirmed the dosimetry targets for glass microspheres

atric illness. All treated patients were evaluated to confirm an acceptable risk of shunting of ^{90}Y-μS to the lungs (< 30 Gy) and no detectable flow to the gastrointestinal organs. Patients who completed treatment of the recommended dose of 80–150 Gy and who demonstrated PVT in the absence of CVT, as determined by CT imaging and hepatic angiography were in-



Modern uses of "-ectomy" started quite quickly thereafter

Patient	Initial RHLV	Final RHLV		Initial LHLV	Final LHLV	
	(cm^3)	(cm^3)	(% change)	(cm^3)	(cm^3)	(% change)
1	1025	717	(–30)	467	850	(+82)
2	1842	739	(–60)	1365	1532	(+12)
3	9[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	(+64)
4	7[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	(+43)
5	6[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	(+86)
6	13[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	(+19)
7	9[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	(+67)
8	6[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	(+56)
9	10[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	(+11)
10	12[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	(+15)
11	7[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	(+80)
12	7[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	(+93)
13	10[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	(+67)
14	7[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	(+32)
15	7[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	(+19)
16	1151	370	(–68)	1226	1558	(+27)
17	1155	402	(–65)	836	1198	(+43)
18	679	325	(–52)	566	758	(+34)
19	1026	810	(–21)	484	994	(+105)
20	790	525	(–34)	827	1095	(+32)
Summary	955	460	(–52)	719	1004	(+40)

1.7, range 1–5) radioembolization sessions. Mean activity delivered to the target lobe, corrected for shunting and residual activity, was 2.20 GBq (range 0.49–4.2 GBq). Mean dose delivered to the target hepatic volume during each treatment session was 103 Gy (median 109 Gy, range 28–151 Gy). Mean cumulative dose delivered to the target hepatic volume over all treatment sessions was 175 Gy (median 132 Gy, range 103–413 Gy). There were no procedure-related complications, no misadministrations, and no gastrointestinal ulcers.

40% overall growth in contralateral lobe

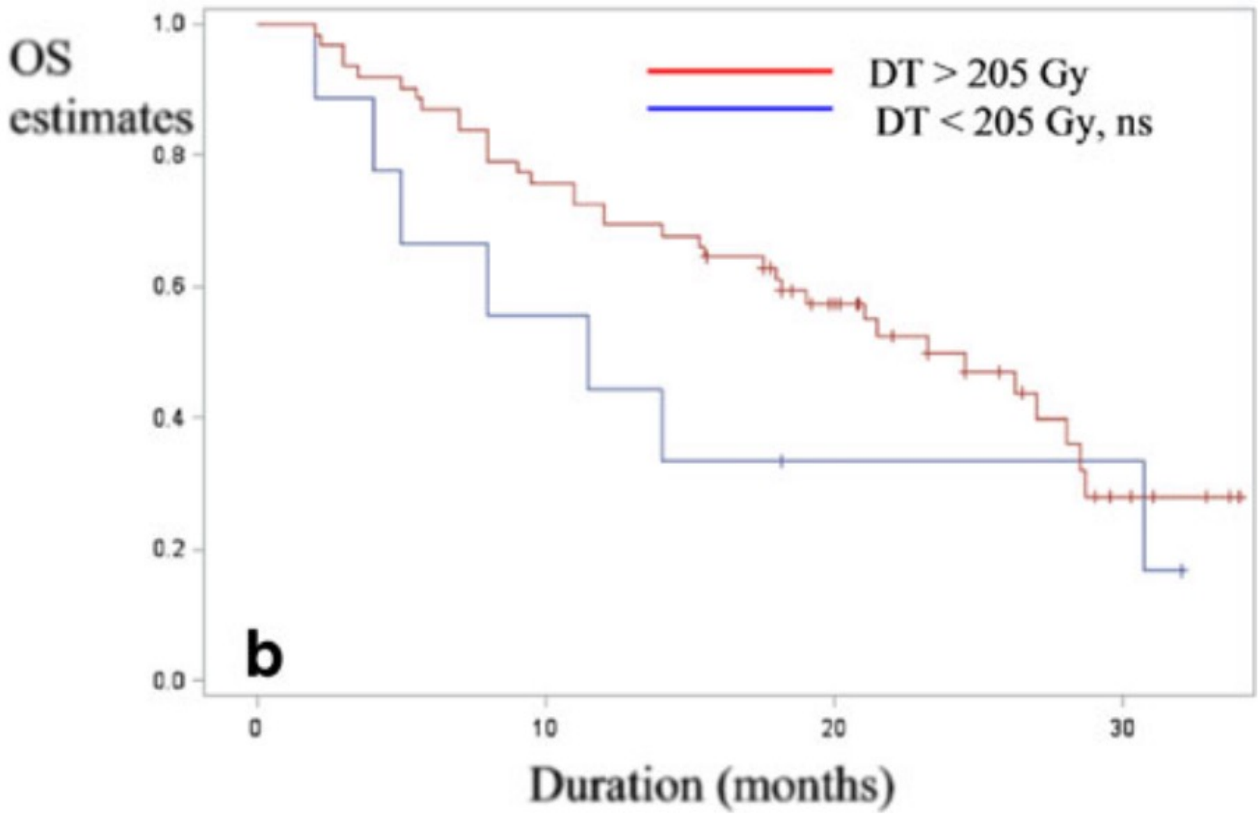
2011 – Where traction was started for HCC

Pretreatment planning dosimetry was based on the assumption that we would only be able to catheterize the lobar hepatic arterial branch and that ^{90}Y infusion would expose the entire lobe to our target of 120 Gy. Tumor hypervascularity would result in preferential flow to the tumor relative to normal parenchyma (13). However, on the day of treatment, because a hypertrophied vessel perfusing the segment containing the tumor could be identified, the entire activity vial was infused in the segmental artery rather than the lobar branch, to increase dose to tumor and minimize exposure to normal hepatic parenchyma. Because glass microspheres function as microembolic particles rather than causing macroembolization, vascular capaci-

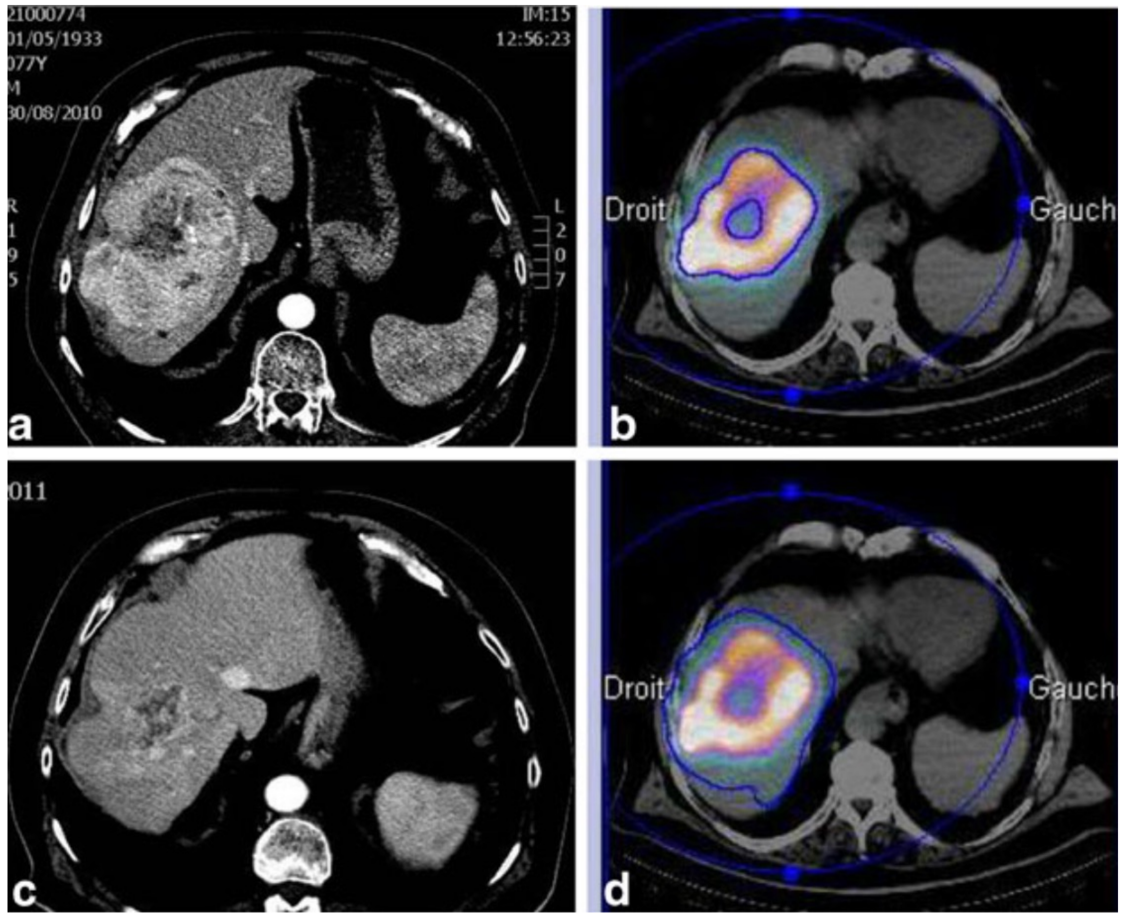
were delivered to the whole liver, one lobe, segment, and the tumor only was 35.5 (32–41.3), 97 (89–110), 521 (404–645), and 1657 (1271–2087) Gy, respectively.

> 400 Gy was in vogue about a decade BEFORE Legacy

Only 2 years after personalization based on MAA was



CIO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01/05/1933
077Y
M
30/08/2010
IM:15
12:56:23
a
Droit
Gauch
b
011
c
Droit
Gauch
d

3 years after rad seg described, 190 Gy MIRD was target

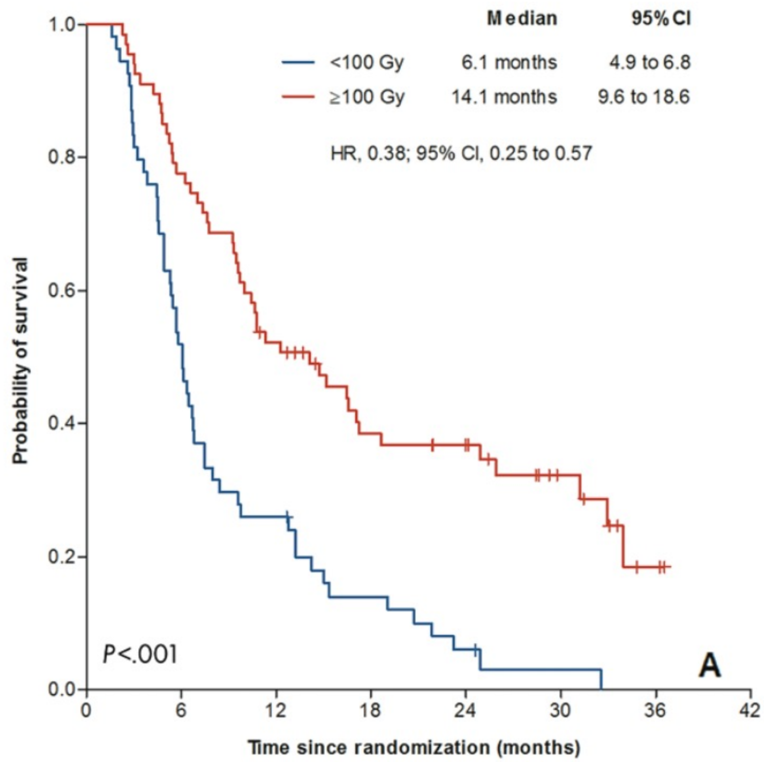
translates to radiation segmentectomy resulting in 90-100% pathology necrosis in all treated patients. More complete necrosis was observed when irradiation dose exceeded 190 Gy ($P = 0.03$; Table 3), suggesting the possibility of a threshold dose needed to achieve CPN. Baseline lesion size, radiation dose, mRECIST response, and pathological response of transplanted patients are

	PN	CPN	Total
<190 Gy	9	3	12
>190 Gy	7	14	21
Total	16	17	33

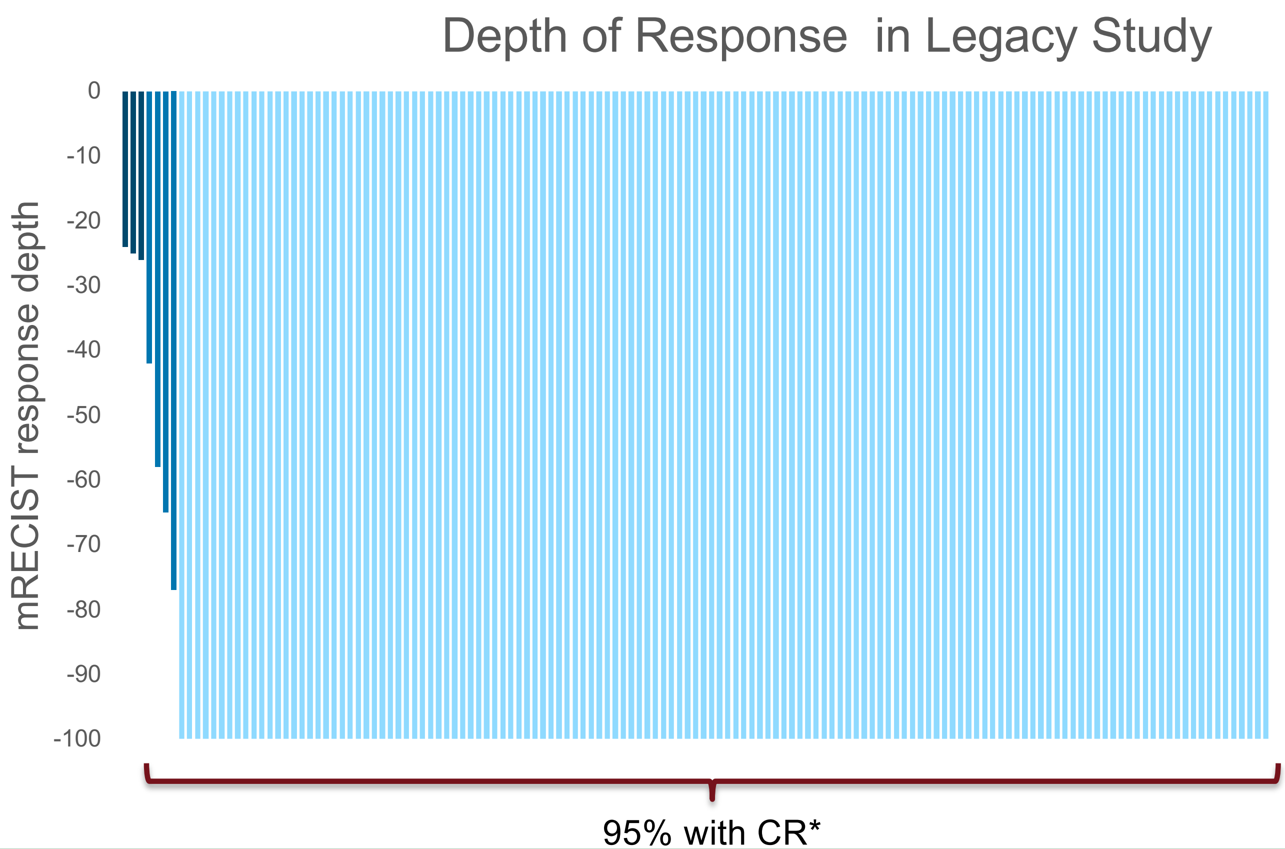
$P = 0.03$ (Fisher's exact test).

What was going on with resin dosimetry?

SARAH says, 100 Gy, and the beginning of partition for Sirspheres

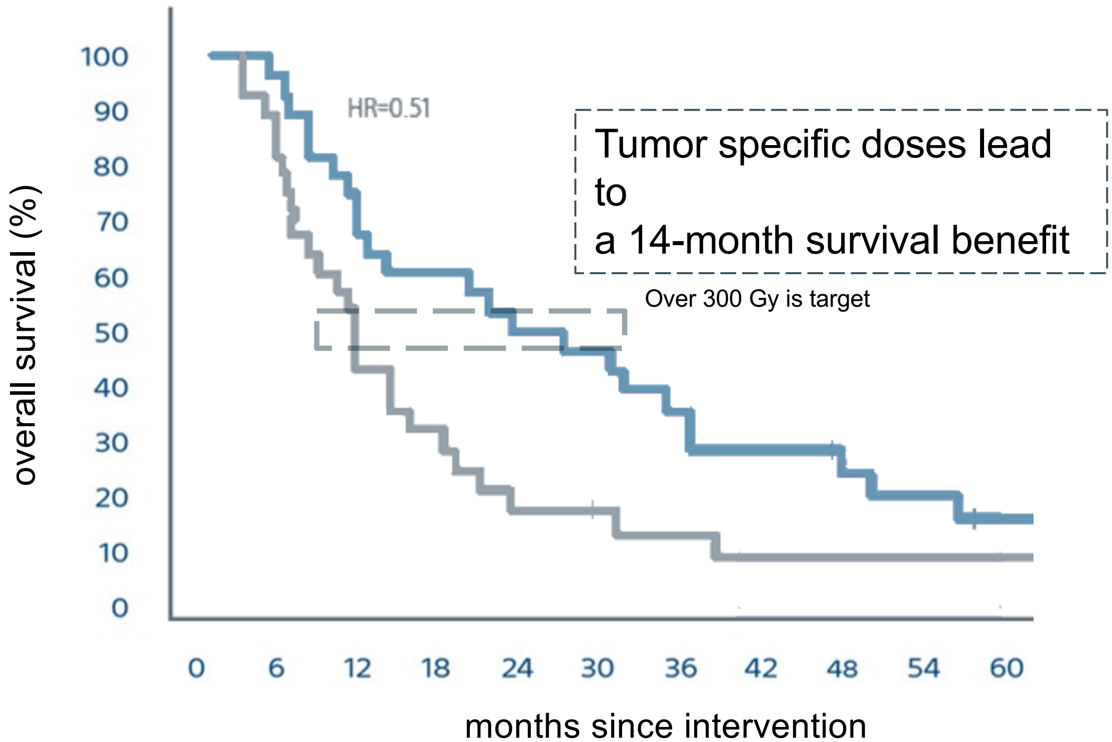


Legacy confirmed radiation segmentectomy (>190 Gy) as SoC



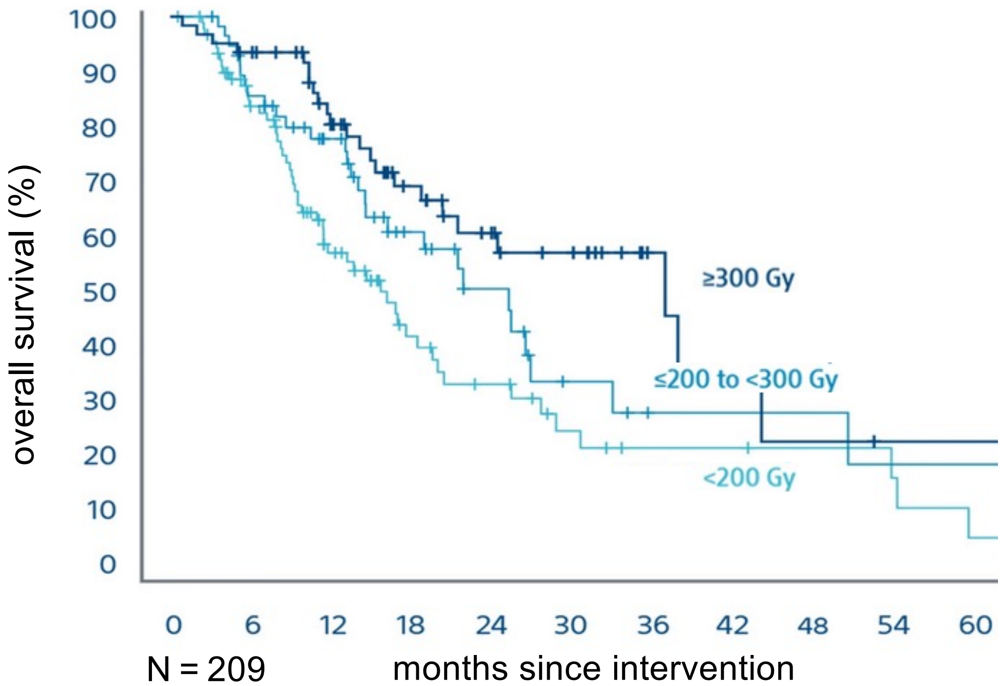
Increased tumor dose is correlated with OS; best at doses >300 Gy

for tumors ~10cm in size with TIV



Median tumor dose is correlated with survival odds for tumors ~7 cm in size

with optimal outcomes seen at doses that are greater than 300 Gy



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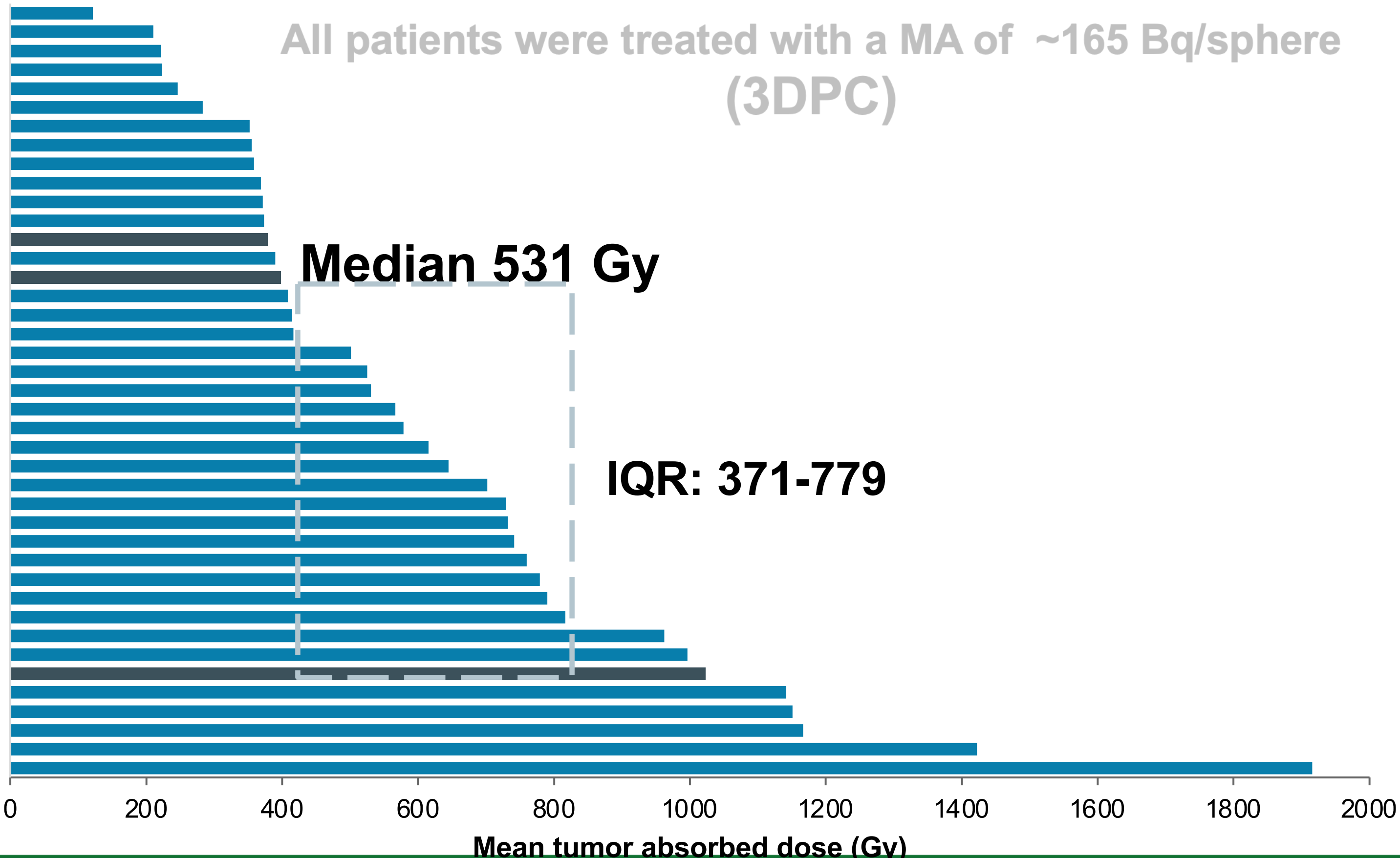
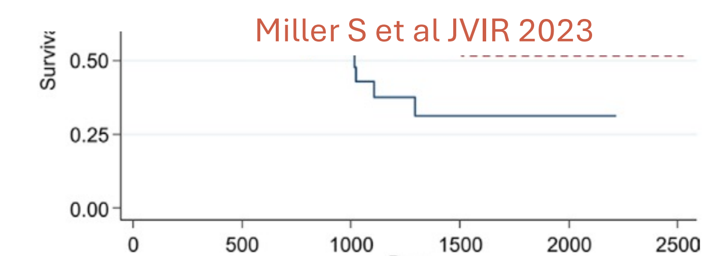
Data is less concrete but developing with resin microspheres



Y90 has had a very exciting past.
What does the future have in store?

- es?
- Improving delivery?



Dosimetry:
How I Do It

Nima Kokabi, MD, FRCPC
Associate Professor of Radiology, Hepatology, Medical Oncology
Vice Chair of Clinical Research
Director of Interventional Oncology
University of North Carolina School of Medicine
Chapel Hill, NC

UNC SCHOOL OF MEDICINE

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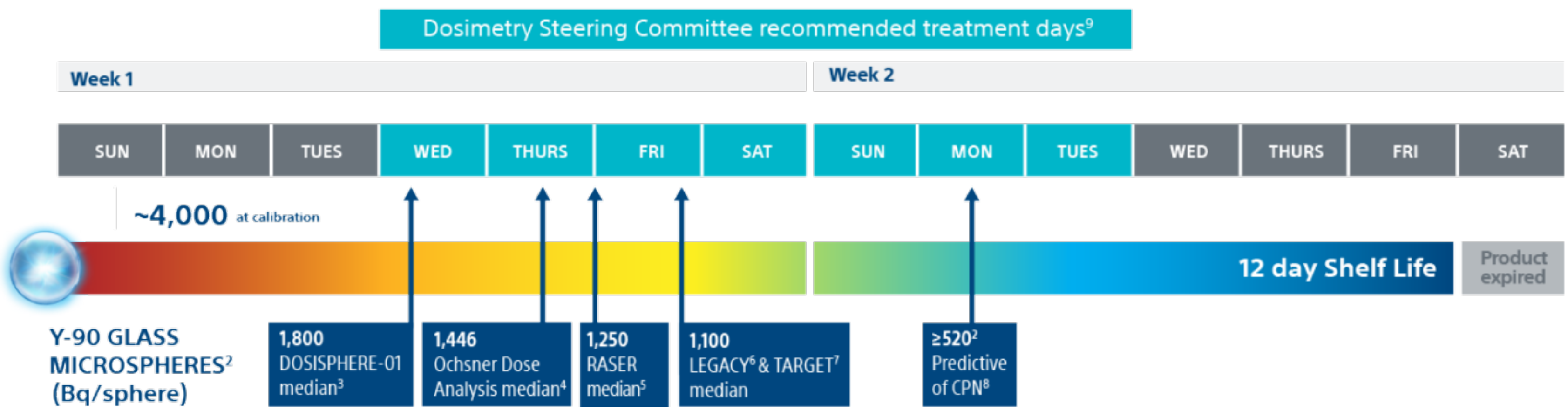
Agenda

- HCC
- Glass and resin
- Calibration to order
- Dosimetry considerations and planning
  - Contemporary data

to
re

Glass Y90



Dosimetry Steering Committee recommended treatment days[9]
Week 1
Week 2
SUN
MON
TUES
WED
THURS
FRI
SAT
SUN
MON
TUES
WED
THURS
FRI
SAT
~4,000 at calibration
12 day Shelf Life
Product expired
Y-90 GLASS MICROSPHERES[2] (Bq/sphere)
1,800 DOSISPHERE-01 median[3]
1,446 Ochsner Dose Analysis median[4]
1,250 RASER median[5]
1,100 LEGACY[6] & TARGET[7] median
≥520[2] Predictive of CPN[8]

Resin Y90


Yttrium-90
Microspheres VOL-5ml
Yttrium-90
Microspheres VOL-5ml

FLEXDose Delivery Program (USA)

Dose Delivery Options	7 days Pre-calibration	6 days Pre-calibration	5 days Pre-calibration	4 days Pre-calibration	3 days Pre-calibration	2 days Pre-calibration	1 day Pre-calibration	Day of Calibration
8:00 AM **Activity** on average 27.3 million microspheres in each delivery vial**	333 mCi 12.34 GBq	257 mCi 9.52 GBq	198 mCi 7.34 GBq	153 mCi 5.66 GBq	118 mCi 4.37 GBq	91 mCi 3.37 GBq	70 mCi 2.60 GBq	54 mCi 2.01 GBq
Dose Draw								
Example: 1 GBq # Microspheres (million) Activity/Microsphere (SIR-Y002 3 mL vial)	~2.2 million spheres 452 Bq	~2.9 million spheres 349 Bq	~3.7 million spheres 269 Bq	~4.8 million spheres 207 Bq	~6 million spheres 160 Bq	~8.1 million spheres 123 Bq	~10.5 million spheres 95 Bq	~13.6 million spheres 73 Bq
Tumor Size/ Distribution	<2 cm	2-4 cm	4-6 cm	6-8 cm	>8 cm/ Seg/lobar	Lobar	Lobar	Lobar

Subsegmentectomy

Segmentectomy

Lobar

RULE OF THUMB

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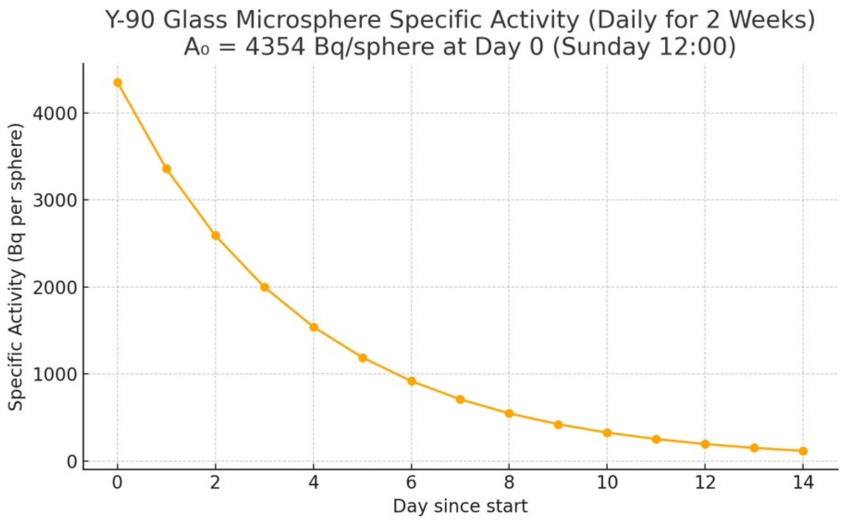
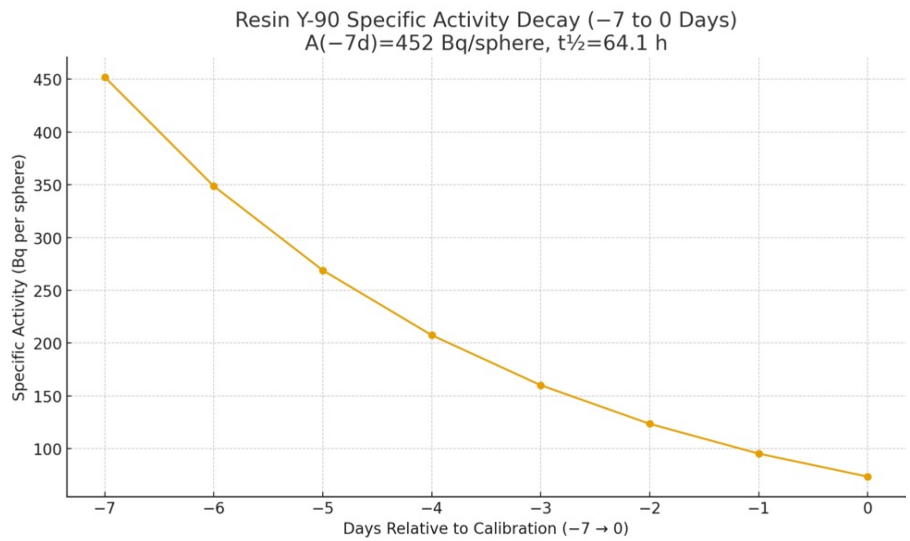
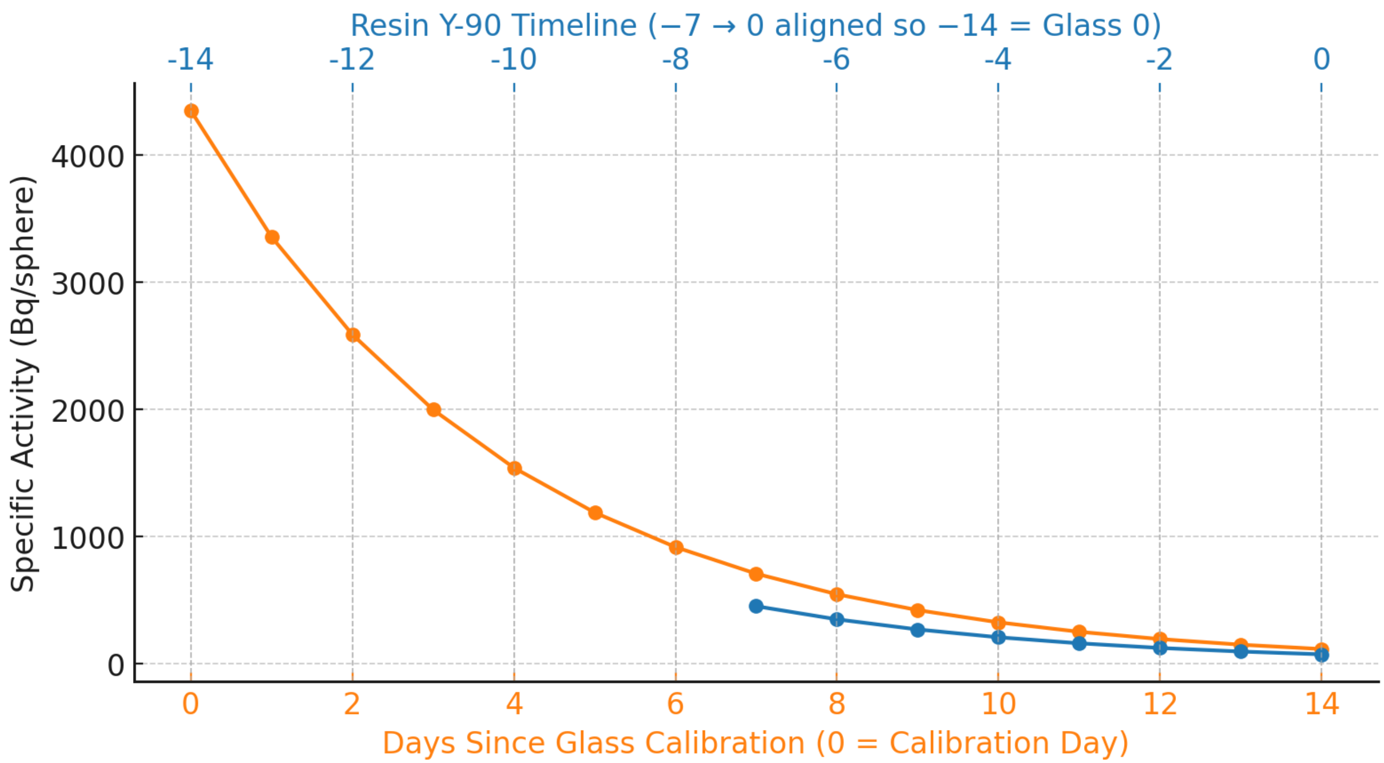
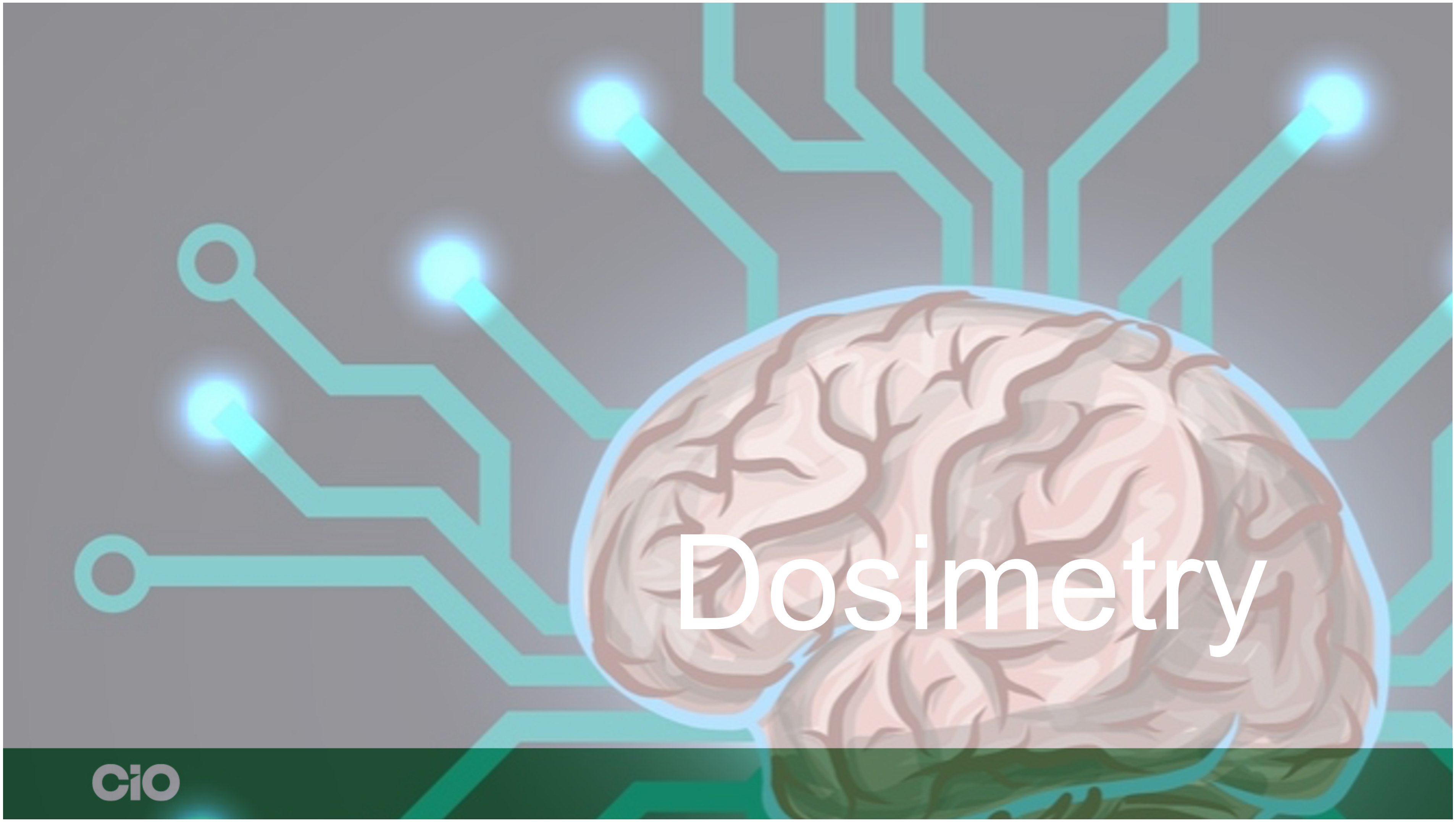
Glass vs Resin Specific Activity





Glass vs Resin Specific Activity




Dosimetry
CiO

I was
Damaged and Fibrosed
Now I have
Demons of...
Malignant hepatocytes
Cursed with
Immortality...
IMMORTAL
UNSTOPPABLE
ME!!
Hepatocellular
Carcinoma
Creative-Med-Doses
©2019 Priyanga Singh

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Yttrium-90 Radioembolization Dosimetry: Dose Considerations, Optimization, and Tips

Alexander Villalobos, MD[1] Johannes L. du Pisanie, MD[1] Ripal T. Gandhi, MD, FSIR, FSVM[1]
Nima Kokabi, MD, FRCPC[1]

[1] Department of Radiology, University of North Carolina at Chapel Hill, Chapel Hill, North Carolina
[2] Miami Cancer Institute, Miami Cardiac and Vascular Institute, Miami, Florida

Address for correspondence Alexander Villalobos, MD, University of North Carolina at Chapel Hill, 101 Manning Drive, Chapel Hill, NC 27514 (e-mail: a.villalobos@unc.edu).

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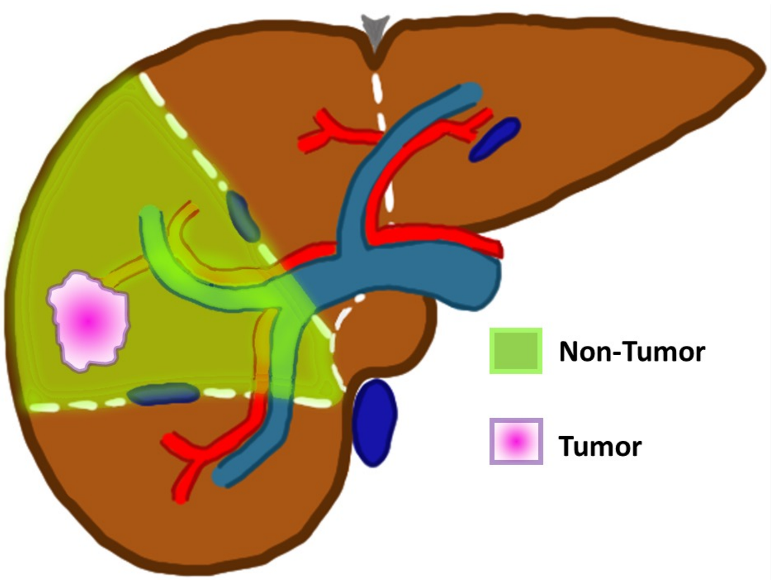
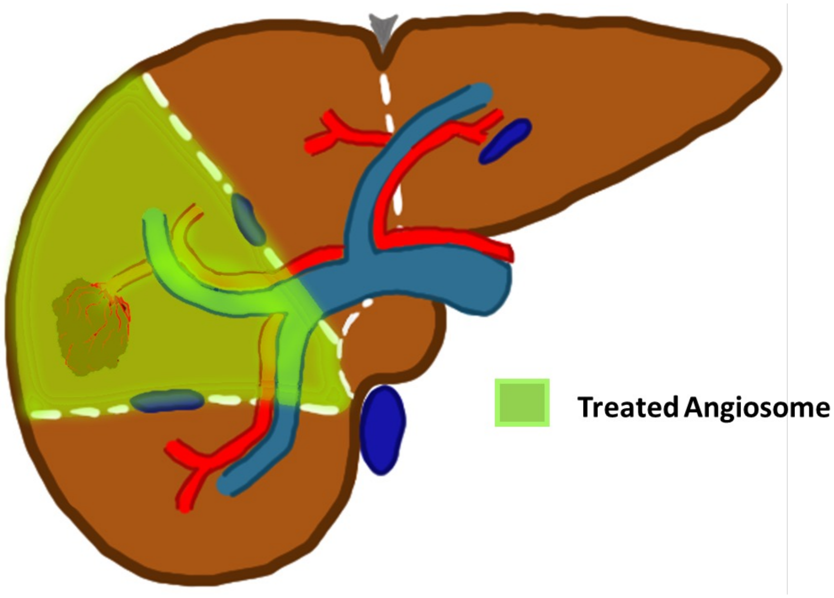
Clinic	
Radia segm (Y90-	ome
Radia lobec (Y90-	0 Gy eally
Multi unilo	iy[c] ally
Multi bilob	iy
HCC micro invas porta thron	ch[c] r

Clinically Prudent Dosimetry Models*

Multi-compartment (Partition)



Single Compartment (MIRD)



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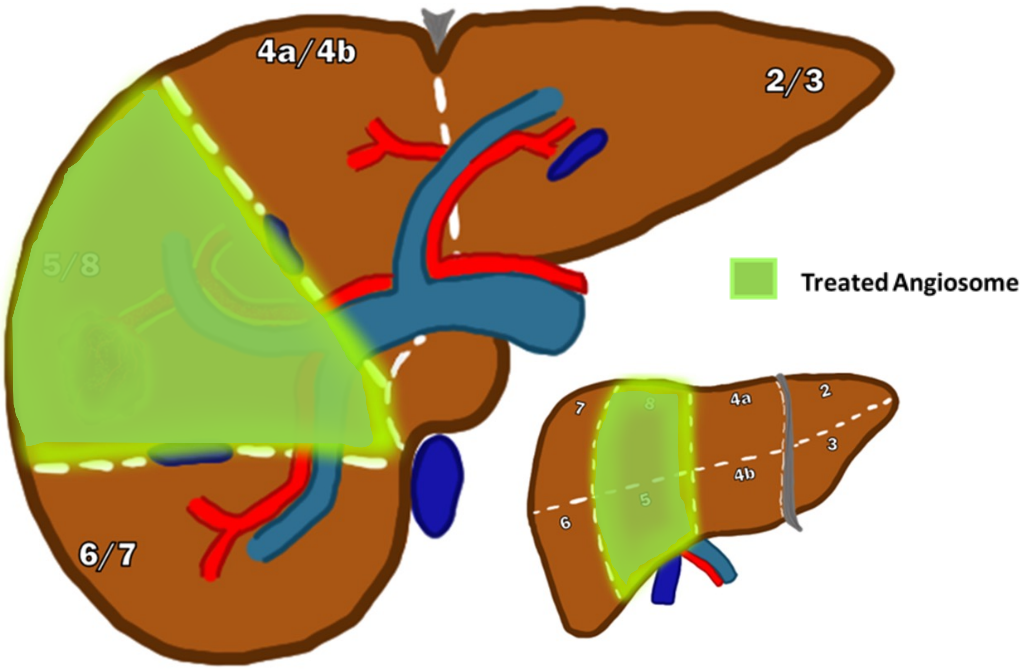
Curative Intent (Glass)

Single Compartment (MIRD) Dosimetry

Wednesday 1st wk- Tuesday 2nd Wk

>500* Gy Angiosome[1,2]



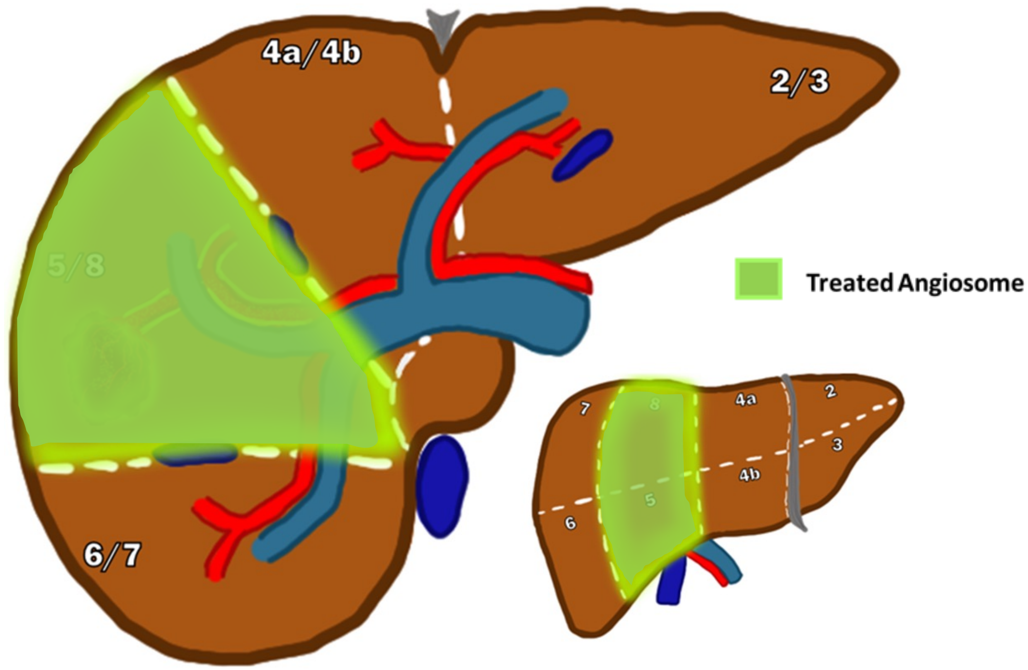
Montazeri SA, et al. *EJNMMI*. 2025;52(9):3145-3150. Pianka KT, et al. EJNMMI. 2024;51(12):3744-3752.

Curative Intent (Resin)

Single Compartment (MIRD) Dosimetry

- **Segmental:**
  3-5 day Pre-Cal
  >350 Gy Angiosome[1,2,3]

- **Sub-Segmental:**
  5-7 Day Pre-Cal
  >400 Gy Angiosome[4]



Kokabi N, et al. *EJNMMI.* 2023;50(6):1743-1752. Sarwar A, et al. *Radiology*. 2024;311(2):e231386. Dabbous H, et al. *CVIR*. 2025;48(8):1113-1125. Villalobos A, Kokabi N. *JVIR*. 2023;34(10):1846-1847.

Particle Distribution for Curative Intent? (Glass)

Home > European Journal of Nuclear Medicine and Molecular Imaging > Article

Achieving Complete Pathologic Necrosis in Hepatocellular Carcinoma Treated with Radiation Segmentectomy before Liver Transplantation: A Comprehensive Glass Microsphere Analysis

Short Communication | Published: 11 March 2025

Volume 52, pages 3145–3150, (2025) Cite this article

Download PDF

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European Journal of Nuclear Medicine and Molecular Imaging

Aims and scope →

Submit manuscript →

S. Ali Montazeri, Cynthia De la Garza-Ramos, Claudia Silver, Ricardo Paz-Fumagalli, Andrew R. Lewis, Gregory T. Frey & Beau B. Toskich

Use our pre-submission checklist →

Avoid common mistakes on your manuscript.

- Different calibrations
- For those **<570 Bq/spheres →**
- **Angiosome PD ≥11.4 × 10³/ml → CPN**
- No correlation between PD and CPN for = >570 Bq/spheres

ELSEVIER

Journal of Vascular and Interventional Radiology

Volume 35, Issue 11, November 2024, Pages 1602-1612.e1

Clinical Study

Using Voxel-Based Dosimetry to Evaluate Sphere Concentration and Tumor Dose in Hepatocellular Carcinoma Treated with Yttrium-90 Radiation Segmentectomy with Glass Microspheres

Tyler Sandow MD [a], Juan Gimenez MD [a], Kelley Nunez PhD [b], Richard Tramel MD [a], Patrick Gilbert MD [a], Brianna Oliver MD [a], Michael Cline MD [a], Kirk Fowers PhD [c], Ari Cohen MD [d], Paul Thevenot PhD [b]

- CR Tumor PD: 13,697/cc
- None-CR tumor PD: 12,279/cc
- **No correlation between PD and CR**

Particle Distribution for Curative Intent? (Resin)

ELSEVIER

Journal of Vascular and Interventional Radiology

Available online 21 March 2023

In Press, Journal Pre-proof ⓘ What's this?

Clinical Study

Yttrium-90 Radiation Segmentectomy of Hepatocellular Carcinoma: A Comparative Study of Effectiveness, Safety, and Dosimetry of Glass vs. Resin-based Microspheres

Alexander Villalobos MD [1], Linzi Arndt BS, MBA [1], Bernard Cheng MD [1], Howard Dabbous MD [1], Mohammed Loya MD [1], Bill Majdalany MD [1], Zachary Bercu MD [1], Nima Kokabi MD FRCPC [1]

European Journal of Nuclear Medicine and Molecular Imaging

https://doi.org/10.1007/s00259-025-07471-0

ORIGINAL ARTICLE

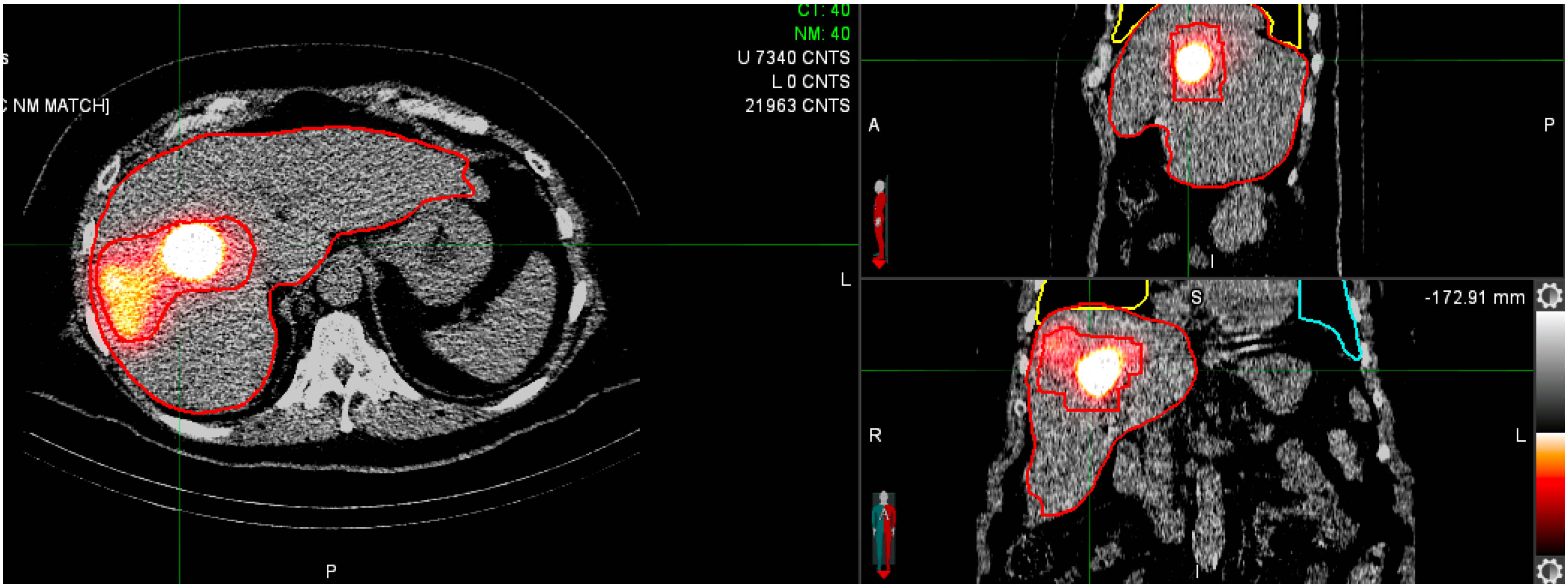
Histopathologic outcomes of hepatocellular carcinoma treated with transarterial radioembolization with yttrium-90 resin microspheres

Ammar Sarwar[1] · Imad Nasser[2] · Jeffrey L. Weinstein[1] · Mahmoud Odeh[1] · Hafsa Babar[3] · Diana Dinh[1] · Michael Curry[4] · Andrea Bullock[5] · Devin Eckhoff[6] · Martin Dib[6] · John A. Parker[7] · Muneeb Ahmed[1]

- 3-day pre-cal Resin
- **Mean: 40,000 microspheres/cc tumor → CR**

- 3-day pre-cal Resin
- **Median: 78,000 microspheres/cc tumor → CPN**

MAA SPECT/CT (Segment Volume Calculation)

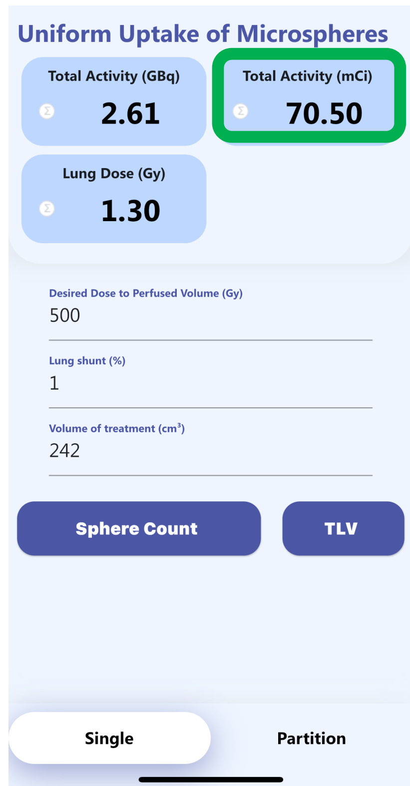


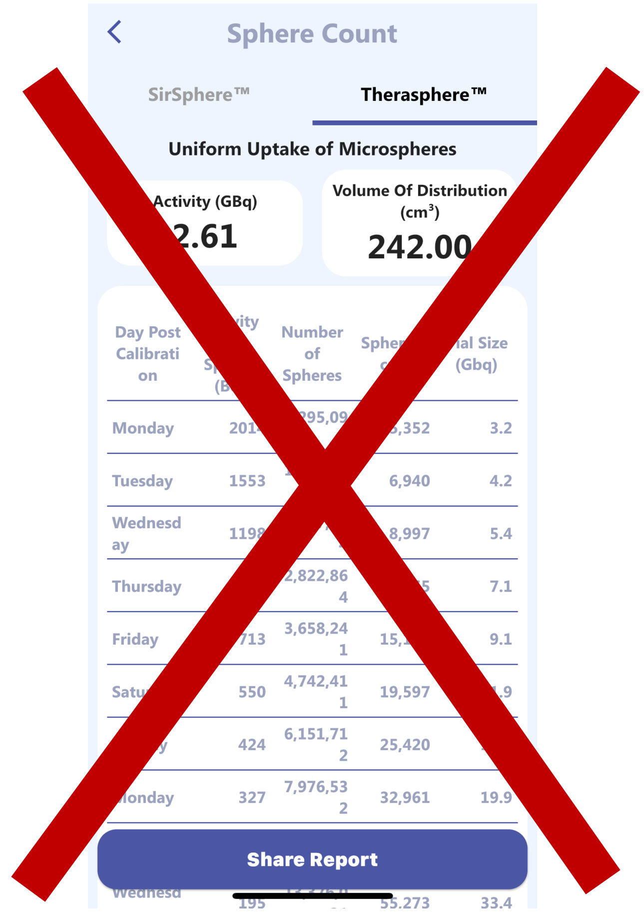
Segment Volume and LSF

Target Region Statistics			
Contour Name =	Liver_L	Liver_R	Unit
Target Region Volume =	545.84	1797.86	cc
Percent of Liver Outside Target Region =	76.71	23.29	%
Percent of Liver Inside Target Region =	23.29	76.71	%
Liver Volume =	2343.7		cc
Tumor Involvement =	0	13.47	%
All Tumors (within Target Region) Volume =	0	242.13	cc
Total Tumor TNR =	N/A	28.36	:1
Tumor 1 (within Target Region) Volume =	0	242.13	cc
TNR Tumor 1 =	N/A	28.36	:1

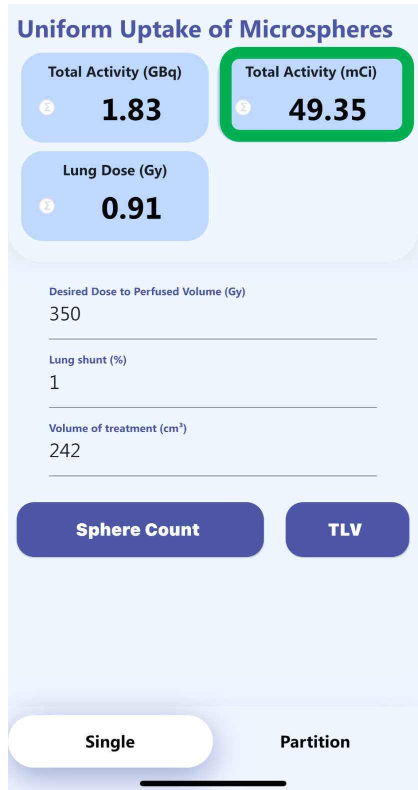
Lung Shunt and Volumes		
Lung Shunt =	1.02	%
Lungs Total Counts =	715.9	kCNTS
Liver Total Counts =	69239.8	kCNTS
Lungs Volume =	1116.95	cc
Liver Volume =	2343.7	cc

Glass Planning





Resin Planning



Particle Density

Sphere Count

SirSphere™ | Therasphere™

Uniform Uptake of Microspheres

Activity (GBq): **1.83**

Volume Of Distribution (cm^3): **242.00**

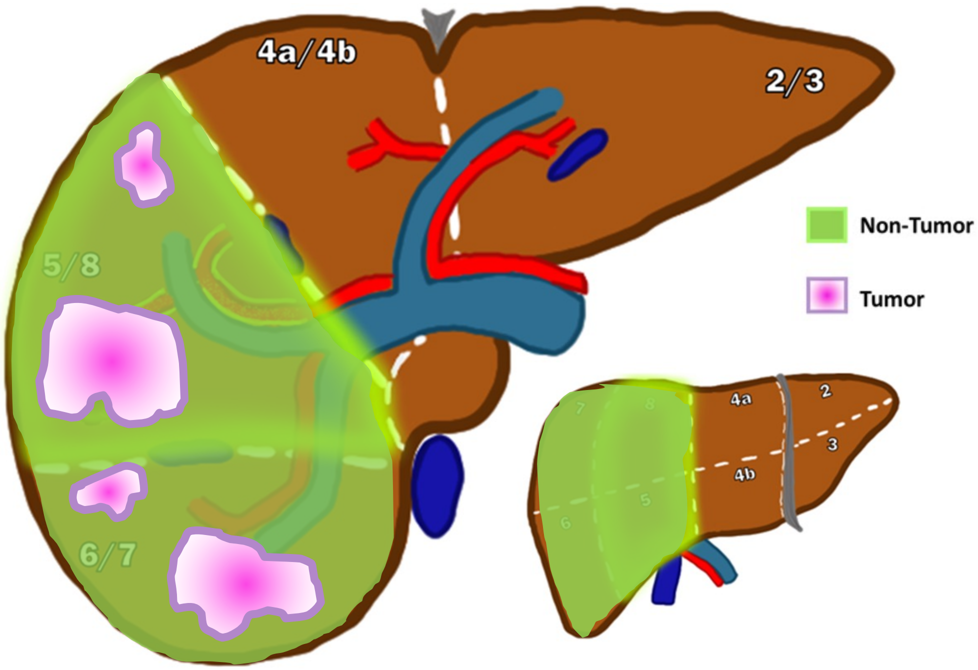
	Activity Per Sphere (Bq)	Number of Spheres	Spheres/ cm^3
DOC	76	24,024,056	99,273
Flex -1	99	18,442,710	76,210
Flex -2	130	14,044,833	58,036
Flex -3	171	10,677,358	44,121
Flex -4	223	8,187,571	33,833
Flex -5	293	6,231,496	25,750
Flex -6	384	4,754,761	19,648

Share Report

Glass: Unilobar HCC (Palliative Intent)

Multicompartment (Partition)

- Mean NTAD
  - <90 Gy (ideal)*
- Mean TD
  - >205 Gy (minimum)
  - >250 Gy (ideally)
- Calibration
  - Late 1st wk or early 2nd week

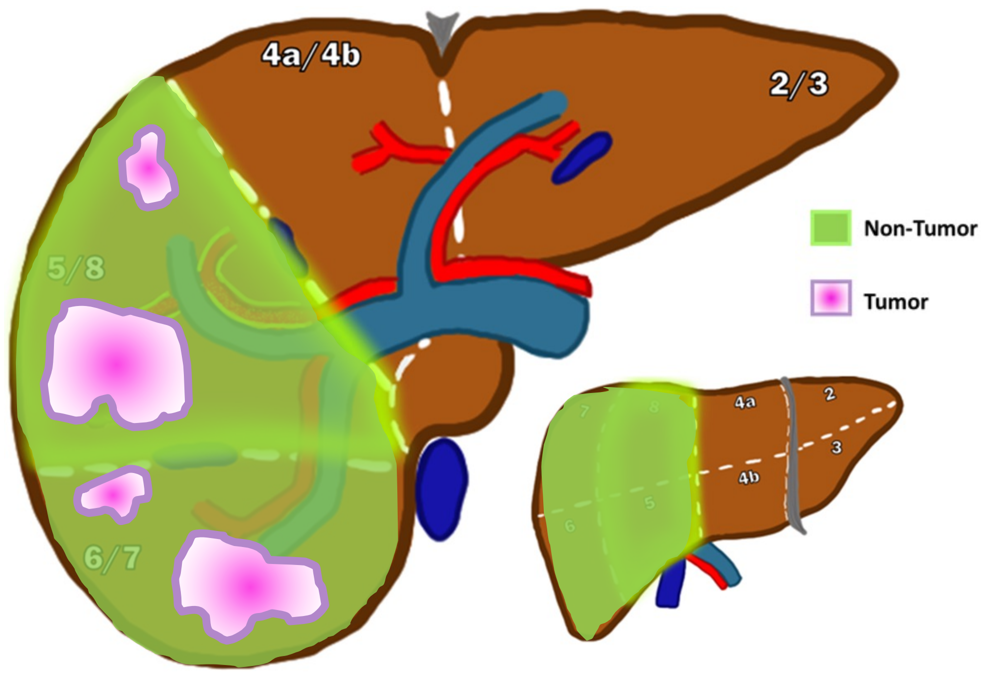


Kokabi N, et al. *EJNMMI.* 2023;50(6):1743-1752. Sarwar A, et al. *Radiology*. 2024;311(2):e231386. Dabbous H, et al. *CVIR*. 2025;48(8):1113-1125. Villalobos A, Kokabi N. *JVIR*. 2023;34(10):1846-1847.

Resin: Unilobar HCC (Palliative Intent)

Multicompartment (Partition)

- Mean NTAD
  - CP A or ALBI 1: <70 Gy
  - CP-B7 or ALBI 2: <40-50 Gy
- Mean TD
  - >120 Gy (minimum)
  - >250-330 Gy (ideally)
- Calibration:
  - 1-2 day pre-cal or DOC



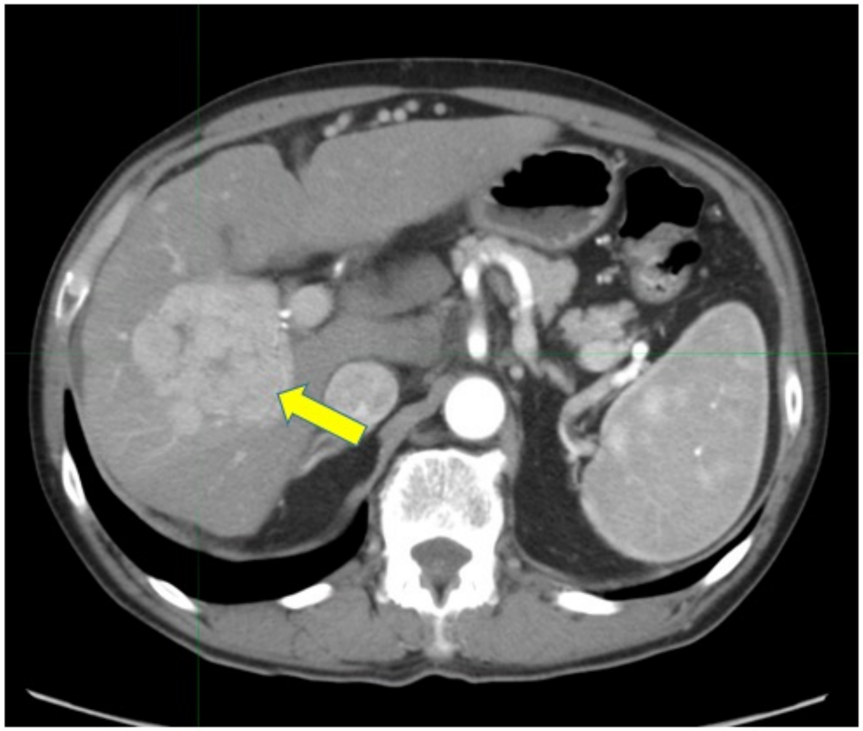
Kokabi N, et al. *EJNMMI.* 2023;50(6):1743-1752. Sarwar A, et al. *Radiology*. 2024;311(2):e231386. Dabbous H, et al. *CVIR*. 2025;48(8):1113-1125. Villalobos A, Kokabi N. *JVIR*. 2023;34(10):1846-1847.

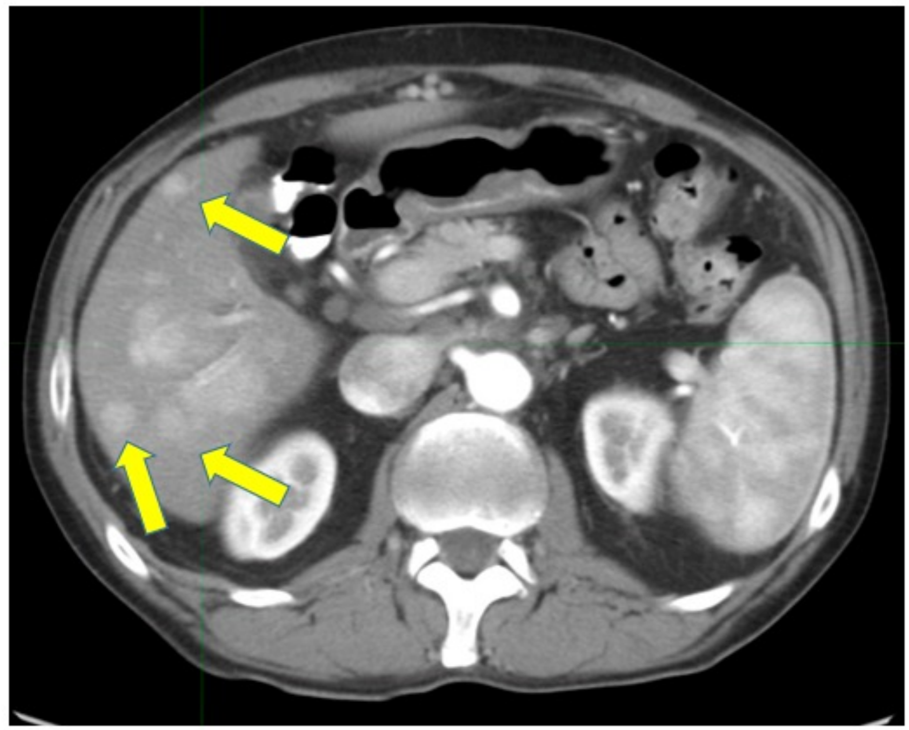
Case: Lobar Treatment

- 64-year-old Male
- Hepatitis C Cirrhosis
- 7.3 cm HCC (right lobe)
    - Several satellite lesions
- CP A-5
- ALBI Grade 1
- ECOG 0

Courtesy of Dr. Armeen Mahvash

Baseline CTA



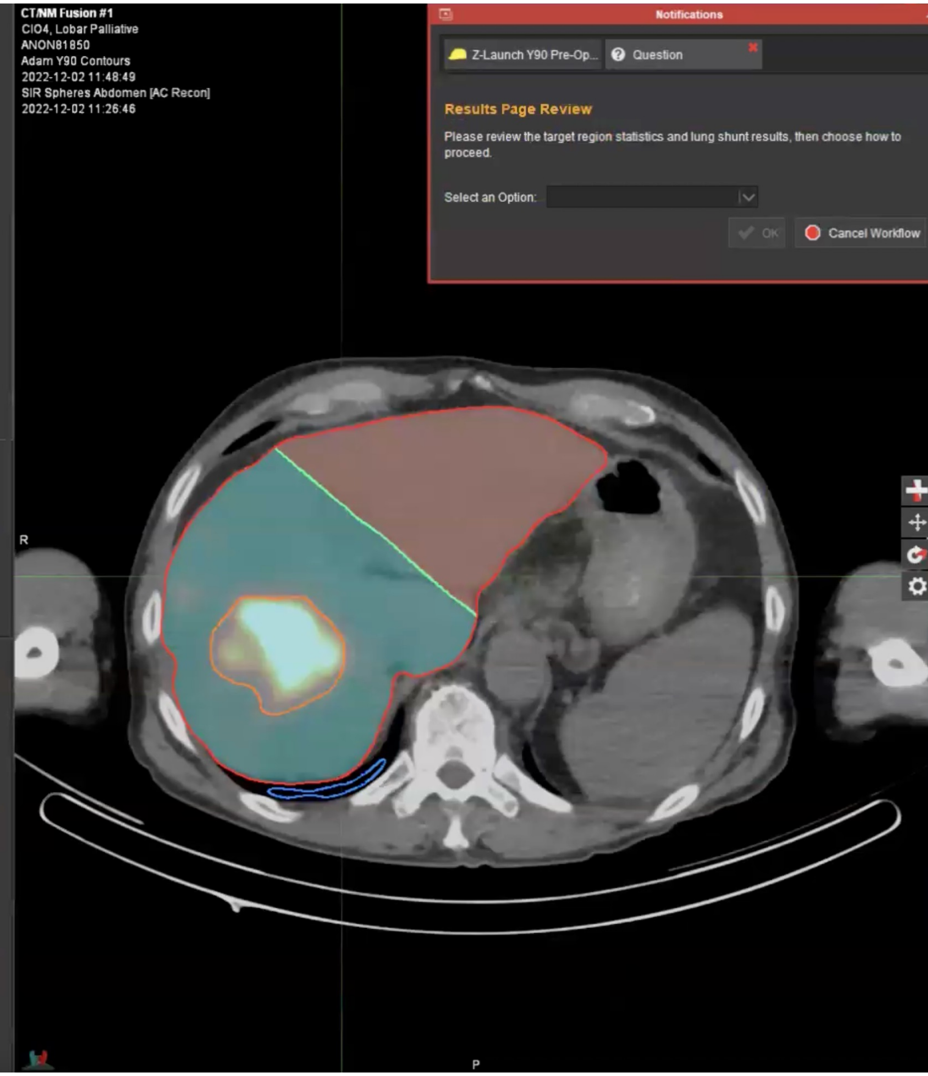


Intraprocedural CT (Mapping)

Target Region Statistics			
Contour Name =	Liver_L	Liver_R	Unit
Target Region Volume =	532.4	1094.86	cc
Percent of Liver Outside Target Region =	67.28	32.72	%
Percent of Liver Inside Target Region =	32.72	67.28	%
Liver Volume =	1627.26		cc
Tumor Involvement =	0	11.2	%
All Tumors (within Target Region) Volume =	0	122.63	cc
Total Tumor TNR =	N/A	10.24	:1
Tumor 1 (within Target Region) Volume =	0	122.63	cc
TNR Tumor 1 =	N/A	10.24	:1

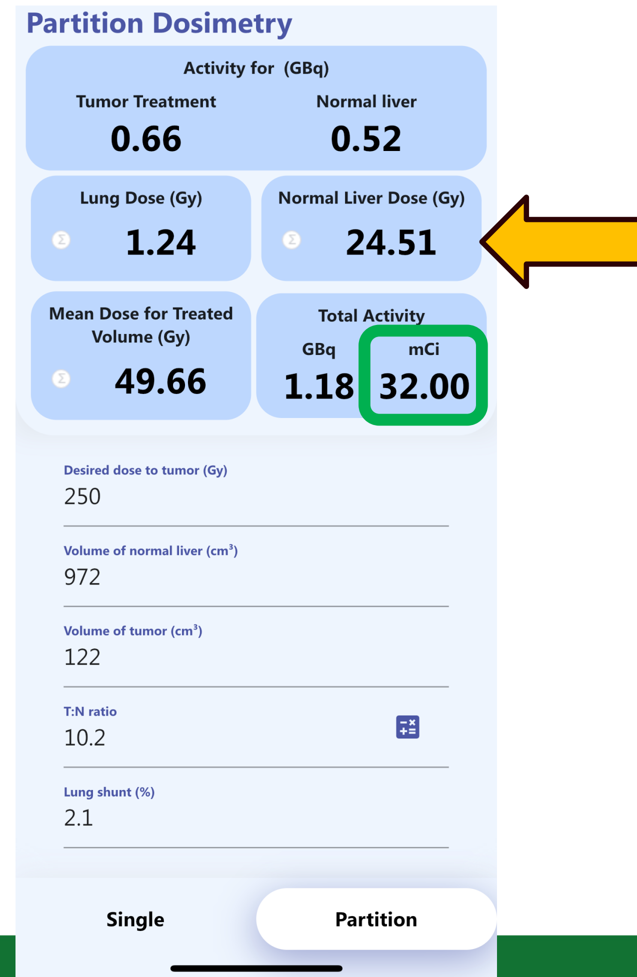
TNR Calculation =	*Tumor Activity (within Target Region) ÷ Tumor Mass (within Target Region)* / *Normal Liver Activity (within Target Region) ÷ Normal Liver Mass (within Target Region)*

Lung Shunt and Volumes		
Lung Shunt =	3.04	%
Lungs Total Counts =	3969.9	kCNTS
Liver Total Counts =	126443.39	kCNTS
Lungs Volume =	3302.18	cc
Liver Volume =	1627.26	cc



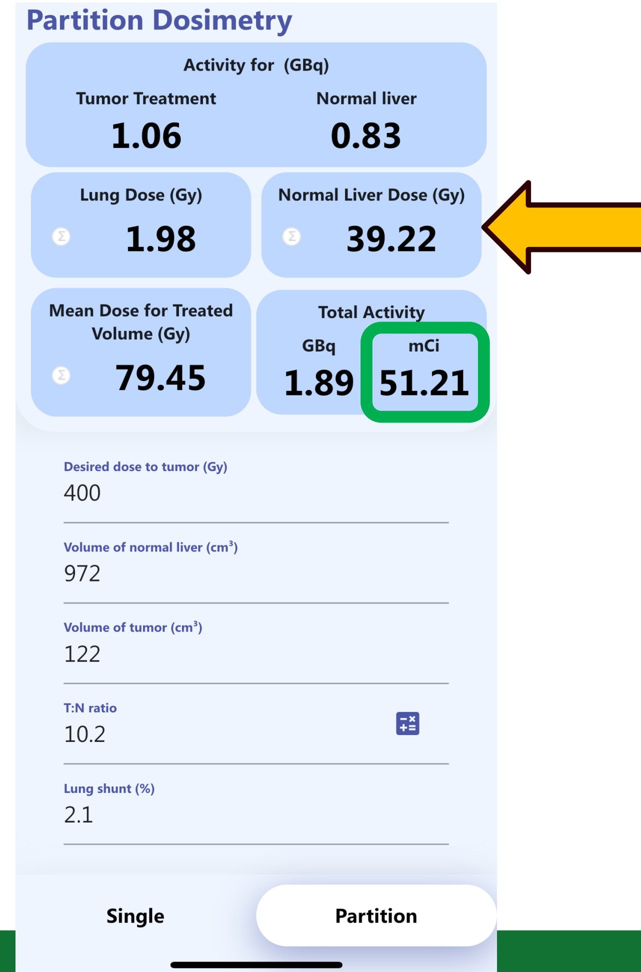
Activity Calculation (Glass)

- The following parameters were used
  - Tumor volume: **<u>122 cc</u>**
  - Right hepatic lobe volume: **<u>972 cc</u>**
  - **<u>TNR: 10.2</u>**
  - **<u>LSF: 2.1%</u>**
  - **<u>Partition Model</u>**
  - Desired non-tumoral liver dose:
    - **<90 Gy (targeted lobe)**
    - **Desired tumor dose: 250 Gy**
  - <u>Prescribed activity: **32 mCi**</u>



Activity Calculation (Glass: Dose Escalation)

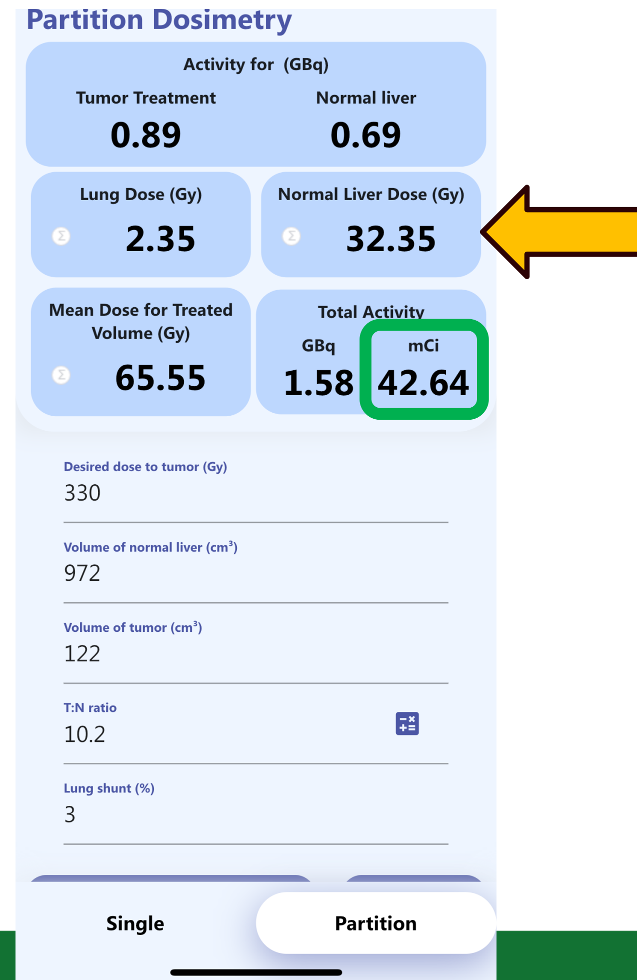
- The following parameters were used
  - Tumor volume: **<u>122 cc</u>**
  - Right hepatic lobe volume: **<u>972 cc</u>**
  - **<u>TNR: 10.2</u>**
  - **<u>LSF: 2.1%</u>**
  - **<u>Partition Model</u>**
  - Desired non-tumoral liver dose:
    - **<90 Gy (targeted lobe)**
    - **Desired tumor dose: 400 Gy**
  - <u>Prescribed activity: **51 mCi**</u>



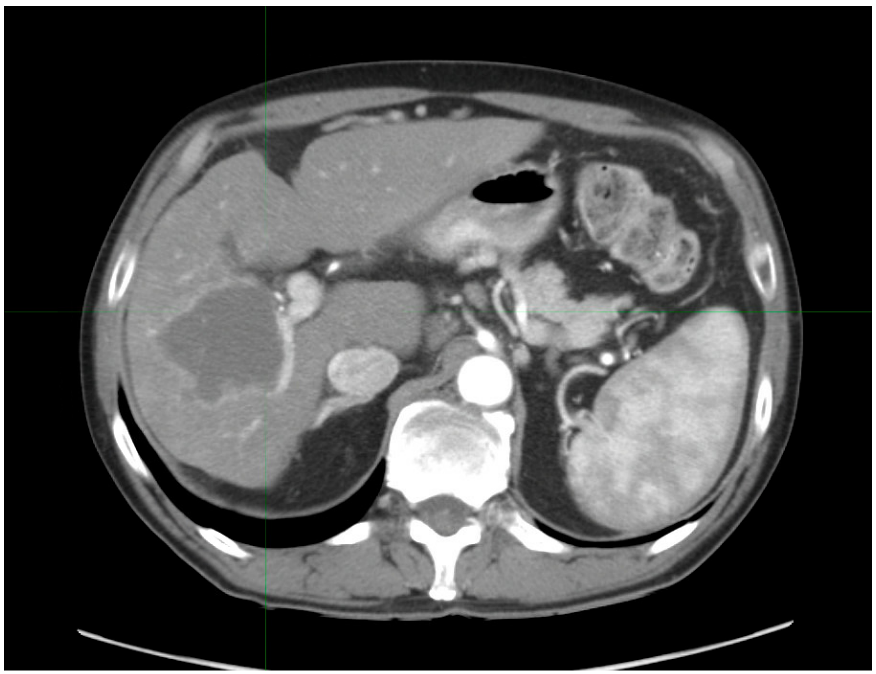
CIO

Activity Calculation (Resin: Dose Escalation)

- The following parameters were used
  - Tumor volume: **122 cc**
  - Right hepatic lobe volume: **972 cc**
  - **TNR: 10.2**
  - **LSF: 2.1%**
  - **Partition Model**
  - Desired non-tumoral liver dose:
    - **<70 Gy (targeted lobe)**
    - **Desired tumor dose: 330 Gy**
  - Prescribed activity: **43 mCi**



F/U CT @ 6 months Post Y90

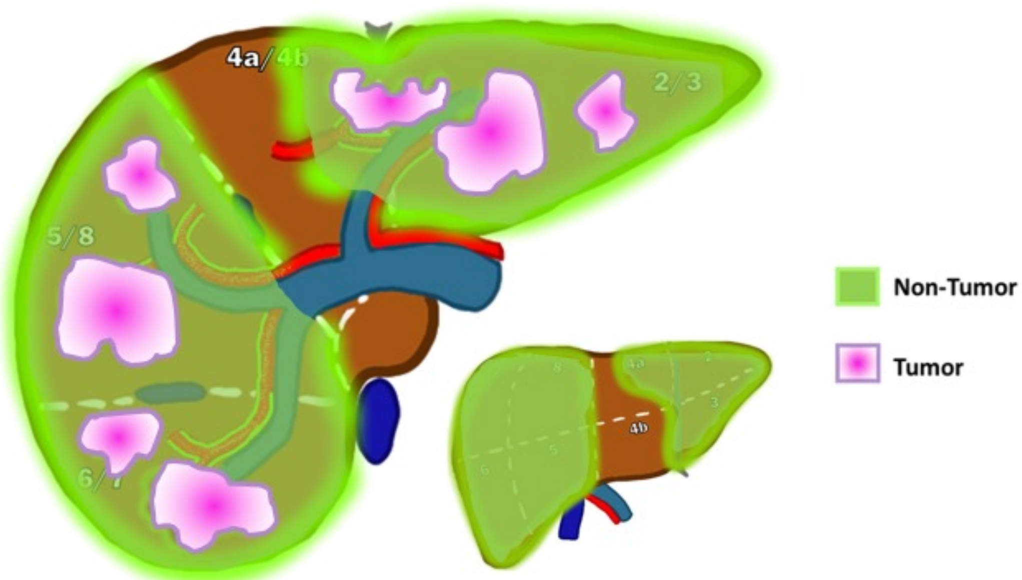


- Treatment cavity
- No residual enhancement
- **Complete response**
- **No grade 2+ treatment-related toxicity @ 6 months**
- **No significant post-radiation changes in the right lobe of the liver**

Multifocal Bilobar HCC (Glass)

Multicompartment (Partition)

- <u>Mean NTAD:</u>
  - <u><40-70 Gy</u>
- Mean TD:
  - >205 Gy (minimum)
  - >250 Gy (ideally)
- <u>Calibration:</u>
  - Late 1st wk or early 2nd week

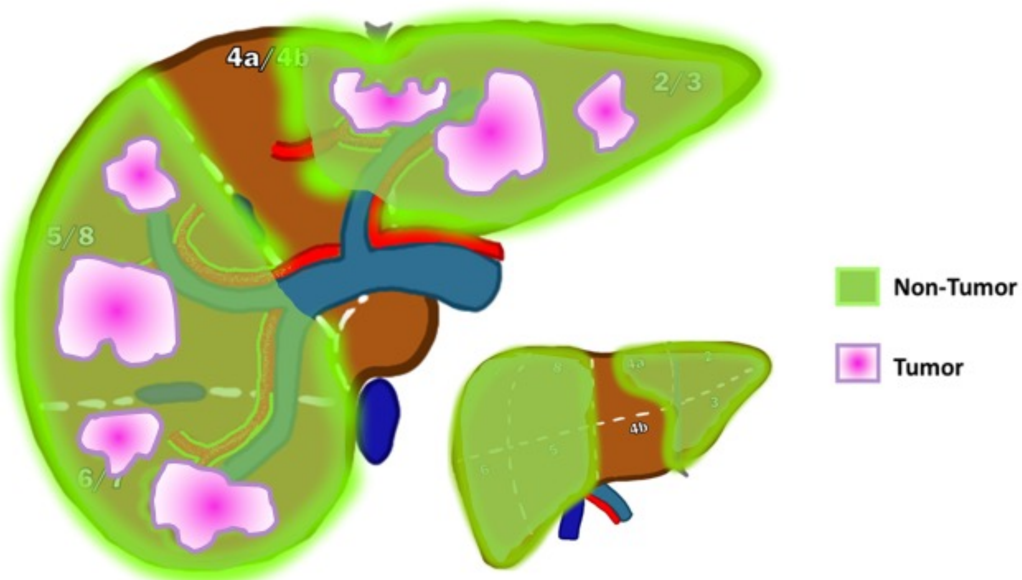


Salem R, et al. *EJNMMI.* 2023;50(2):328-343.

Multifocal Bilobar HCC (Resin)

Multicompartment (Partition)

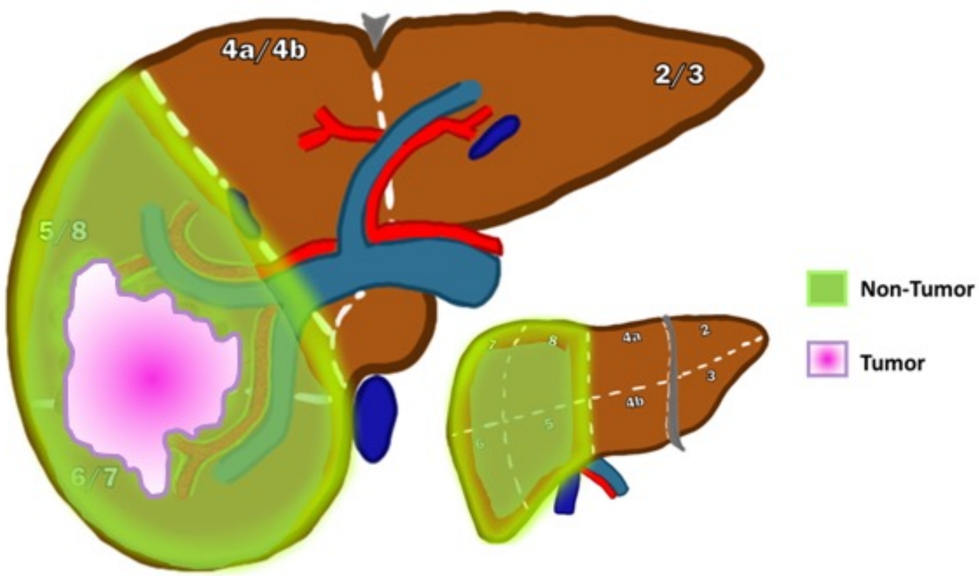
- **Mean NTAD:**
  - **<30-40 Gy**
- **Mean TAD:**
  - **>100 Gy (minimum)**
  - **>150 Gy (ideally)**
- **Calibration:**
  - **1-2 day pre-cal or DOC***



Levillain H, et al. *EJNMMI.* 2021;48(5):1570-1584.

Partition Model: Preferred Dosimetry Approach

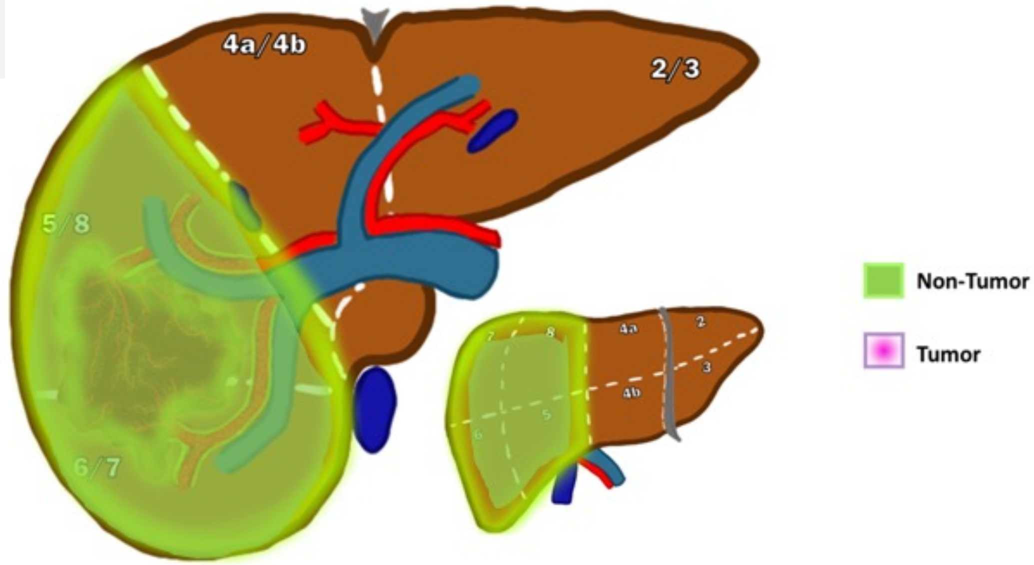
- Liver Function: CP A and ALBI 1
- NTL Dose
  - >70 Gy (Resin)
  - >88 Gy (Glass)
- Tumor(s): Could consider a 2nd Segmental Dose to tumor
  - >300 Gy (Resin)
  - >400 Gy (Glass)
- Calibration
  - Glass: wk 1 (Wednesday) to wk 2 (Tuesday)
  - Resin: DOC or 1-day pre-Cal



Salem R, et al. *EJNMMI.* 2023;50(2):328-343. Levillain H, et al. *EJNMMI.* 2021;48(5):1570-1584.

Single Compartment Dosimetry: Less Preferred

- **Single Compartment (MIRD)**
  - **>80-100 Gy (Resin)**
  - **>140-150 Gy (Glass)**

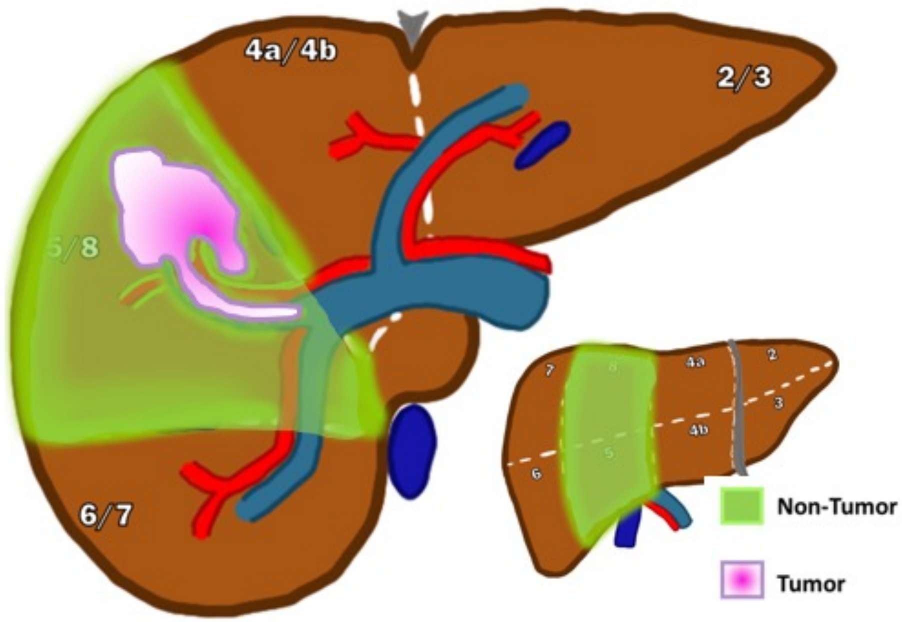


Salem R, et al. *EJNMMI.* 2023;50(2):328-343. Levillain, et al. Levillain H, et al. *EJNMMI.* 2021;48(5):1570-1584.

Tumor with Macrovascular Invasion

- **Segmental: Rad Segmentectomy**
- **Unilobar: Rad lobectomy (partition)**
- **Bilobar: Biloboar w/o MVI (partition)**

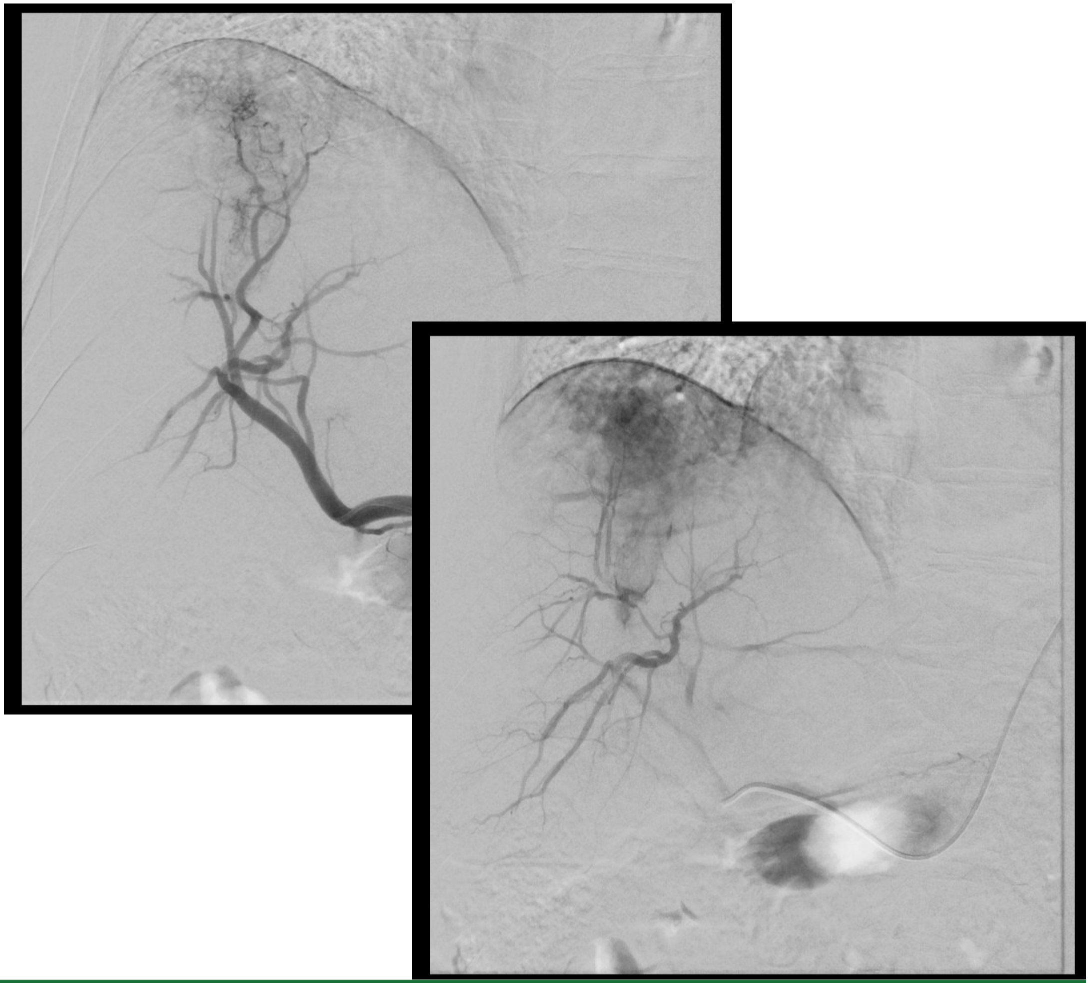
- **Key: Arterial Enhancement and/or Tc99-MAA uptake on mapping**



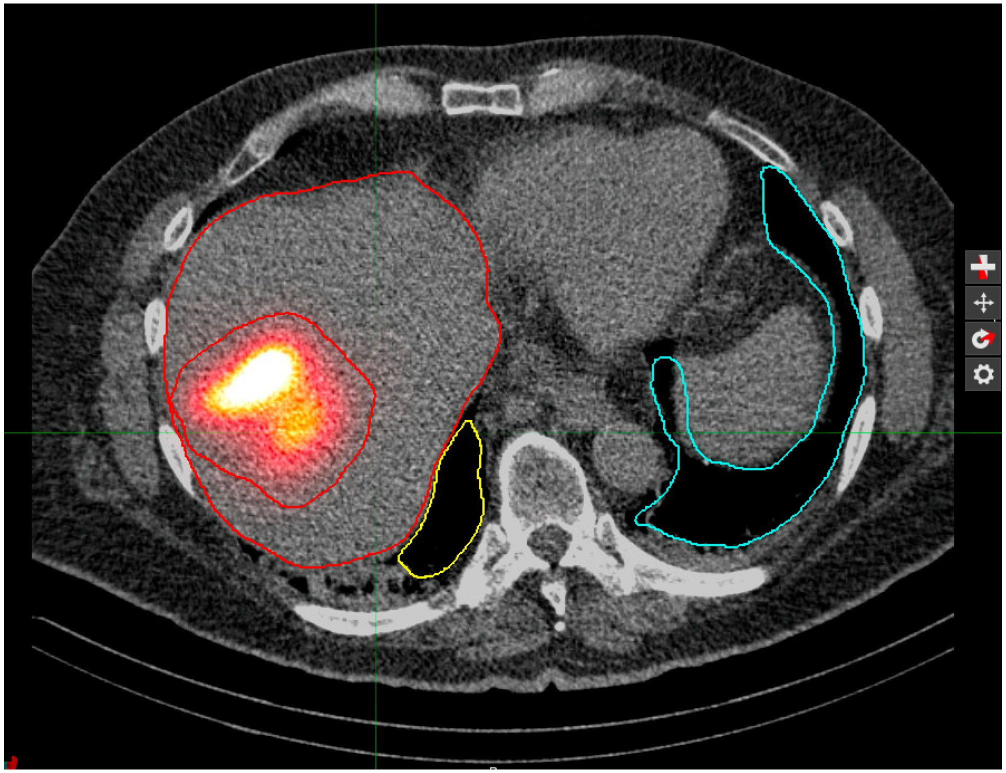
CIO

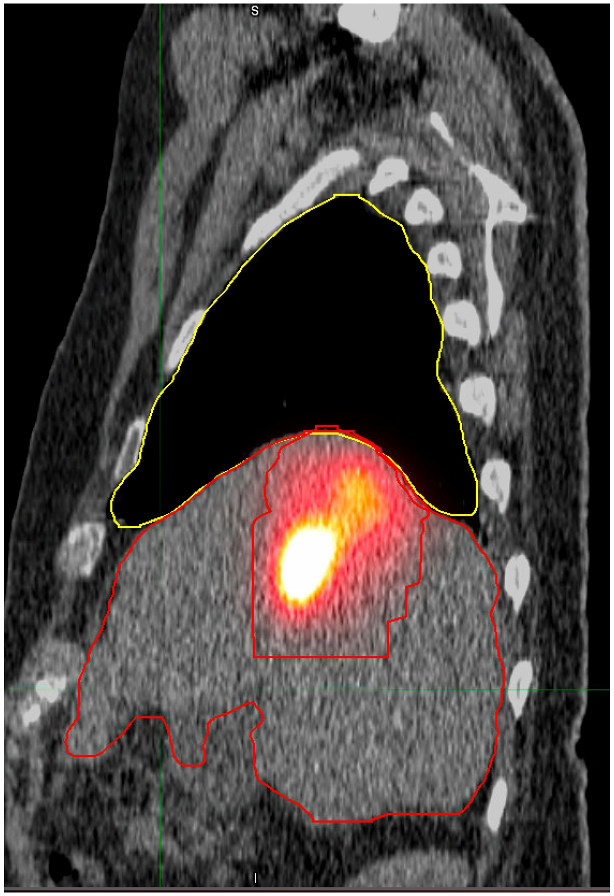
Case: HCC w/ MVI

- 67-year-old Male
- 3.6 cm HCC (Seg 8) w/ PVT
- CP A
- ECOG 0

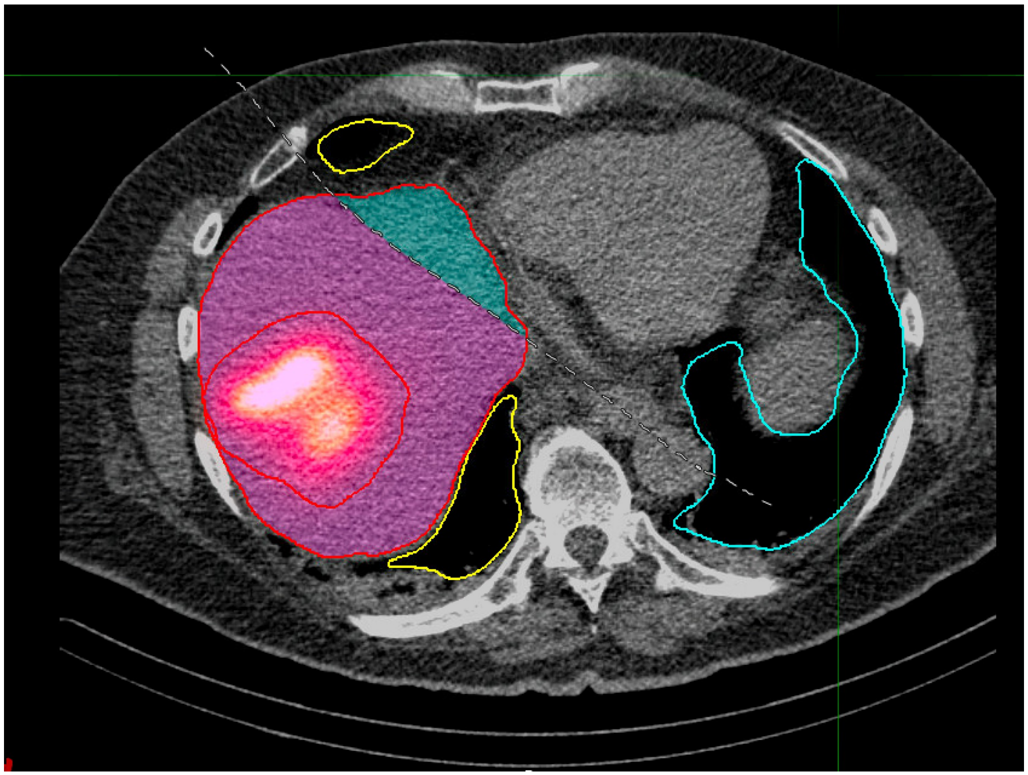


MAA SPECT/CT





MAA SPECT/CT

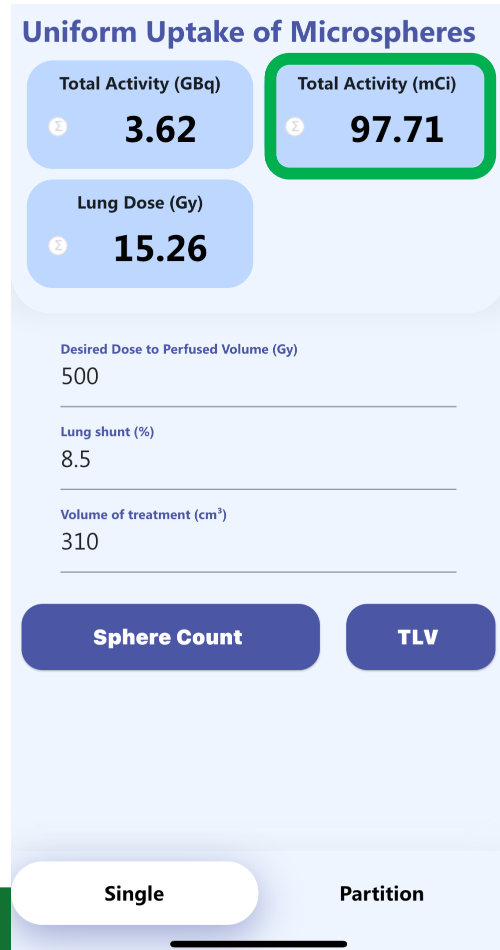


Target Region Statistics			
Contour Name =	Liver_L	Liver_R	Unit
Target Region Volume =	762.97	1879.95	cc
Percent of Liver Outside Target Region =	71.13	28.87	%
Percent of Liver Inside Target Region =	28.87	71.13	%
Liver Volume =	2642.92		cc
Tumor Involvement =	0	16.51	%
All Tumors (within Target Region) Volume =	0	310.29	cc
Total Tumor TNR =	N/A	40.21	:1
Tumor 1 (within Target Region) Volume =	0	310.29	cc
TNR Tumor 1 =	N/A	40.21	:1

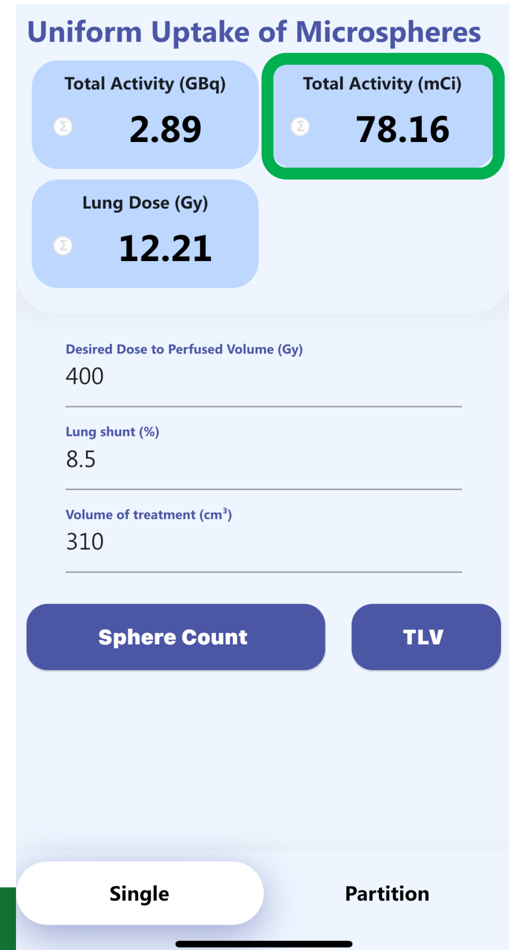
Lung Shunt and Volumes		
Lung Shunt =	8.46	%
Lungs Total Counts =	5032.45	kCNTS
Liver Total Counts =	54470.24	kCNTS
Lungs Volume =	2863.95	cc
Liver Volume =	2642.92	cc

Dosimetry Planning

Glass



Resin



Take Home Points

- **Personalized Y90 is key to success in HCC**
- Always keep in mind the **treatment goal**
- **Segmentectomy:** Single compartment (T/N = 1)
- **Everything Else:** Multicompartment (Partition)
- **Particle Density Matters to achieve CR and CPN in Resin**
  - **No convincing evidence on Glass side so far**

Getting the Particles Where You Want Them:
Advanced Flow Diversion Techniques

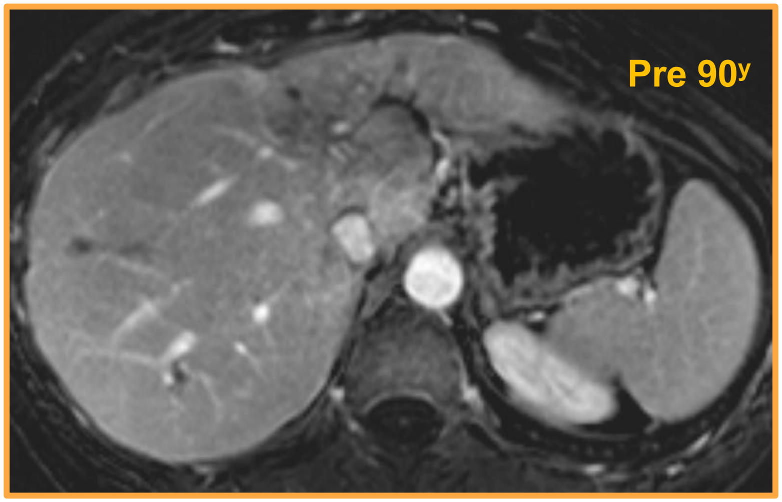
Jacob Core, DO
Vascular and Interventional Radiology, Assistant Professor
Mayo Clinic Florida

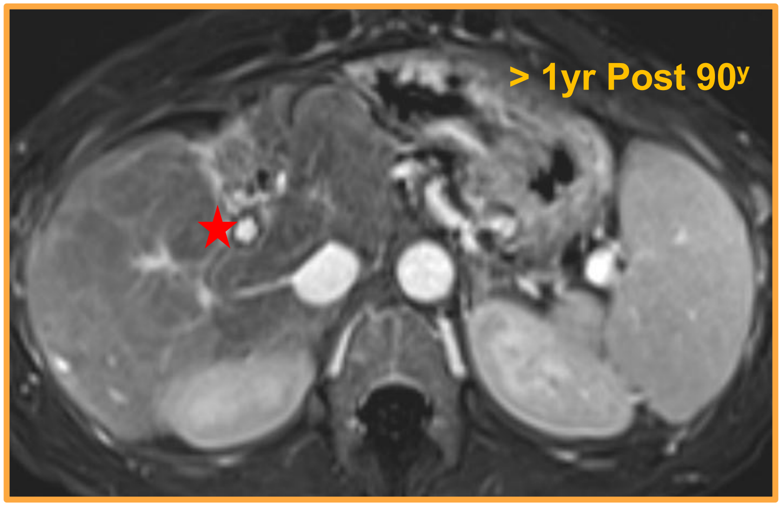
MAYO CLINIC

CIO

Early years of radioembolization showed that large-volume radioembolization can lead to hepatic failure

Whole Liver Resin 90y @ 0.9GBq





Radiation-Induced Liver Disease (RILD)

Increased age, elevated baseline serum bilirubin (**ALBI**), **Whole Liver 90^{y}**, and baseline **cirrhosis** in earlier literature have shown to be predictors of RILD risk following radioembolization[1,2]

Cirrhosis	Treatment	Prior Chemo	Standard Protocol (n=75) All Cases	Standard Protocol (n=75) CTC≥3	Modified Protocol (n=185) All Cases	Modified Protocol (n=185) CTC≥3
No Cirrhosis			10/51 (19.6%)	7	4/121 (3.3%)*	2**
	Whole-liver	No Chemo	1/6 (16.7%)	1	0/20	0
		Chemo	9/31 (29.0%)	6	4/52 (7.7%)**	2**
	Selective	No Chemo	0/9		0/21	
		Chemo	0/5		0/28	
	Global disease control		28 (54.9%)		58 (47.9%)	
	Local disease control		32 (62.7%)		72 (59.5%)	
Cirrhosis			7/24 (29.1%)	3	6/64 (9.3%)**	2
	Whole-liver	No Chemo	3/9 (33.0%)	1	0/5	0
		Chemo	2/2 (100%)	1	1/1 (100%)	0
	Selective	No Chemo	2/13 (15.4%)	1	5/57 (8.8%)	2
		Chemo	–		0/1	
	Global disease control		18 (75%)		46 (71.9%)	
	Local disease control		18 (75%)		51 (79.7%)	

*$P < 0.001$ for comparison with standard protocol group.
**$P < 0.05$ for comparison with standard protocol group. CTC: grade by NCI Common Toxicity Criteria v. 3.0.

[1]Riaz A, et al. Complications following radioembolization with yttrium-90 microspheres: A comprehensive literature review. *J Vasc Interv Radiol.* 2009;20(9):1121–1130.
[2]Gil-Alzugaray B, et al. Prognostic factors and prevention of radioembolization-induced liver disease. *Hepatology.* 2013;57(3):1078–1087.

Modern radioembolization technique involves segmental or superselective administrations unless lobar delivery is necessary for best clinical outcome

RADIATION SEGMENTECTOMY: A NOVEL APPROACH TO INCREASE SAFETY AND EFFICACY OF RADIOEMBOLIZATION

AHSUN RIAZ, M.D.,* VANESSA L. GATES, M.S.,* BASSEL ATASSI, M.D.,*
ROBERT J. LEWANDOWSKI, M.D.,* MARY F. MULCAHY, M.D.,† ROBERT K. RYU, M.D.,*
KENT T. SATO, M.D.,* TALIA BAKER, M.D.,‡ LAURA KULIK, M.D.,† RAMONA GUPTA, M.D.,*
MICHAEL ABECASSIS, M.D.,‡ AL B. BENSON, III, M.D.,† REED OMARY, M.D.,* LAURA MILLENDER, M.D.,§
ANDREW KENNEDY, M.D.,|| AND RIAD SALEM, M.D.*‡

However, complex/unfavorable blood supply may not allow for selective infusions

Riaz A, et al. Radiation segmentectomy: A novel approach to increase safety and efficacy of Radioembolization. *Int J Radiat Oncol Biol Phys.* 2011;79(1):163-171.

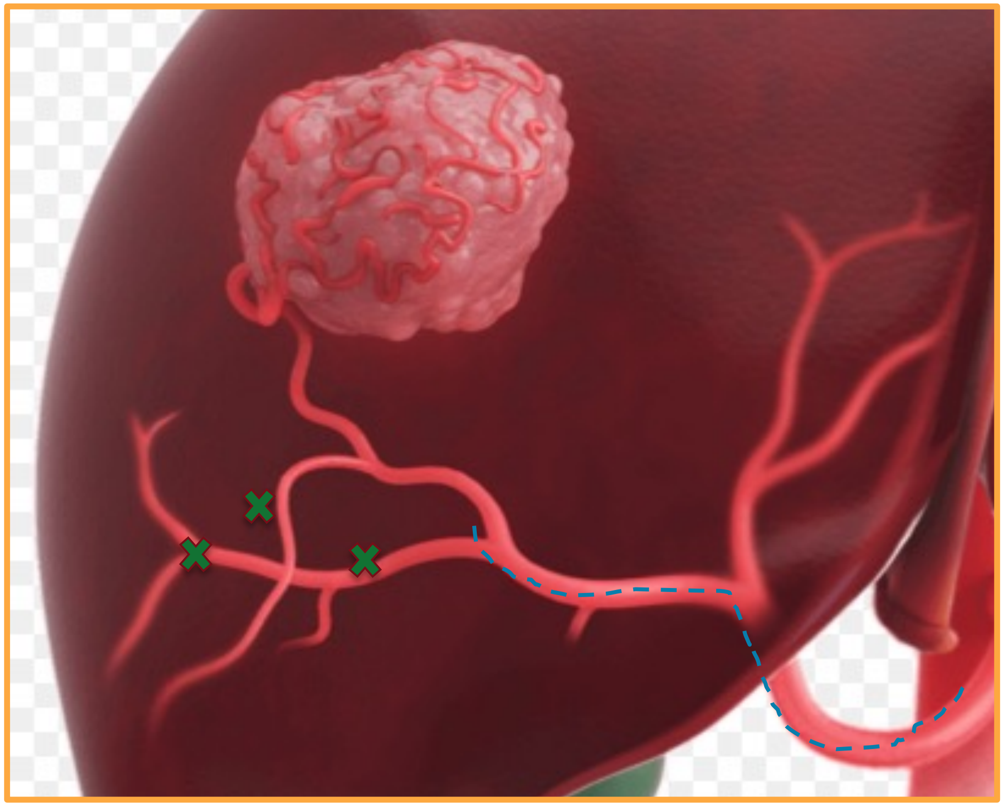
Flow Diversion and Flow Redistribution

Definitions

- Flow Diversion – Technique to promote blood (and dose) to the intended treatment bed and mitigate toxicity to non-target tissue
- Flow Redistribution – Technique that typically involves occlusion of a tiny tumor supplying artery(s) to promote flow and coverage via a larger feeder artery to the intended treatment bed
- Proximal Radioembolization Enabled by Distal Angiosomal Trunctation (PREDATr)

[1]Kim HC. Radioembolization: Technical tips and follow-up imaging. *J Korean Soc Radiol.* 2025;86(4):457. [2]Core JM, et al. Increasing yttrium-90 dose conformality using proximal radioembolization enabled by distal angiosomal truncation for the treatment of hepatic malignancy. *J Vasc Intervent Radiol.* 2020;31(6);934-942.

Does PREDATr result in increased particle deposition in the tumor bed and reduce deposition in non-target tissue?



[1]What is hepatocellular carcinoma? Cleveland Clinic. Last reviewed Feb. 2, 2024. Accessed Oct. 17, 2025. https://my.clevelandclinic.org/health/diseases/21709-hepatocellular-carcinoma-hcc [2]Core JM, et al. Increasing yttrium-90 dose conformality using proximal radioembolization enabled by distal angiosomal truncation for the treatment of hepatic malignancy. *J Vasc Interv Radiol.* 2020;31(6):934-942.

CIO

Temporary distal balloon occlusion for hepatic embolization: a novel technique to treat what cannot be selected

Michael W Itagaki [1]

Affiliations + expand

PMID: 24322307 DOI: 10.1007/s00270-013-0816-7

Cardiovasc Intervent Radiol (2017) 40:1624–1630
DOI 10.1007/s00270-017-1688-z

CIRSE CrossMark

TECHNICAL NOTE

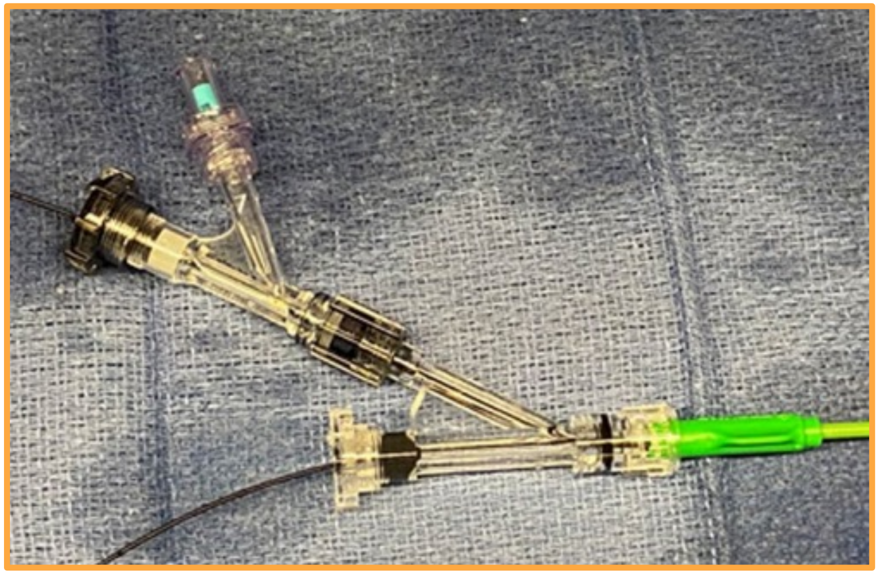
Prophylactic Temporary Occlusion of the Cystic Artery Using a Fibered Detachable Coil During ^{90}Y Radioembolization

Jin Woo Choi[1] · Min Young Yoo[2,3] · Hyo-Cheol Kim[1] · Jin Chul Paeng[3] · Yoon Jun Kim[4] · Jin Wook Chung[1]

CIO

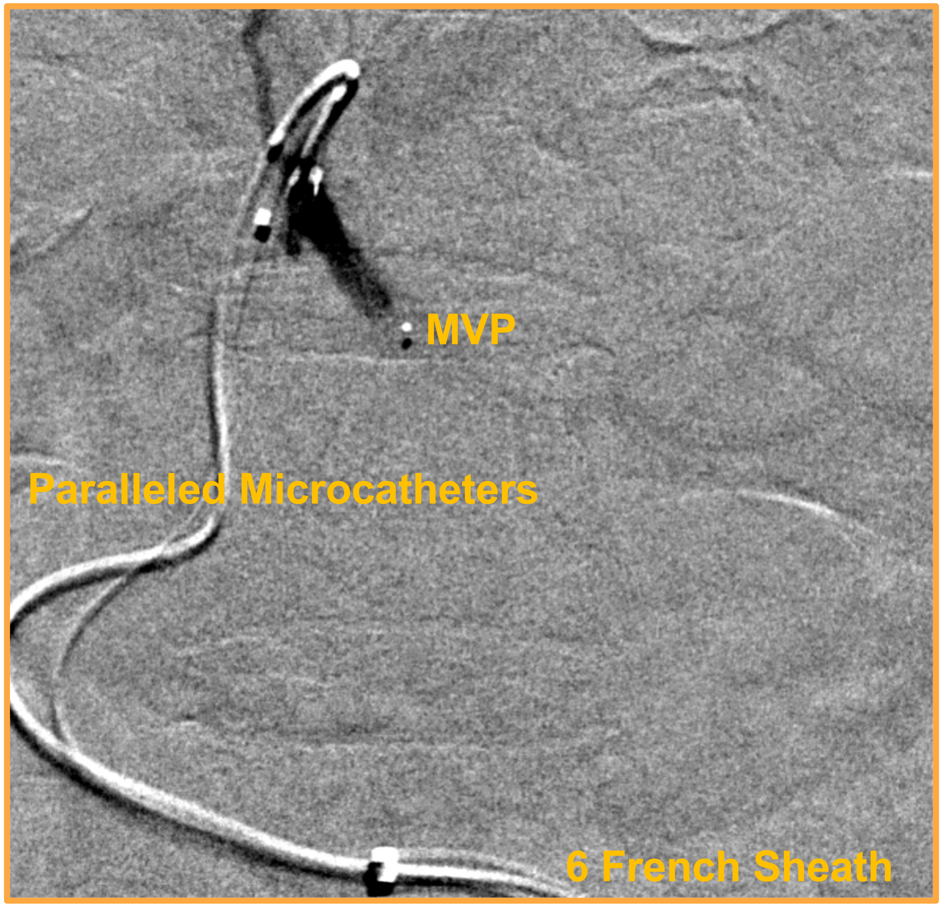
Temporary Occlusion Devices and Technique

- Microvascular Plug (Medtronic™)
- Retrievable Coil (Concerto™, Covidien)
- Gelatin Slurry (Gelfoam®) (Surgifoam™, Ethicon)
- Balloon Microcatheter (Sniper™, Embolx)
- Balloon Microcatheter + Gelfoam
- Double Balloon Microcatheter Technique
- Degradable Starch Microspheres (Embocept-S®, PharmaCept)



[1]Barth KH, et al: Long-term follow-up of transcatheter embolization with autologous clot, oxycel, and Gelfoam in domestic swine. *Invest Radiol.* 1977;12(3):273-280. [2]Tanaka M, et al. The double-balloon technique: A safe and effective adjunctive technique in patients undergoing arterial therapy for hepatic malignancies with vascular supply not amenable to selective administration. *CVIR Endovasc.* 2023;6(1):3.

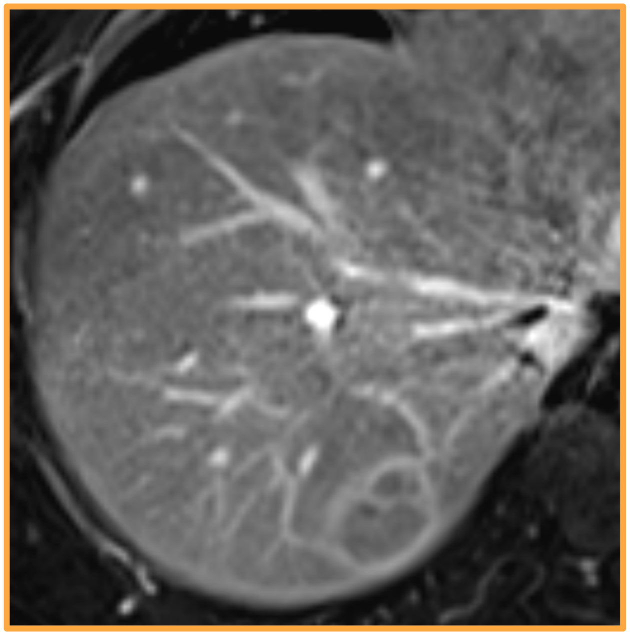
CIO

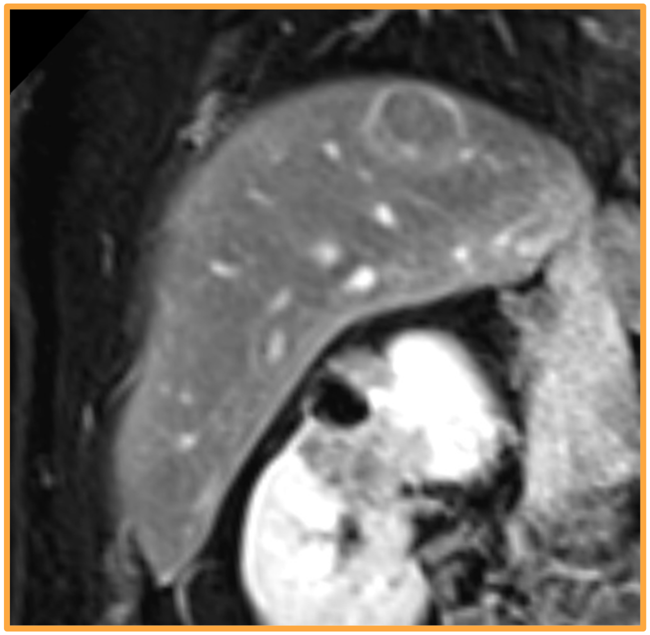

MVP
Paralleled Microcatheters
6 French Sheath

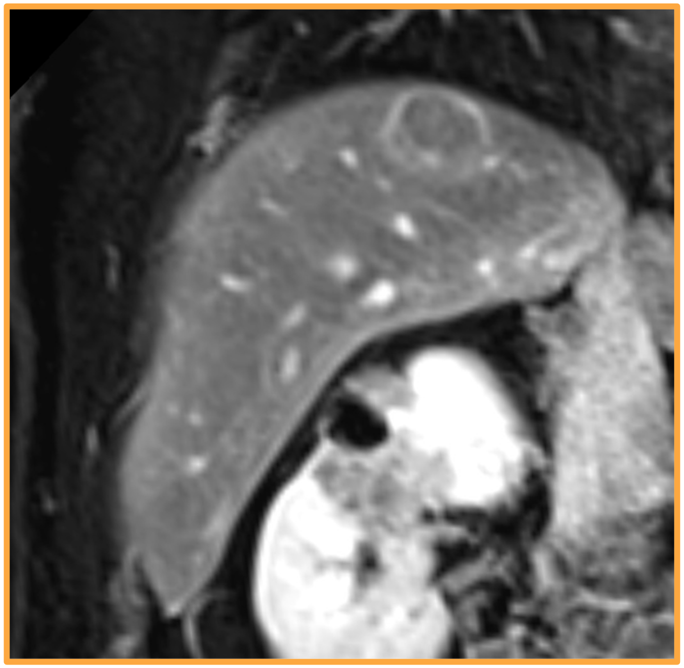
Case Examples

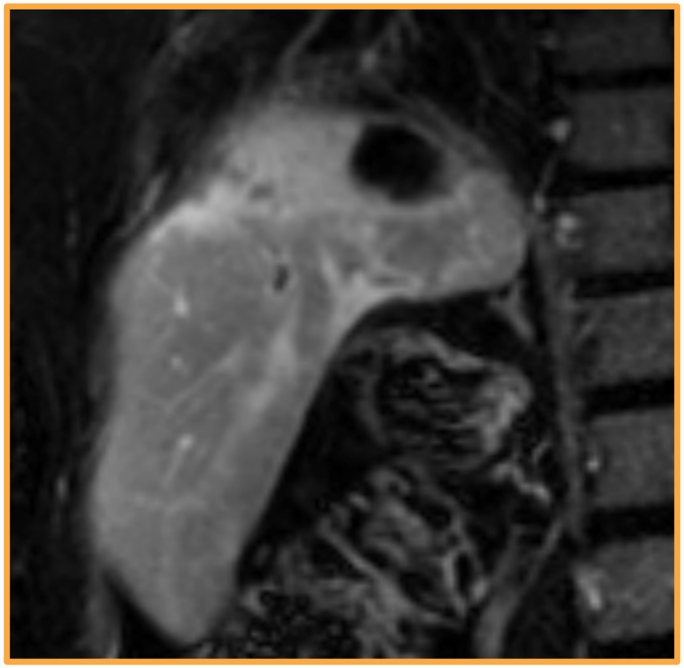
Special thanks to my partners Beau Toskich MD, Andrew Lewis MD, Gregory Frey MD, Ricardo Paz Fumagalli MD, and Zlatko Devcic MD, and Charles Ritchie MD

Balloon Microcatheter



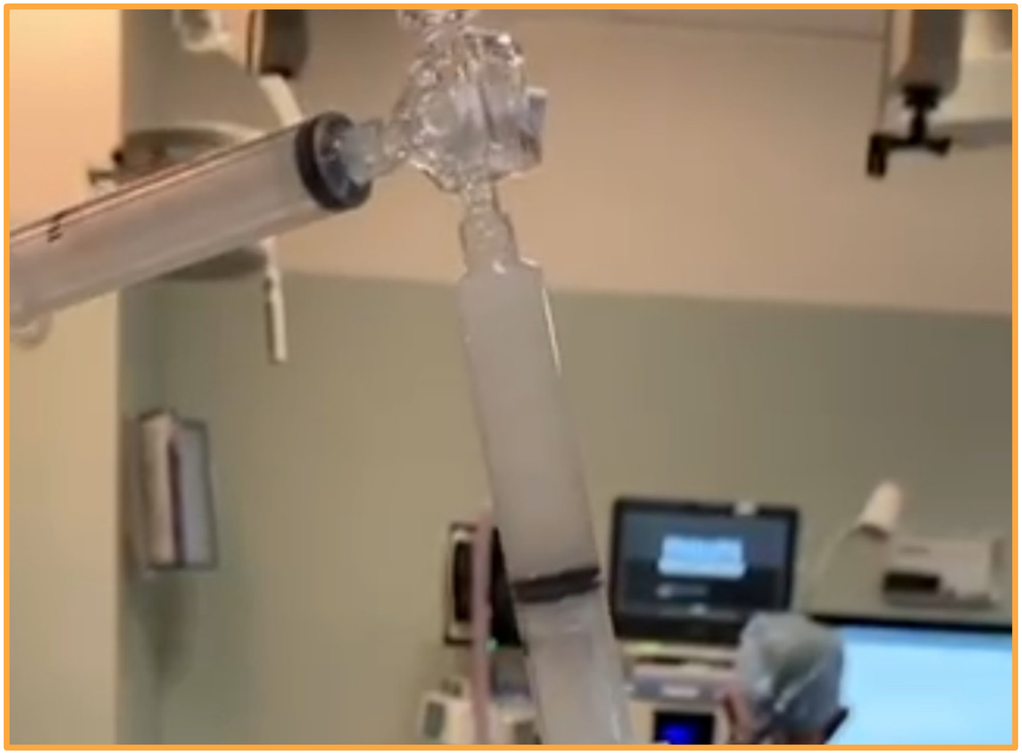


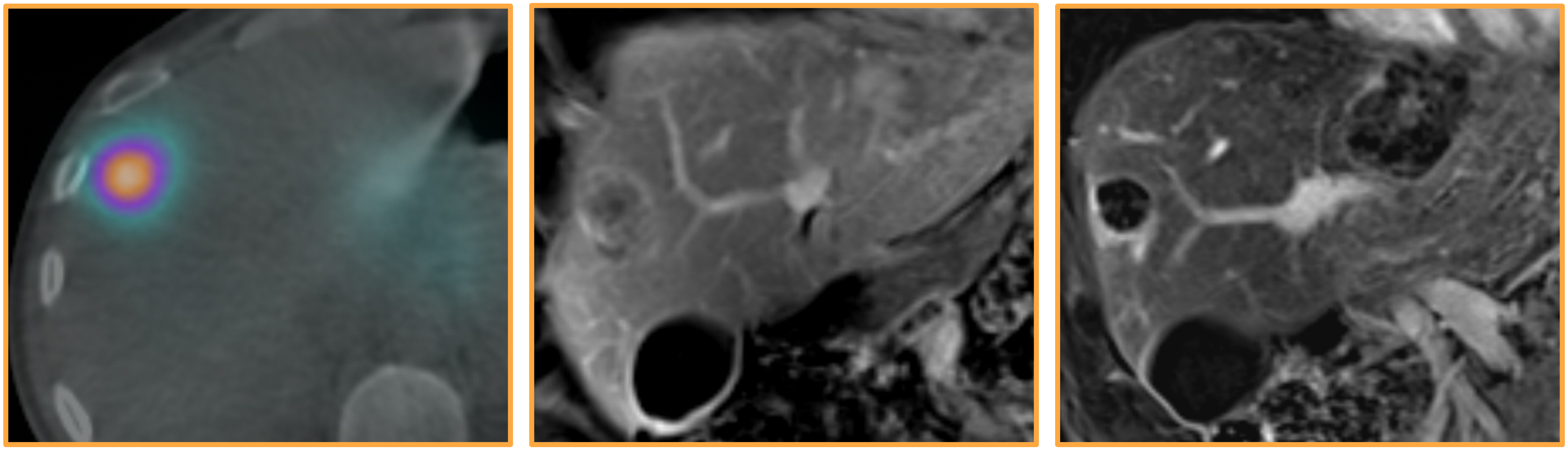




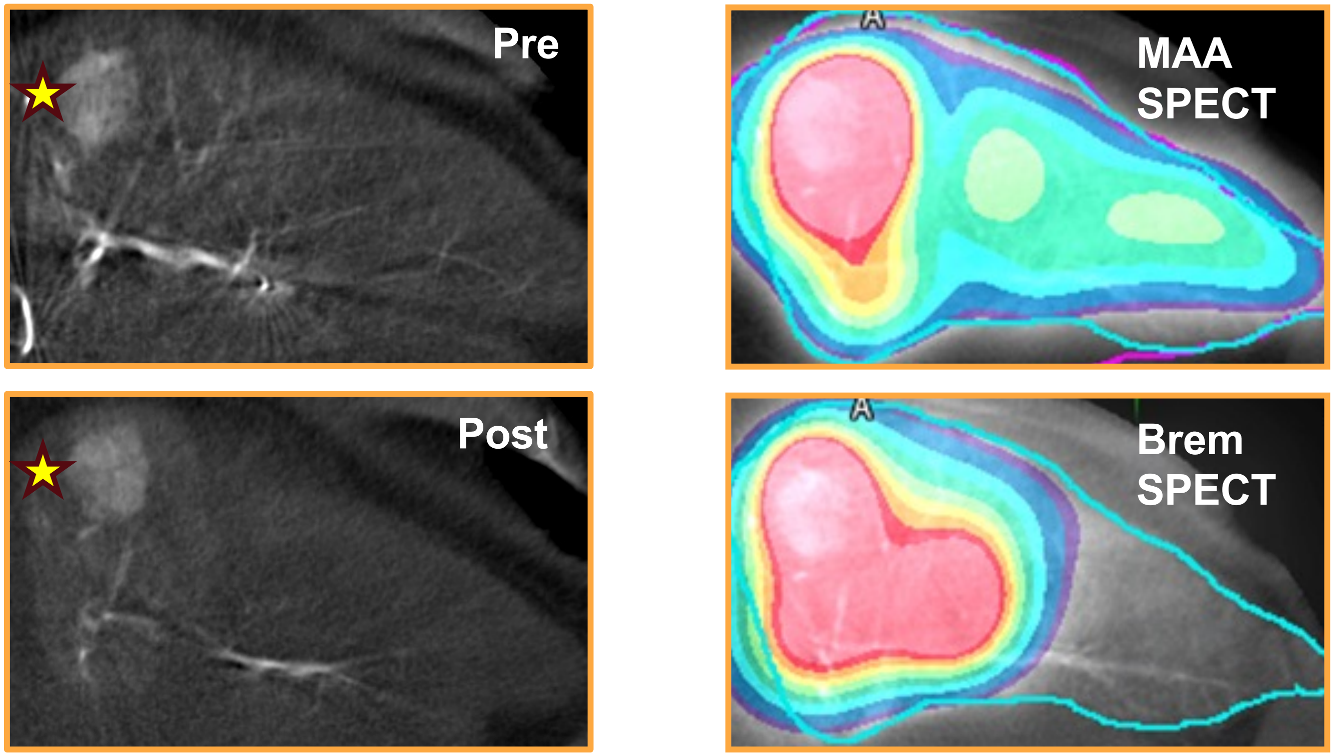
Gelfoam

- 2 10cc syringes
- 10 mL of 100% contrast
- Fine pledgets
- Evacuate ALL air bubbles
- Distal catheterization to reduce reflux into tx vessel
- Flush 3x
- Check result with DSA

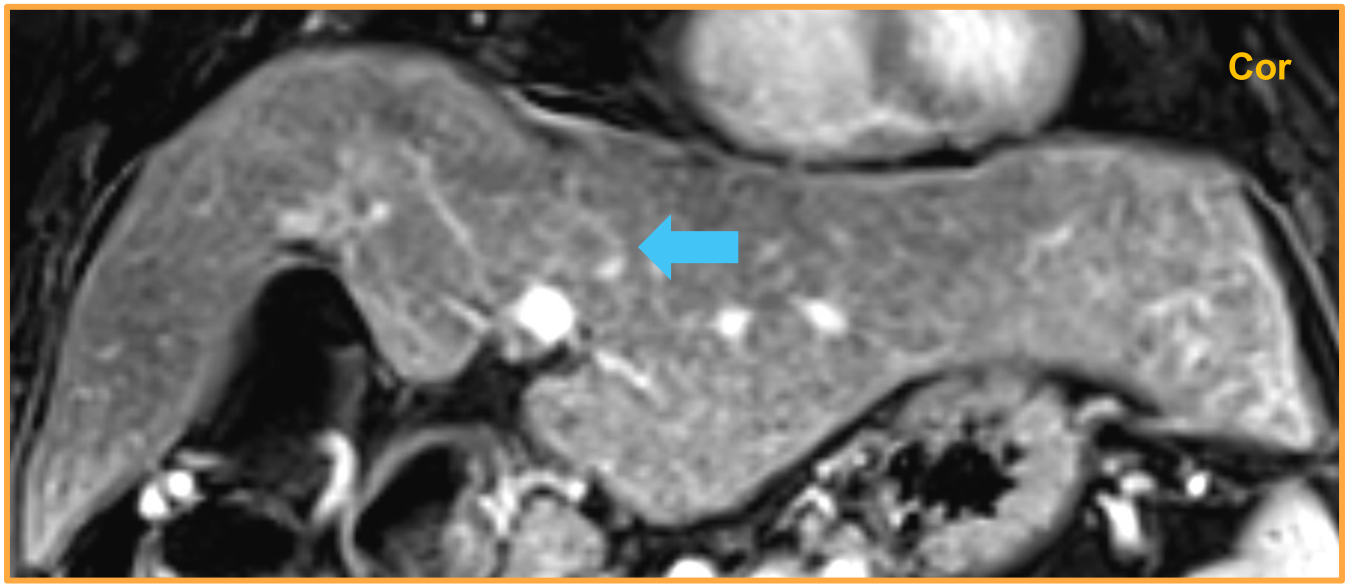


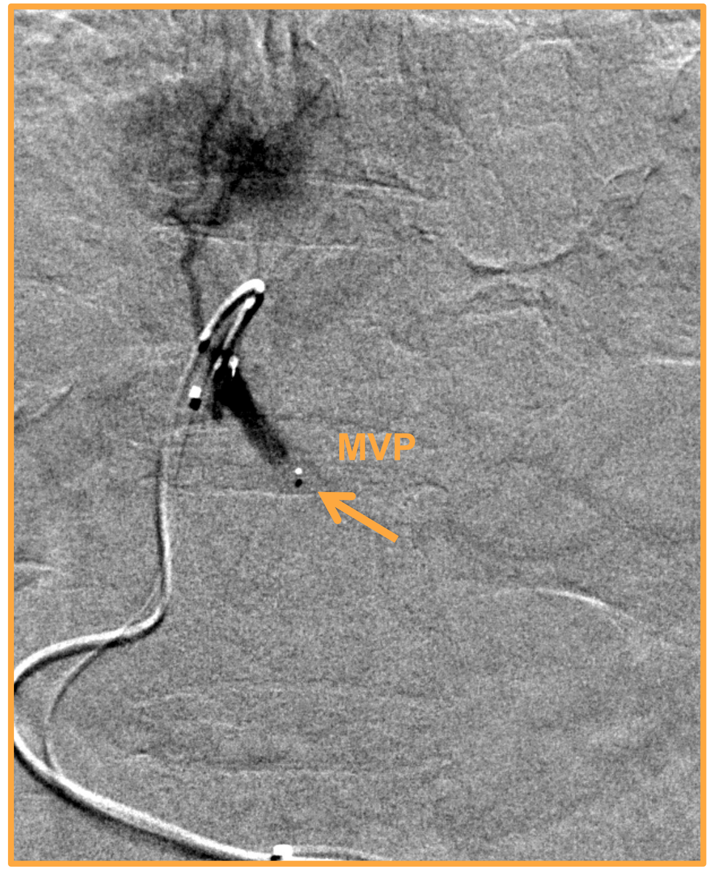


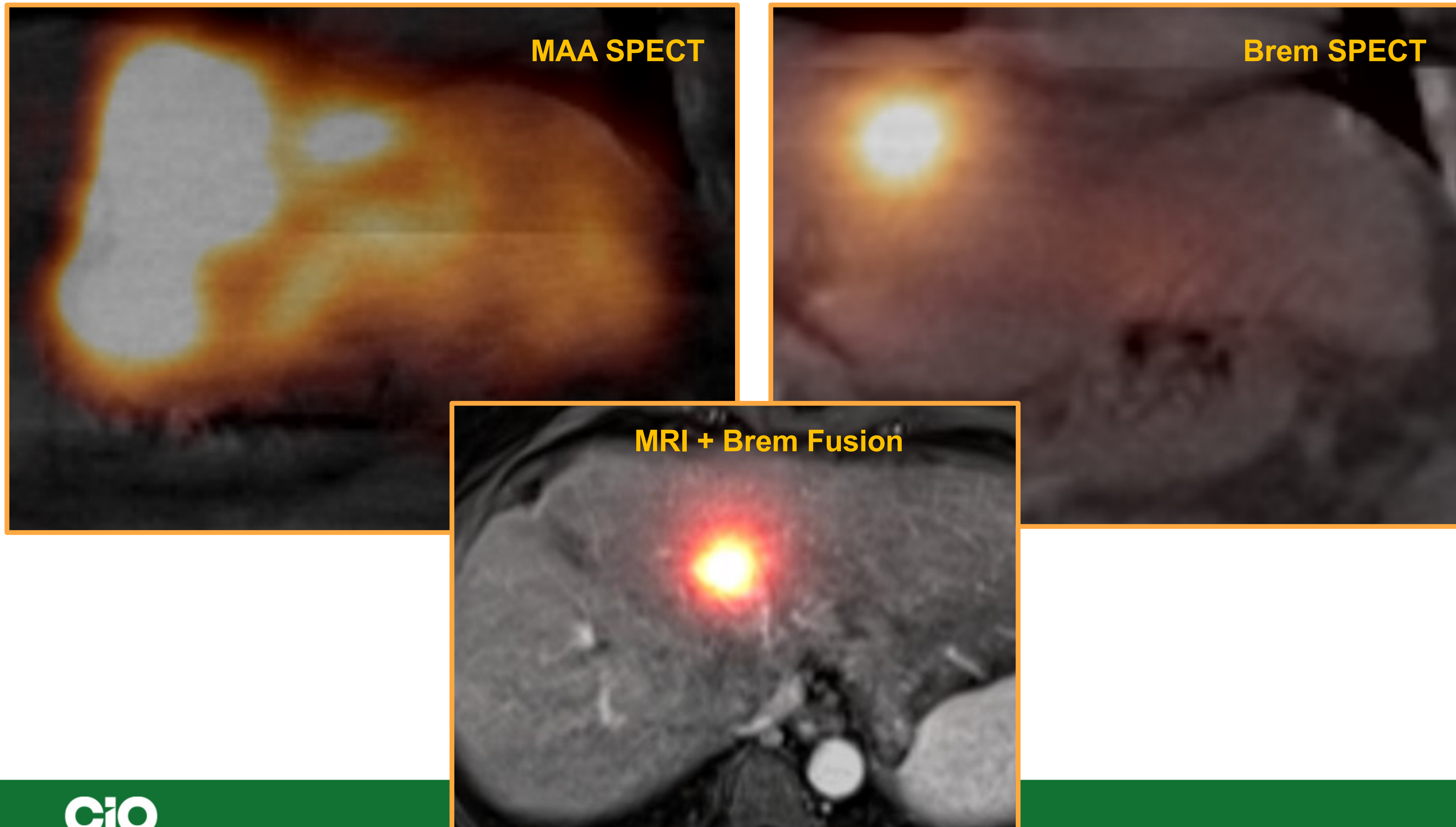
Balloon-Assisted Gelfoam Delivery

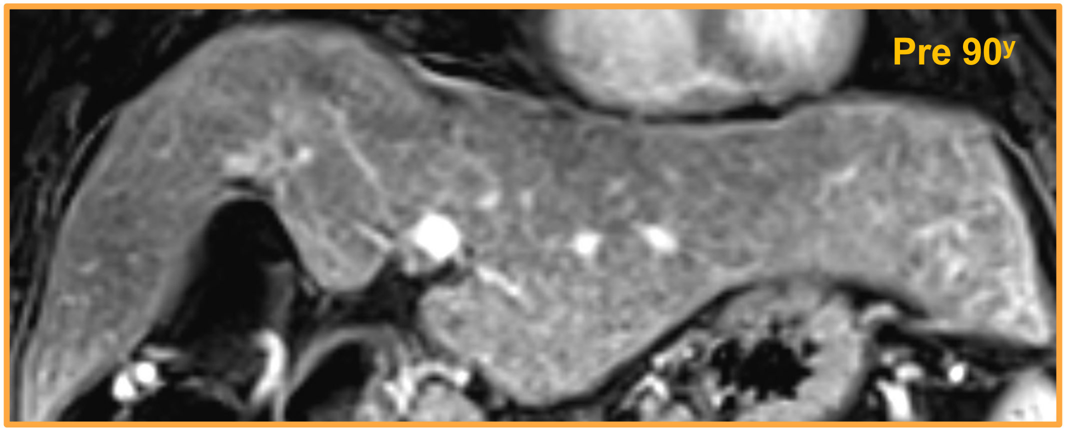


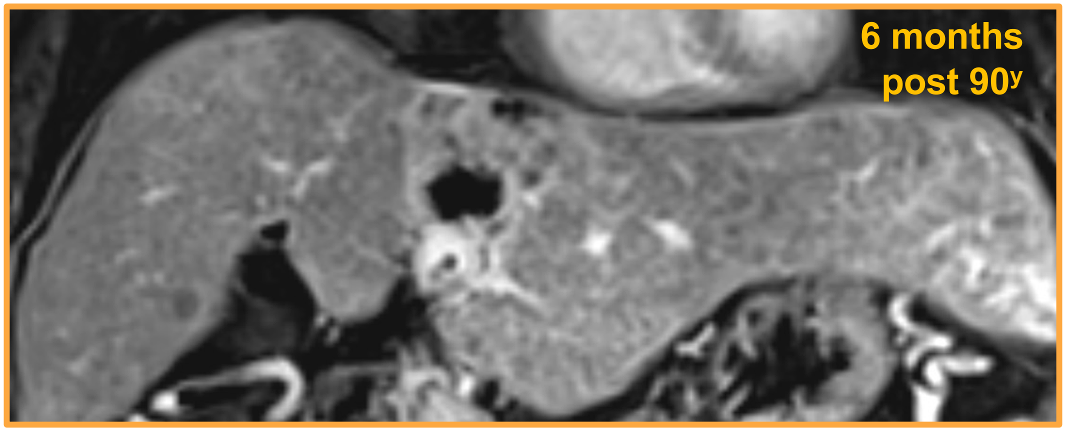
Microvascular Plug




MVP

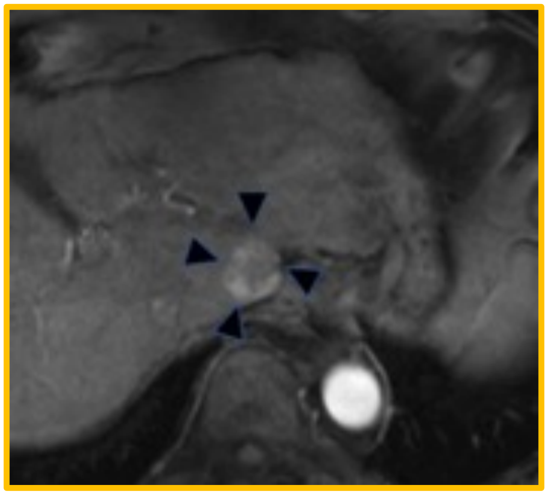

MAA SPECT
Brem SPECT
MRI + Brem Fusion

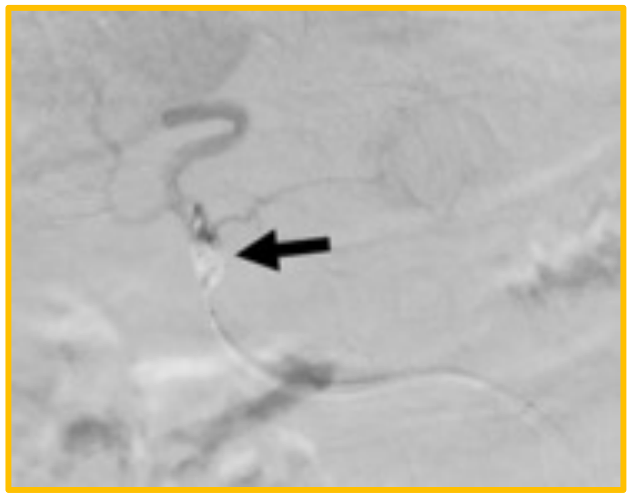

Pre 90^{y}

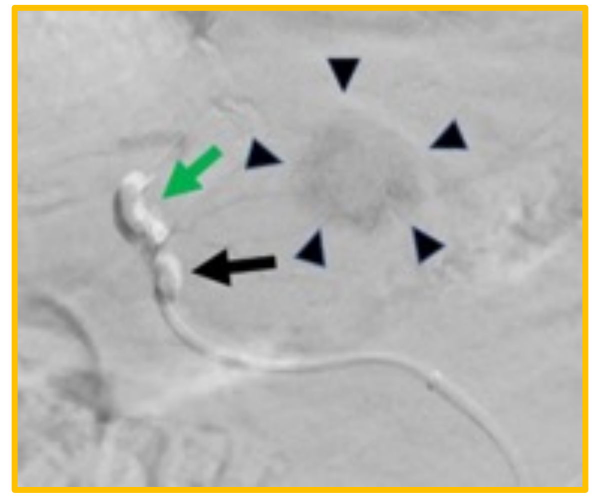

6 months
post 90^{y}

Double Balloon Microcatheter Technique

Distal and proximal protection







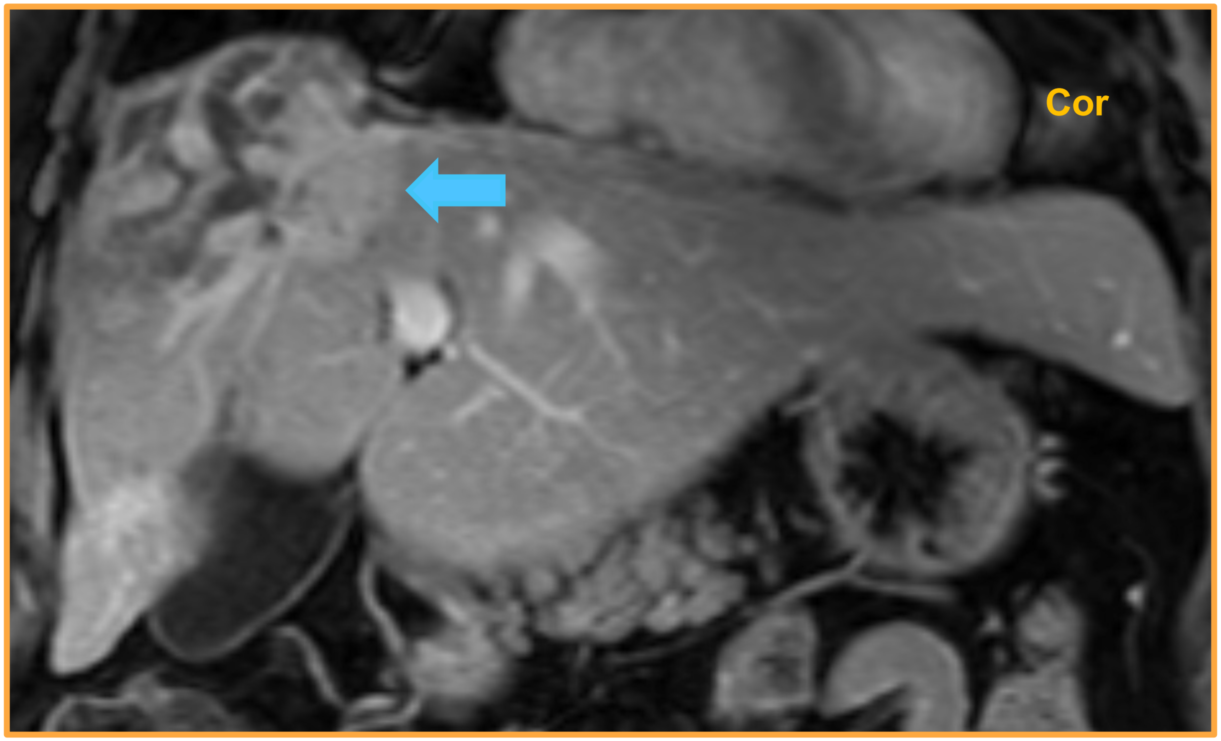
Tanaka M, et al. The double-balloon technique: A safe and effective adjunctive technique in patients undergoing arterial therapy for hepatic malignancies with vascular supply not amenable to selective administration. *CVIR Endovasc.* 2023;6(1):3.

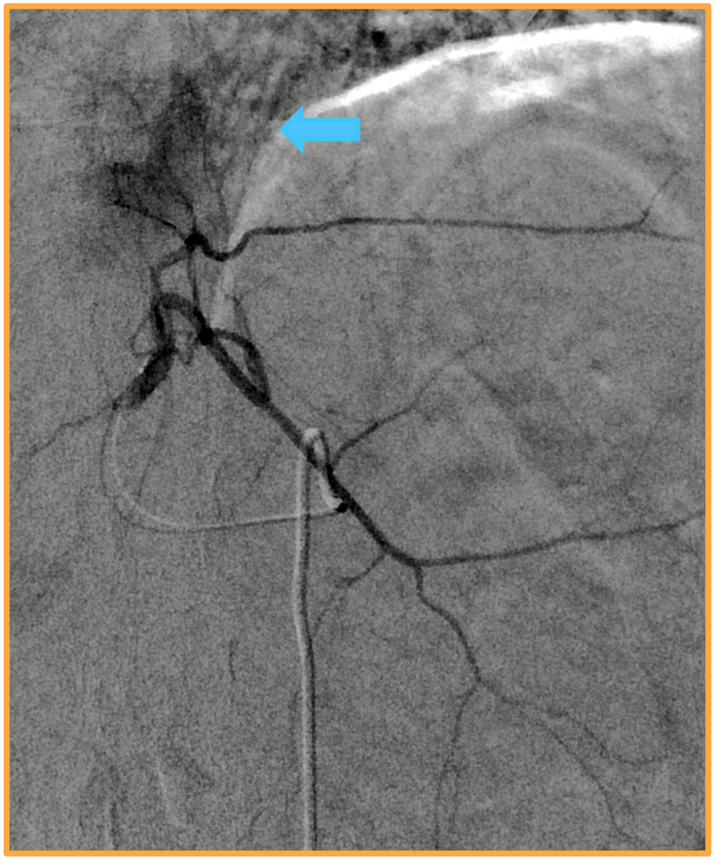
Degradable Starch Microspheres

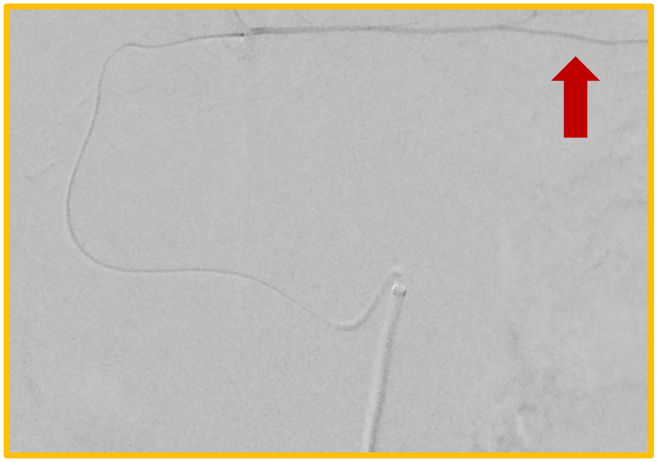
- 50 µm particles with a half-life of ~35 min
- Degraded by α-amylase
- No reports of sustained vessel occlusion
- No need for a second microcatheter (Gelfoam)

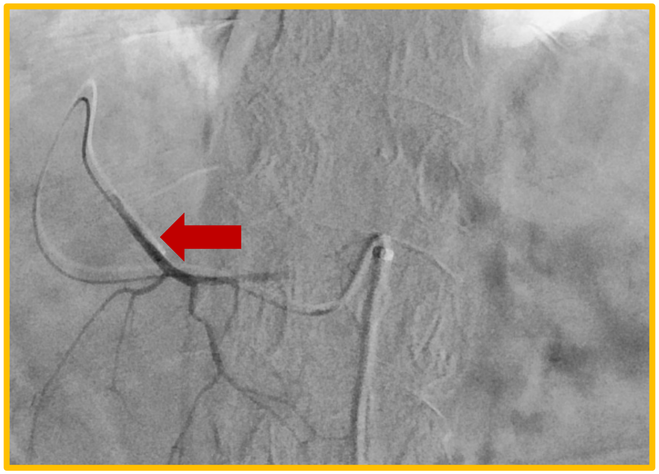
Gil-Alzugaray B, et al. Prognostic factors and prevention of radioembolization-induced liver disease. *Hepatology.* 2013;57(3):1078-1087. Meyer C, et al. Feasibility of temporary protective embolization of normal liver tissue using degradable starch microspheres during radioembolization of liver tumours. *Eur J Nucl Med Mol Imaging.* 2013;41(2):231-237.

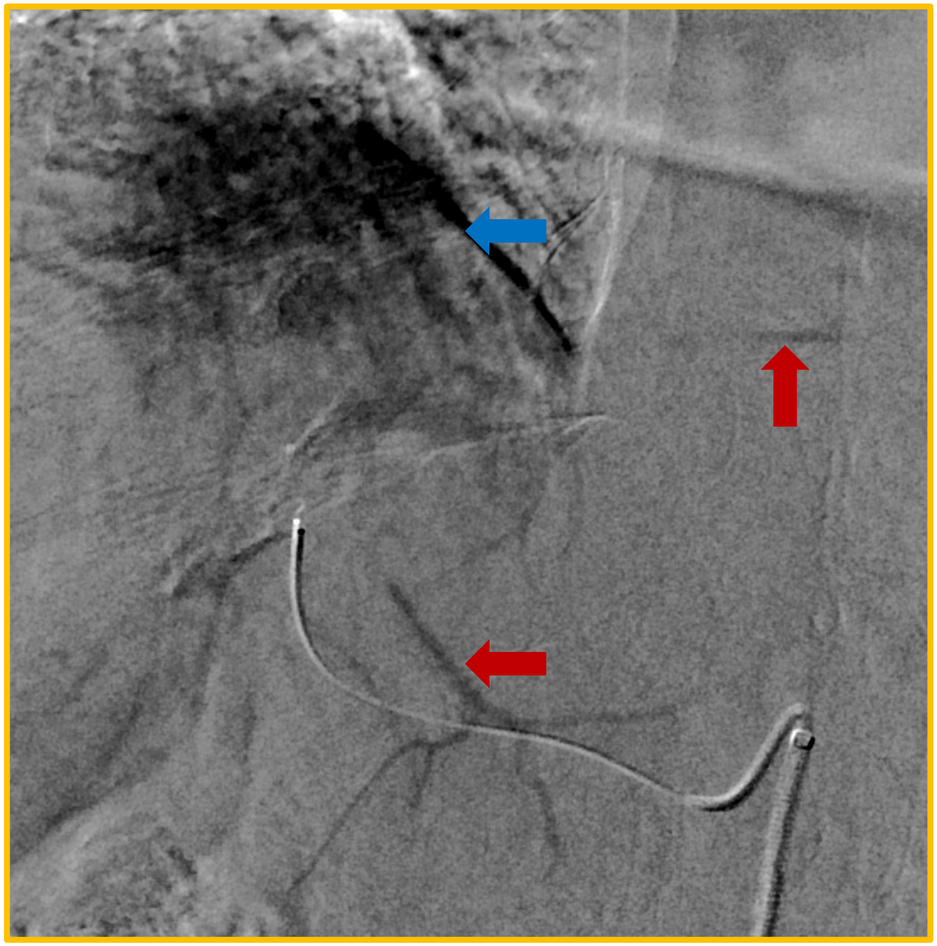
Post PREDATr Patency?

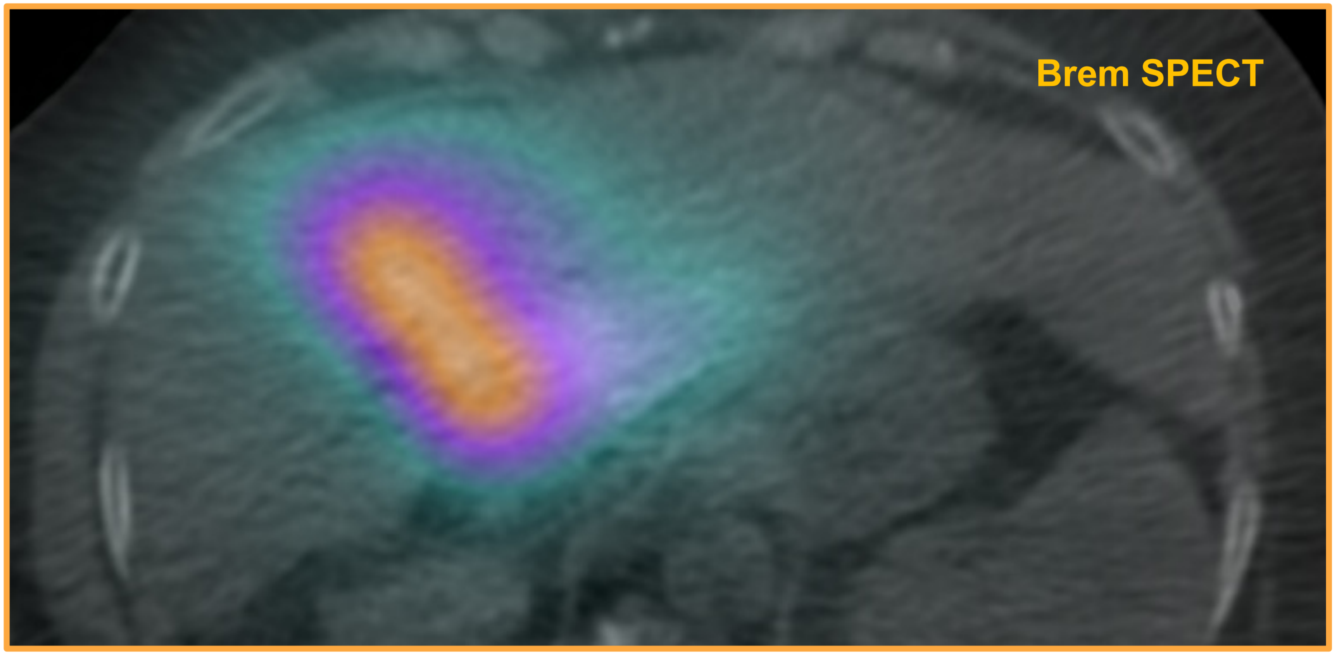

Cor





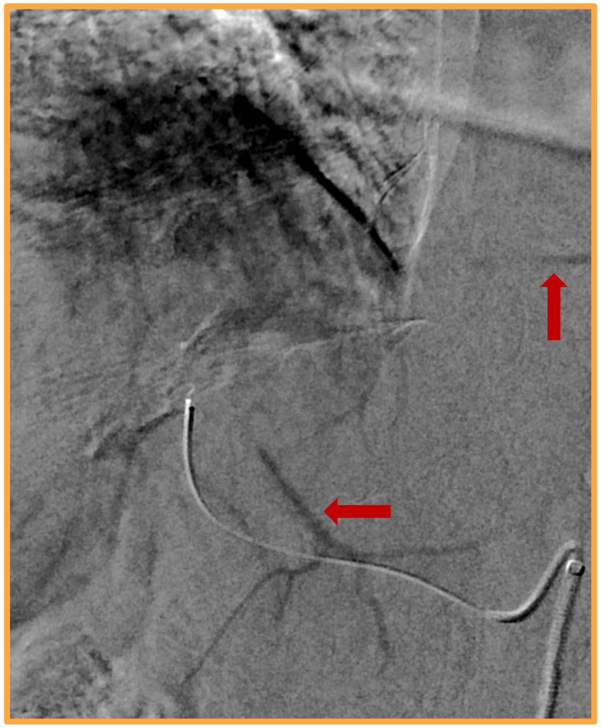


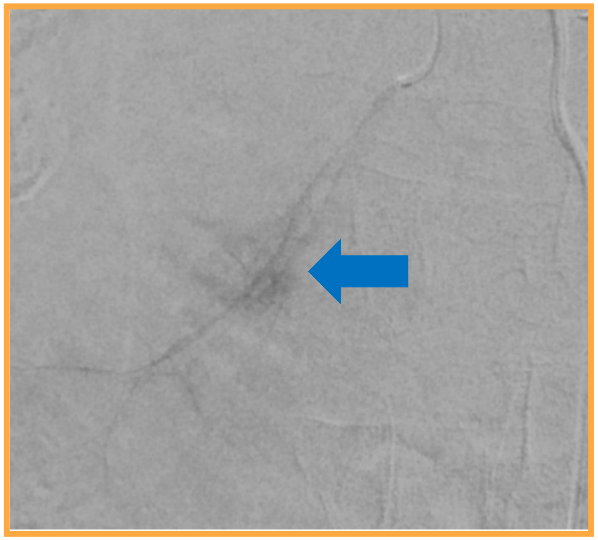



Brem SPECT

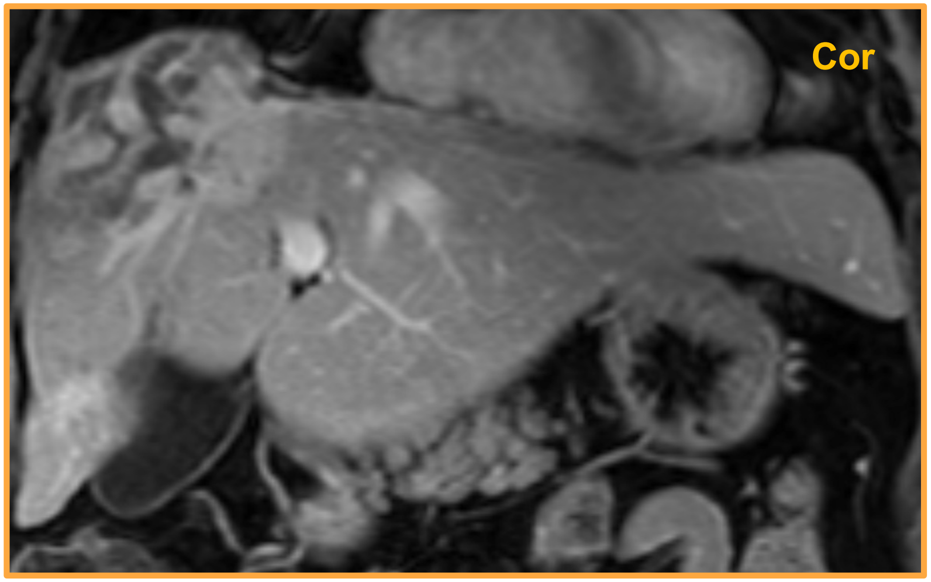
Radioembolization through previously gelfoamed artery?

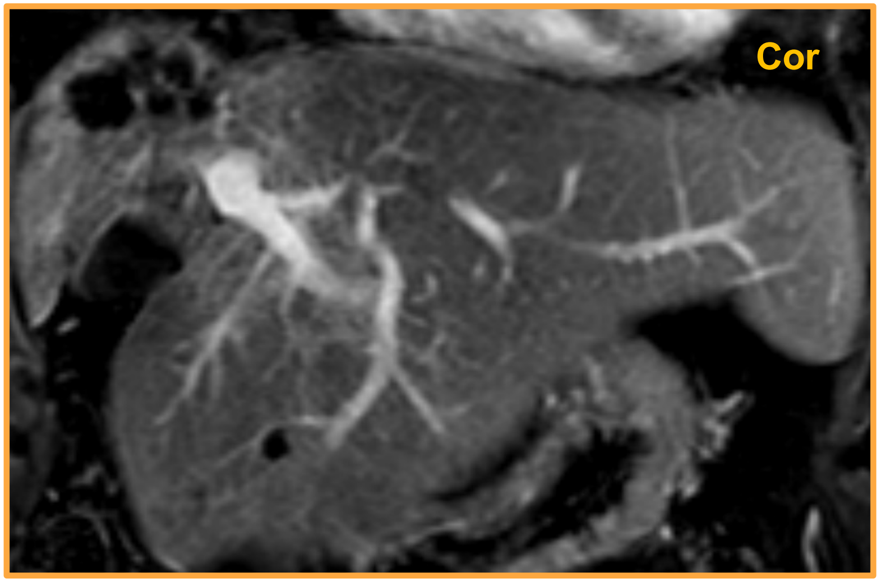
CIO



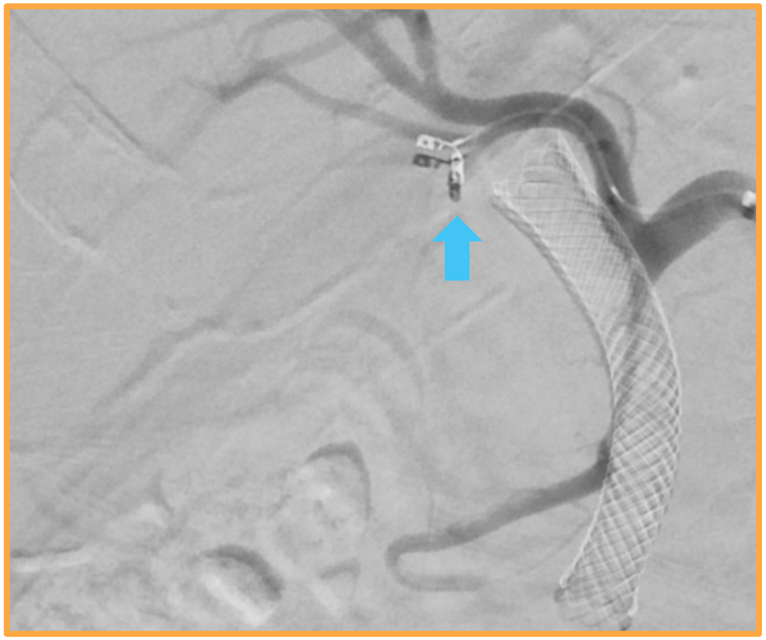


The importance of reducing non-target 90y





Detachable Coil



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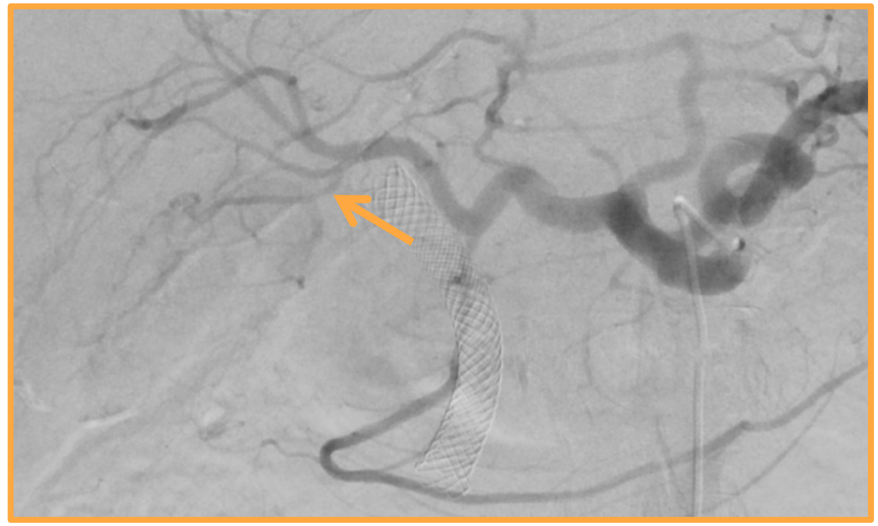
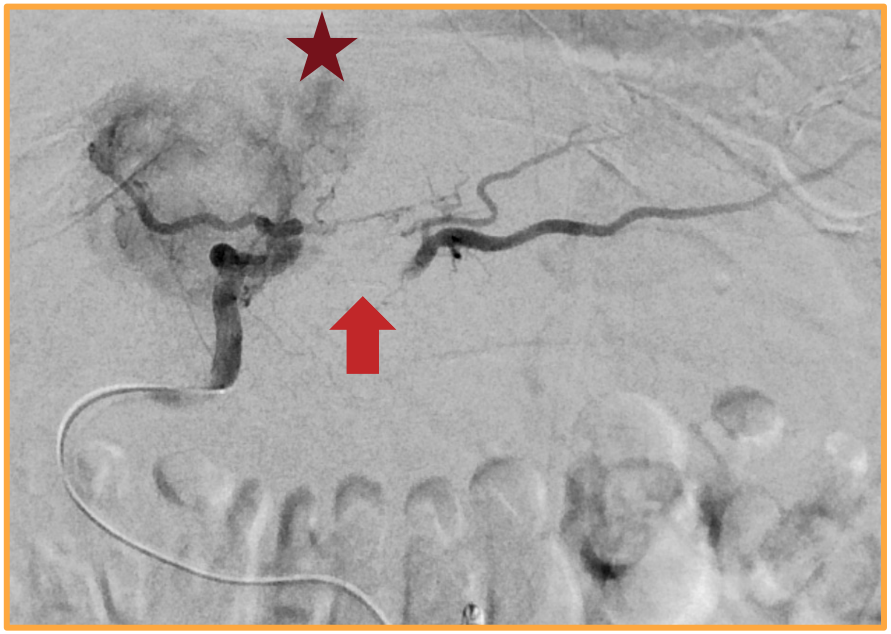
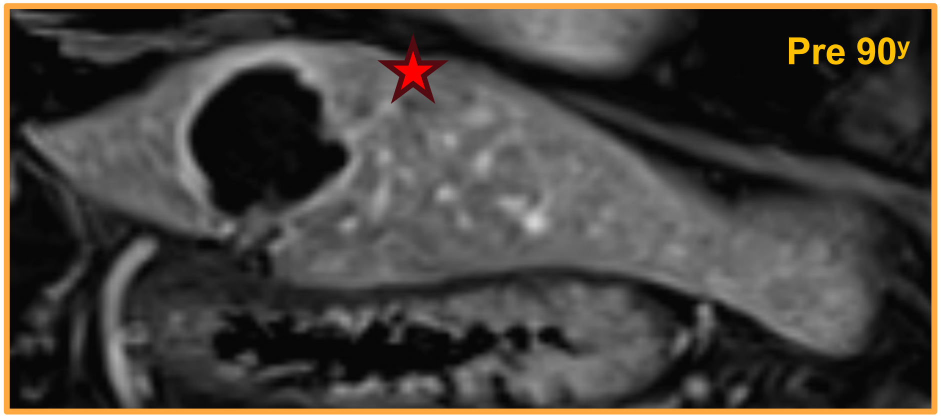


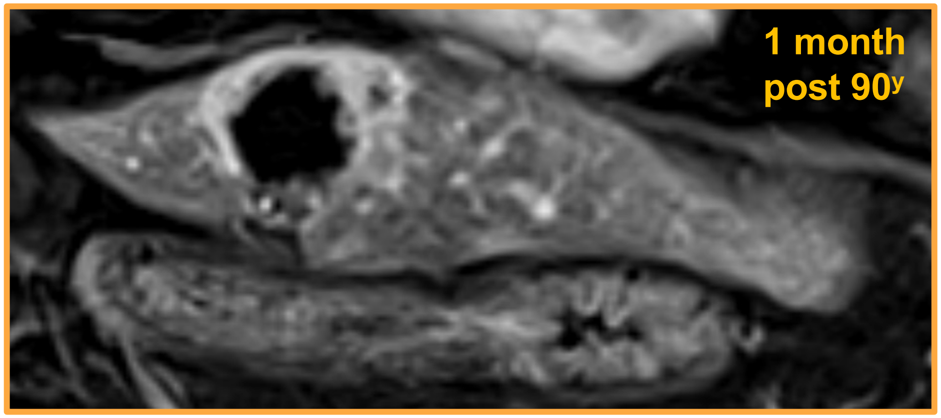
What have we learned?

Reduction Does Not Always Equal Occlusion

Balloon Microcatheter




Pre 90y


1 month
post 90y

Concerns and Limitations of the Procedural Technique

- Cost (balloon microcatheter, MVP, detachable coil)
- Procedure (fluoro) time
- Gelfoam embolization prior to Y90 administration may reflux into the treatment vessel
- Could potentially increase immediate toxicity of treatment if large-volume embolizations are performed
- No consensus on degree of stasis necessary to achieve result

Summary

- PREDATr technique is safe and feasible
- Extends the option of “segmental/selective” 90^{y} to patients with sub-optimal vascular supply
- Potential dose reduction to non-target parenchyma and dose intensification to the intended treatment bed