

# Planning Arteriography for Yttrium-90 Microsphere Radioembolization

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Yttrium-90 radioembolization (<sup>90</sup>Y RE) is a contemporary transcatheter locoregional therapy for primary and secondary hepatic malignancies that is commonly utilized in modern Interventional Radiology (IR) practice.<sup>1</sup> Unlike other targeted endovascular therapies, such as transarterial chemoembolization (TACE) and transarterial embolization (TAE), the current standard of care protocol for <sup>90</sup>Y RE treatment of liver tumors involves a two-stage treatment process consisting of a planning arteriography procedure followed by the therapeutic <sup>90</sup>Y RE, typically performed 1 to 2 weeks later. The diagnostic planning procedure has threefold intent: (1) to delineate hepatic and tumor vascular anatomy relevant to <sup>90</sup>Y microsphere dosimetry and administration; (2) to identify and possibly embolize extrahepatic vessels at risk for nontarget microsphere deposition; and (3) to quantify the degree of hepatopulmonary shunting using technetium-99m macroaggregated albumin (<sup>99m</sup>Tc-MAA) scanning.<sup>2</sup> Given the multifactorial basis for performance of mapping arteriography, and despite some literature guidelines outlining procedure methodology,<sup>3,4</sup> this procedure is often technically challenging, labor intensive, and time consuming. This article aims to present a simple overview of a single operator's technical approach to planning arteriography performed prior to <sup>90</sup>Y RE—including tips, tricks, and pitfalls—based on experience gained in having performed hundreds of hepatic arteriography procedures. Technical details of <sup>90</sup>Y RE dosimetry and microsphere administration are beyond the scope of the current topic, and will not be discussed.

## Preprocedure Considerations

As with all IR locoregional liver therapies, <sup>90</sup>Y RE treatment at the author's institution is preceded by an IR clinic consultation. The intent of the outpatient encounter is to obtain patient historical information; to perform a baseline physical examination; to identify any potential procedural contraindications; and to review the patient's diagnosis and treat-

ment plan, as well as clinical outcome goals and expectations with him/her. Relevant contraindications to <sup>90</sup>Y RE are well described,<sup>5</sup> but particular attention is paid to baseline performance status and serum bilirubin level, which, if elevated, may preclude treatment. While renal insufficiency does not represent an absolute procedural contraindication, the author prefers to pursue a single-session therapy such as transarterial chemoembolization as opposed to two-stage <sup>90</sup>Y RE to limit iodinated contrast volume administered to patients with kidney dysfunction. In terms of other preprocedure needs, all patients should have an up-to-date, high-quality contrast-enhanced triple-phase (liver protocol) computed tomography (CT) or magnetic resonance (MR) imaging scan for baseline tumor staging, ideally performed within a couple of weeks of initial therapy. On the day of the arteriography procedure, prophylactic antibiotics are typically not required.

## General Procedure Approach

The ternary objective of the planning arteriogram prior to <sup>90</sup>Y RE warrants IR operators to consider the optimal chronological order in which to undertake the required tasks. Given that injection of <sup>99m</sup>Tc-MAA is always the last step of a planning arteriogram, this decision revolves around whether to perform complete diagnostic arteriography first and embolization second, or vice versa. The author's preferred approach is that of diagnostic arteriography followed by nontarget vessel embolization. This sequence is favored based on multiple considerations. First, the need for embolization of nontarget vessels such as the gastroduodenal artery (GDA) and right gastric artery (RGA) may not be known until the planned <sup>90</sup>Y administration site is clarified by hepatic arteriography. As such, embolization pursued at the procedure outset may result in unnecessary vessel occlusion. Second, diagnostic arteriography, including delineation of tumor vascular supply and identification of prospective <sup>90</sup>Y administration sites,

requires careful attention by the operating IR physician. If technically challenging, performance of nontarget vessel embolization first may result in operator fatigue that might undermine the allotment of sufficient concentration. Third, performing hepatic arteriography first allows dedication of ample iodinated contrast volume to the diagnostic component of the procedure and helps prevent over usage of iodinated contrast material by avoiding initial over utilization during the embolization component of the procedure.

### Step-by-Step Procedural Technique

#### Getting Started

Hepatic arterial mapping procedures with <sup>99m</sup>Tc-MAA administration are performed in the IR suite using intravenous moderate sedation. General anesthesia is rarely required and is limited to cases of patient preference or tolerance to narcotic medications commonly used for sedation and analgesia. To begin, routine arterial access is gained via the common femoral artery using sonographic guidance and a 21-gauge needle (Micropuncture Introducer Set; Cook Medical, Bloomington, IN). Vascular access is dilated to a 5F sheath (Pinnacle; Terumo, Somerset, NJ). While not used at the author's institution, the radial artery represents an alternative vascular access site.<sup>6</sup>

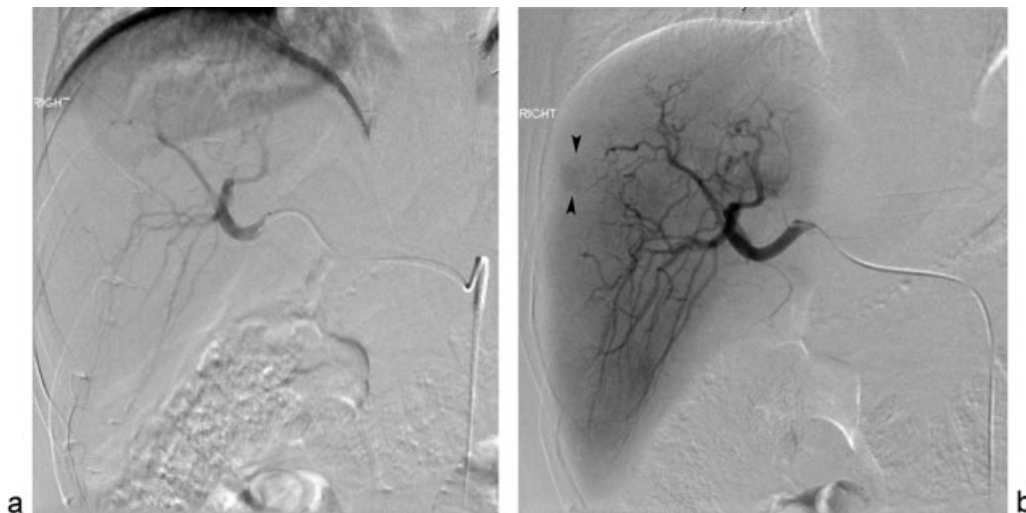
#### Diagnostic Arteriography

As previously noted, the aim of diagnostic arteriography performed during <sup>90</sup>Y RE planning is to delineate hepatic vascular anatomy relevant to microsphere dosimetry and administration, and to identify extrahepatic vessels at risk for nontarget microsphere deposition. At the conclusion of the diagnostic component of the procedure, the IR operator should have a firm understanding of where tumor vascular supply is derived from, which vascular territories and vessels require treatment, the flow characteristics in these vascular beds, and the likelihood for nontarget microsphere deposition based on likely <sup>90</sup>Y

administration location. This is accomplished by systematic catheter interrogation of the celiac and hepatic vasculature.

To begin, celiac arteriography is performed using a 5F catheter such as SOS Omni Selective (AngioDynamics; Queensbury, NY), SIM 1 (Cook Medical), or C2 (Cook Medical) catheter. In the author's opinion, performance of an aortogram or superior mesenteric arteriogram is typically not necessary (in the absence of known variant vascular anatomy), as high-quality preprocedure cross-sectional imaging with CT or MR imaging routinely provides anatomic information about vascular anatomy—including aberrant vasculature—and portal venous patency. Furthermore, the iodinated contrast volume saved by deferring aortography and superior mesenteric arteriography can be applied to performing more hepatic arteriograms or undertaking more arteriography during embolization, if necessary. Nonetheless, celiac imaging carried through the venous phase may depict splenoportal patency via a delayed splenoportogram.

Hepatic arteriography is performed after placement of a coaxial 3F microcatheter such as a Renegade Hi-Flo (Boston Scientific, Natick, MA), or after exchange for a 4F catheter (Glidecath; Terumo). Use of a 4F catheter system can often improve arteriographic imaging and tumor visualization by providing higher iodinated contrast injection rate capability compared with most microcatheter systems, which may not be able to overcome very hyperdynamic hepatic arterial flow as is often seen in liver cirrhosis (—Fig. 1). When performing hepatic arteriography, it is of paramount importance to achieve adequate filling of injected vascular beds to ensure complete filling of all arteries to guarantee visualization of both tumor and any potential nontarget vessels that may require embolization. Complete hepatic arteriography typically includes selective common hepatic, proper hepatic, left hepatic, and right hepatic arteriography, as well as segmental arteriography and/or super selective arteriography performed at the discretion of the IR physician. Some extrahepatic vessels—such as the right inferior phrenic artery—may



**Fig. 1** Hepatic arteriograms in same patient performed using microcatheter (a) and 4F catheter (b) demonstrate improved vessel filling with greater contrast injection capability of larger caliber catheter, with hypervascular tumor visualization (arrowheads).

on occasion require arteriographic interrogation, as these can contribute to parasitized blood flow to primary liver tumors. Typical iodinated contrast material injection rates used by the author for the celiac artery and hepatic or other branches relevant to  $^{90}\text{Y}$  RE planning are presented in ►Table 1.

### Selection of $^{90}\text{Y}$ Administration Site

Once a tumor vascular supply is identified, the IR operator should select an appropriate site for later  $^{90}\text{Y}$  microsphere administration. A suitable catheter position for  $^{90}\text{Y}$  RE should be in the lobar or segmental distribution of tumor beyond any potential nontarget vessels and at enough distance from branch points distal to the catheter tip to ensure homogeneous distribution of injected microspheres into arborizing vessels (►Fig. 2). Presence of nontarget vessels distal to a planned  $^{90}\text{Y}$  RE should call for embolization of these branches or may require dose fractionation into separate branch vessels beyond the nontarget vessel origin, with microsphere delivery via different dose vials. In assessing tumor blood supply, the operator should also confirm that the entirety of all tumors or tumor parts for which treatment is planned are contained within a particular hepatic arterial injection representing the planned  $^{90}\text{Y}$  administration site. Angiographically, absent tumors or tumor portions may receive blood supply from other arterial sources, and lack of recognition of this finding can result in incomplete treatment (►Fig. 3). From the tumor vascular supply, the IR operator can also assess factors that may impact selection of the particular  $^{90}\text{Y}$  microsphere product (resin vs. glass) to be used, if not already chosen; such parameters include vessel size and flow rate, as well as perfused liver bed size and vascularity. The operator may also use this opportunity to test the feasibility of any special maneuvers that may be used during  $^{90}\text{Y}$  microsphere administration, such as flow-directed catheter repositioning.<sup>7</sup> Finally, the IR physician should scrutinize angiographic images for findings that may suggest the presence of a

high lung shunt fraction, such as arterioportal shunting (►Fig. 4) or hepatic artery to hepatic vein shunting/fistulae. Such findings may call for measures to reduce shunting, such as large particle embolization or transarterial chemoembolization as a bridge to  $^{90}\text{Y}$  RE (►Fig. 5).<sup>8</sup> Excessive shunting that cannot be reduced using such techniques, and that results in persistently high lung shunt fraction (LSF), may preclude safe  $^{90}\text{Y}$  RE.

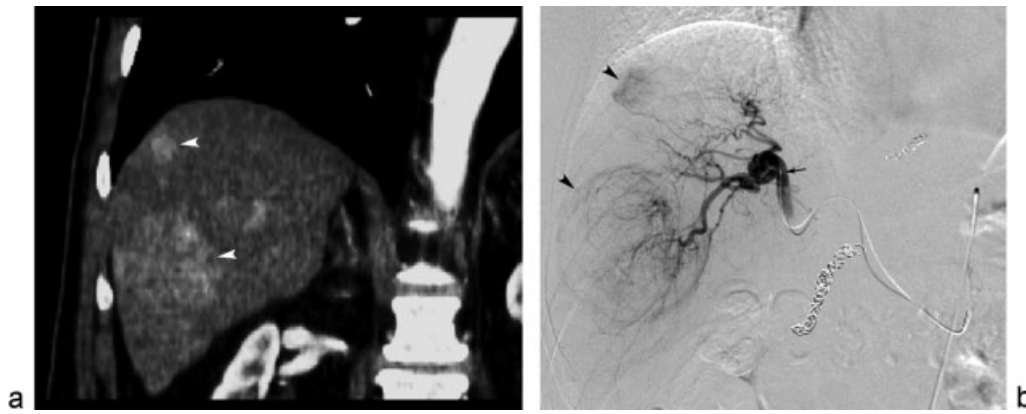
### Nontarget Vessel Embolization

The multitude of vessels at risk for potential nontarget microsphere deposition have been well described in the literature, and include the GDA, RGA, falciform artery (►Fig. 6), and cystic artery, among others.<sup>4</sup> The decision of whether to embolize a potential nontarget vessel can often be challenging. Early in an IR operator's  $^{90}\text{Y}$  RE practice, it is probably prudent to occlude all potential nontarget vessels that can safely be embolized—most frequently the GDA and RGA—using metallic coils such as MicroNester coils (Cook Medical), to avoid radiation-induced ulcers and to ensure a high level of procedural safety during initial experience with this therapy. As one's know-how expands and clinical practice matures, embolization of such extrahepatic vessels may not be considered mandatory if  $^{90}\text{Y}$  RE can be performed at a safe distance from the vessel origin, per the judgment of the IR physician.<sup>9</sup> However, since arterial stasis is a risk factor for gastrointestinal ulceration,<sup>10</sup> embolization should be strongly considered when a high  $^{90}\text{Y}$  microsphere load is to be used for therapy, as in the case of resin microspheres, or when small or low flow vascular territories are to be treated. In the author's practice, nontarget vessel embolization is typically performed when resin microspheres are to be used for treatment, when the prospective  $^{90}\text{Y}$  administration site is close in proximity to the GDA or RGA, for all arterial variants arising from an intrahepatic artery (e.g., accessory gastric artery arising from left hepatic artery, ►Fig. 7), and prior to

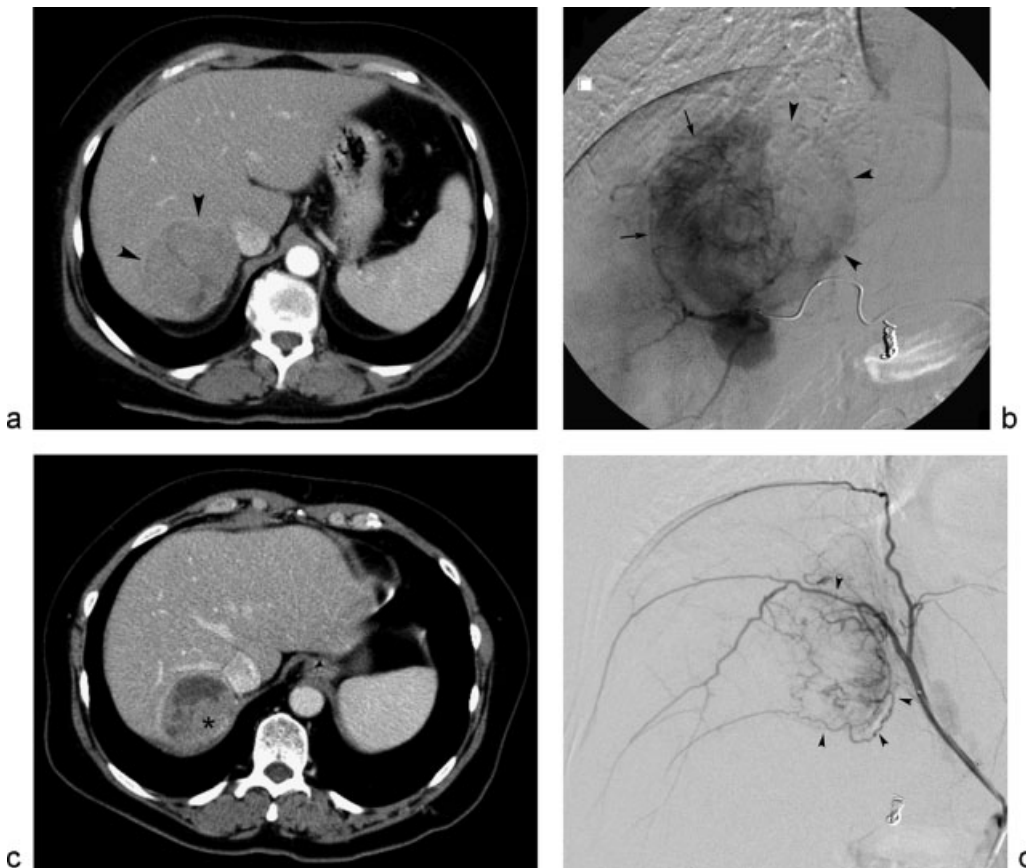
**Table 1** Standard vessel injection rates

Artery	Iodinated contrast injection rate	Iodinated contrast injection volume (mL)
Celiac artery	–5 mL/s	16–20
CHA	3–4 mL/s	12–16
PHA	3–4 mL/s	12–16
Left hepatic artery	1–2 mL/s	8–10
Right hepatic artery	2–3 mL/s	10–15
Segmental HA	1–2 mL/s	6–8
GDA	2–3 mL/s	6–9
RGA	Manual injection	1–2
LGA	2–3 mL/s	8–12
Falciform artery	Manual injection	1–2
Phrenic artery	Manual injection	2–4

Abbreviations: CHA, common hepatic artery; GDA, gastroduodenal artery; HA, hepatic artery; LGA, left gastric artery; PHA, proper hepatic artery; RGA, right gastric artery.



**Fig. 2** Selection of catheter position for  $^{90}\text{Y}$  RE. Coronal reformatted contrast-enhanced CT scan (a) shows two hepatocellular carcinoma nodules (arrowheads) within right hepatic lobe. Arteriogram (b) displays suitable microcatheter position for lobar  $^{90}\text{Y}$  RE, with tip (arrow) in right hepatic artery in vascular distribution of both tumors (arrowheads), but sufficiently proximal to branching to allow homogeneous microsphere dispersal.



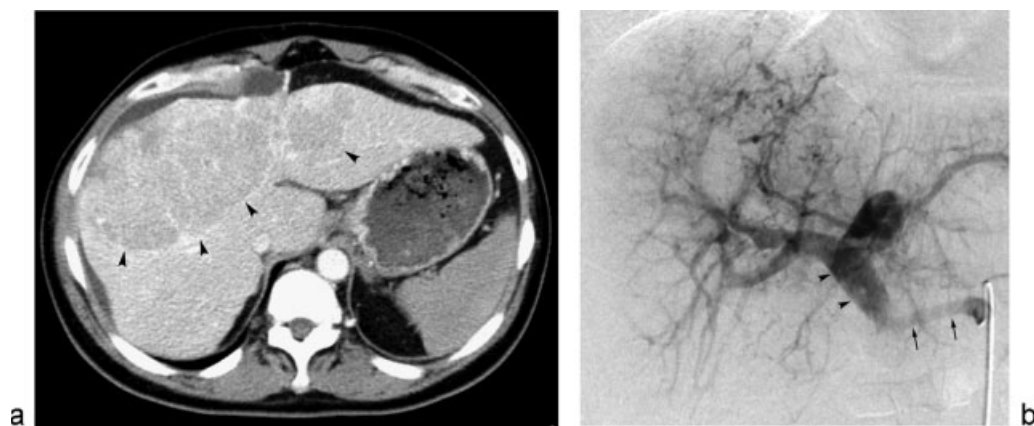
**Fig. 3** Incomplete treatment due to extrahepatic tumor blood supply. Axial contrast-enhanced CT scan (a) demonstrates segment 7 hepatocellular carcinoma (arrowheads). Arteriogram (b) shows hypervascular tumor (arrows). However, note absent perfusion along posteromedial margin (arrowheads), which was unnoticed prior to  $^{90}\text{Y}$  RE. Posttreatment axial contrast-enhanced CT scan (c) displays partial tumor response, with persistent viable tumor enhancement (asterisk). Arteriogram performed during retreatment (d) reveals tumor blood supply (arrowheads) via inferior phrenic artery, which was treated with transarterial chemoembolization.

left lobe  $^{90}\text{Y}$  therapies (given the proximity of the  $^{90}\text{Y}$  administration site to the GDA and RGA). While embolic protection of the cystic artery in the case of right lobar  $^{90}\text{Y}$  RE is feasible,<sup>11</sup> this is not typically pursued by the author, given the low overall risk for biliary complications after right hepatic lobe  $^{90}\text{Y}$  RE<sup>12</sup>; instead,  $^{90}\text{Y}$  RE administration

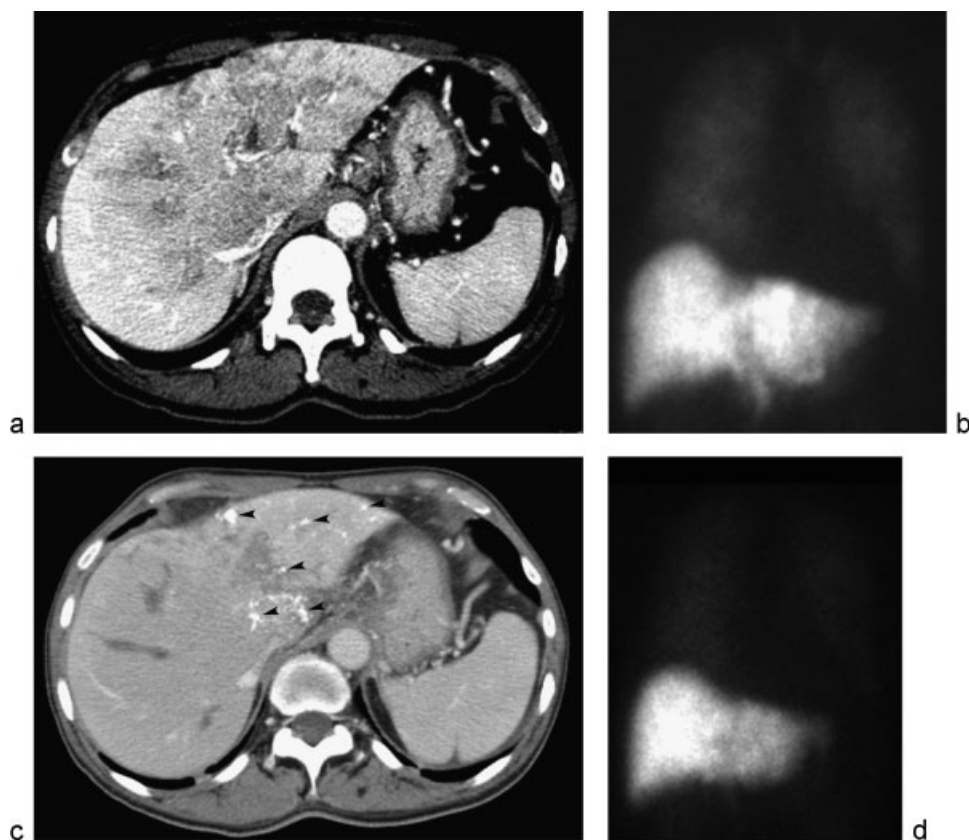
that is planned for proximal to the cystic artery is treated with a weeklong course of antibiotic coverage.

#### Embolization Technique

From a technical standpoint, embolization of a medium-sized vessel such as the GDA is generally straightforward. Most



**Fig. 4** Arteriportal shunting. Axial contrast-enhanced CT scan (a) shows large primary liver tumor (arrowheads). Arteriogram (b) performed during  $^{90}\text{Y}$  RE planning demonstrates extensive arteriportal shunting, with early portal vein visualization (black arrowheads) during late arterial phase of imaging (black arrows delineate common hepatic artery). Shunt subsequently closed with large particles.

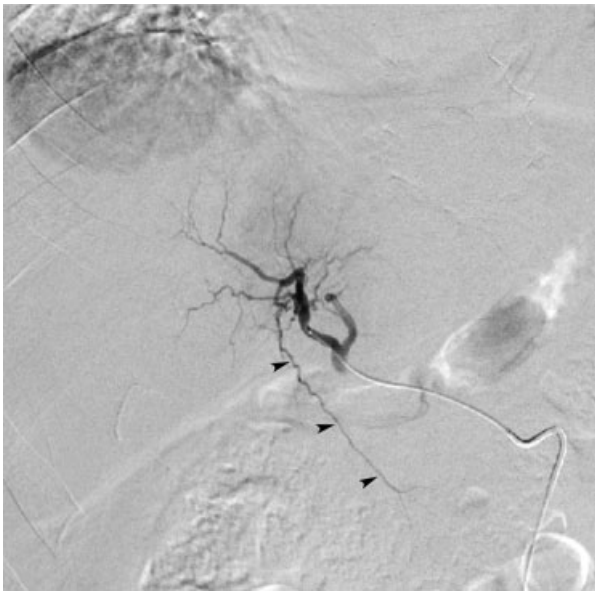


**Fig. 5** Chemoembolic shunt reduction to allow  $^{90}\text{Y}$  RE. Axial contrast-enhanced CT scan (a) demonstrates left hepatic lobe infiltrative tumor with portal vein invasion.  $^{99\text{m}}\text{Tc}$ -MAA scan (b) shows high lung shunt fraction measuring 30%. Axial contrast-enhanced CT scan (c) performed after transarterial chemoembolization shows high attenuation chemoembolic material (arrowheads) in left hepatic lobe tumor. Repeat  $^{99\text{m}}\text{Tc}$ -MAA scan (d) obtained following chemoembolization reveals lung shunt fraction reduced to 22%.  $^{90}\text{Y}$  RE to left liver lobe subsequently performed at later date.

challenges in GDA embolization arise with placement of the last coil near the vessel origin from the common hepatic artery, where careless technique can result in coil migration. Tips to successful deployment of the last coil include use of the “anchor” technique ( $\blacktriangleright$ Fig. 8) and use of a supporting 4F catheter advanced to the GDA origin to ensure avoidance of microcatheter recoil and dislodgment from the vessel during

coil deployment ( $\blacktriangleright$ Fig. 8). Detachable coils or vascular plug devices may also be useful in this circumstance, given the capacity for precise placement ( $\blacktriangleright$ Fig. 9) and for potential removal if malpositioned.

RGA embolization is often a source of frustration. An obvious key to successful embolization of this vessel is catheterization. To this end, the author always performs a



**Fig. 6** Arteriogram performed for  $^{90}\text{Y}$  RE planning illustrates typical falciform artery (arrowheads) arising from segment 4 branch of left hepatic artery.



**Fig. 8** Anchor technique shown on postembolization arteriogram after gastroduodenal artery (GDA) embolization. Note proximal coil (black arrowheads) anchored into GDA side branch (arrow) to ensure coil positional stability, as well as base catheter tip (white arrowhead) advanced to near GDA origin for extra support.



**Fig. 7** Accessory gastric artery. Left hepatic arteriogram (a) shows branch vessel (arrowheads) supplying hypervascular "tuft" (arrows) in abdominal left upper quadrant. Arterial (b) and venous (c) phase angiograms performed after microcatheter interrogation reveal gastric fundal enhancement (arrowheads) with venous drainage via left gastric vein (arrowheads), confirming vessel to be accessory gastric artery.



**Fig. 9** Plug embolization. Postembolization common hepatic arteriogram shows plug device (arrowheads) accurately positioned at the origin of gastroduodenal artery.

common hepatic arteriogram at full magnification to clearly identify the RGA origin (**Fig. 10**), which assists with successful wire cannulation. Once catheterized, the author typically embolizes this vessel using 3-mm coils “un-sheathed” from the microcatheter using a wire pusher, to avoid pushing the microcatheter out of the vessel during aggressive coil advancement. If the RGA cannot be catheterized primarily, retrograde catheterization and embolization via a left gastric artery to RGA arcade—if present—is a useful and well-described approach (**Fig. 11**). If embolization of the RGA or another vessel is technically unsuccessful during the planning arteriogram procedure, the IR operator should remember that he/she will have a second opportunity to attempt the embolization at the time of  $^{90}\text{Y}$  administration.



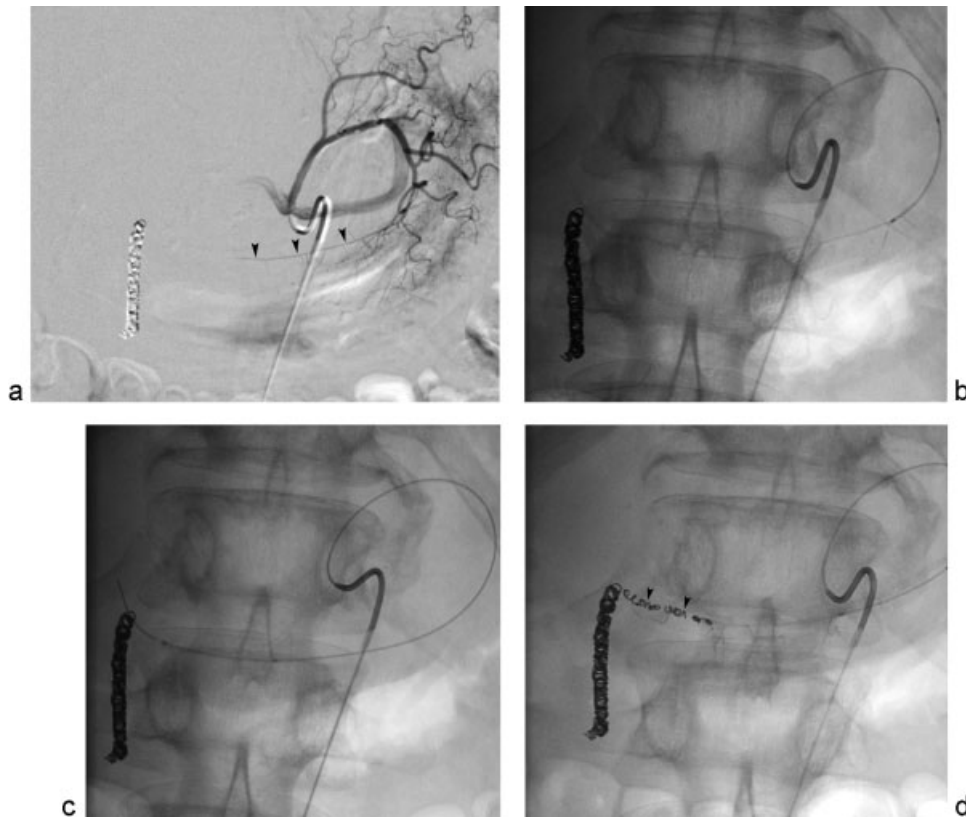
**Fig. 10** Magnified common hepatic arteriogram nicely delineates right gastric artery origin (arrowheads) from right lateral wall of proper hepatic artery.

Another option is to use an antireflux catheter for  $^{90}\text{Y}$  microsphere administration. Finally, the decision to push versus inject coils is usually at the discretion of the primary IR operator. The author’s preference is to inject most coils and to reserve coil pushing to cases of small vessel (e.g., RGA) embolization and for last coil deployment near a vessel origin from a parent artery.

While everyone performing mapping arteriography prior to  $^{90}\text{Y}$  RE procedures will inevitably encounter a coil migration incident, the response to this mishap is important. While it is desirable to remove a migrated coil from a hepatic circulation for which treatment is desired, too much or careless manipulation can also result in injury such as vessel dissection. In the circumstance of coil migration into the hepatic circulation or even herniation of a coil into a parent vessel, the author will attempt to remove or retrieve the coil if a free end is available for capture (**Fig. 12**), aiming to avoid overmanipulation that may lead to vessel injury. However, if snaring the coil is not technically feasible,  $^{90}\text{Y}$  RE is often not precluded, with treatment possible through a coil pack and/or collateral tumor supply (**Fig. 13**). An innovative approach to dealing with coil migration into the vascular distribution of prospective  $^{90}\text{Y}$  RE is intrahepatic vascular flow redistribution, a strategy used to consolidate arterial flow to tumors by embolizing accessory feeders to allow single vessel  $^{90}\text{Y}$  RE.<sup>13,14</sup> In this scenario, complete occlusion of the branch vessel into which coil migration occurred may be used to develop collateral blood supply from other intrahepatic arteries to allow  $^{90}\text{Y}$  administration (**Fig. 14**); while not an ideal circumstance, this approach may be the most successful in some patients.

### Special Considerations

As has been noted by others,  $^{90}\text{Y}$  RE treatment of the left hepatic artery may be precarious, as this vessel more commonly harbors relevant anatomic variants compared with the right hepatic artery. Examples include a gastrohepatic trunk (**Fig. 15**), as well as accessory gastric, esophageal, and phrenic (**Fig. 16**) arteries that may go unrecognized and which may increase the risk for nontarget  $^{90}\text{Y}$  delivery. Moreover, compared with the right hepatic artery, the left hepatic artery is typically smaller in caliber, has a shorter undivided segment that does not permit as distal microcatheter positioning, supplies a smaller liver volume, and possesses a less capacious vascular bed, all of which theoretically raise the risk for embolic stasis, reflux, and/or vascular saturation. With these considerations in mind, the author routinely pursues GDA and RGA embolization in the setting of unilateral left hepatic lobe  $^{90}\text{Y}$  RE, knowing that the incidence of gastrointestinal ulceration is likely low when protective measures are applied. In cases of bilobar malignant disease, however, the author has occasionally adopted a treatment approach that omits left hepatic lobe  $^{90}\text{Y}$  (and risk for gastrointestinal ulceration) altogether and employs a locoregional strategy that potentially affords some practical, methodological, and logistical benefits. In cases of bilobar tumor, the author performs left



**Fig. 11** Retrograde right gastric artery (RGA) embolization for patient depicted in ► **Fig. 10**. Left gastric arteriogram (a) portrays complete arcade (arrowheads) with RGA along lesser curvature of stomach. Fluoroscopic images (b) and (c) display sequential microcatheterization across arcade, with successful coil embolization (arrowheads) illustrated in fluoroscopic image (d).

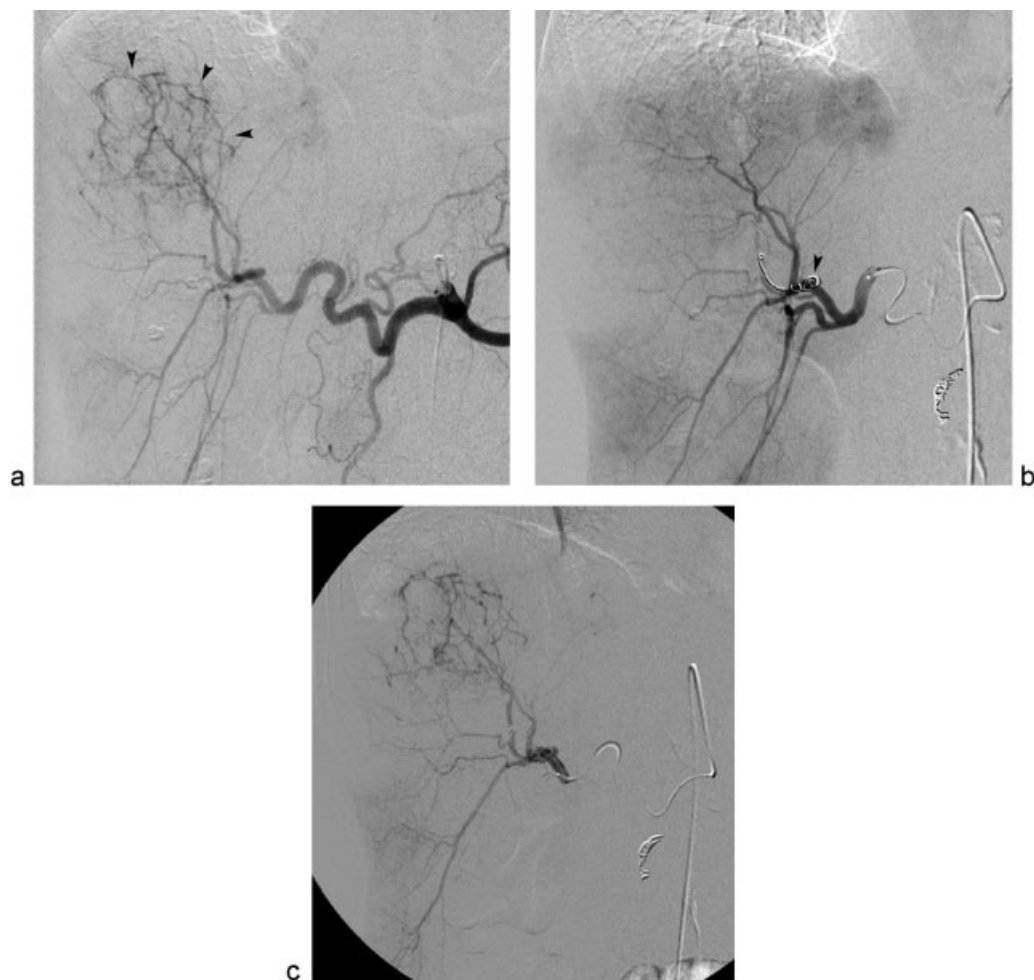


**Fig. 12** Coil malposition. Common hepatic arteriogram (a) demonstrates herniation of gastroduodenal artery (GDA) coil (arrows) into parent artery, which could limit later  $^{90}\text{Y}$  RE; second coil (white arrowhead) located in right gastric artery. GDA coil retrieved by snaring free end (black arrowhead), and GDA then embolized again with better result, shown in arteriogram (b).

hepatic lobe transarterial chemoembolization—without GDA or RGA embolization—at the time of mapping arteriography for  $^{90}\text{Y}$  planning, and subsequently pursues  $^{90}\text{Y}$  RE to the right hepatic lobe the usual 10 to 14 days later. Although nontarget chemotherapy may result in gastrointestinal side effects as well,<sup>15</sup> the risk is anecdotally less

than that with radiotherapy, and the utilization of a radiographically visible chemoembolic therapeutic agent that may be administered in small aliquots under direct fluoroscopic visualization helps avoid reflux and nontarget deposition through real-time monitoring in contrast,  $^{90}\text{Y}$  microspheres cannot typically be infused in such a





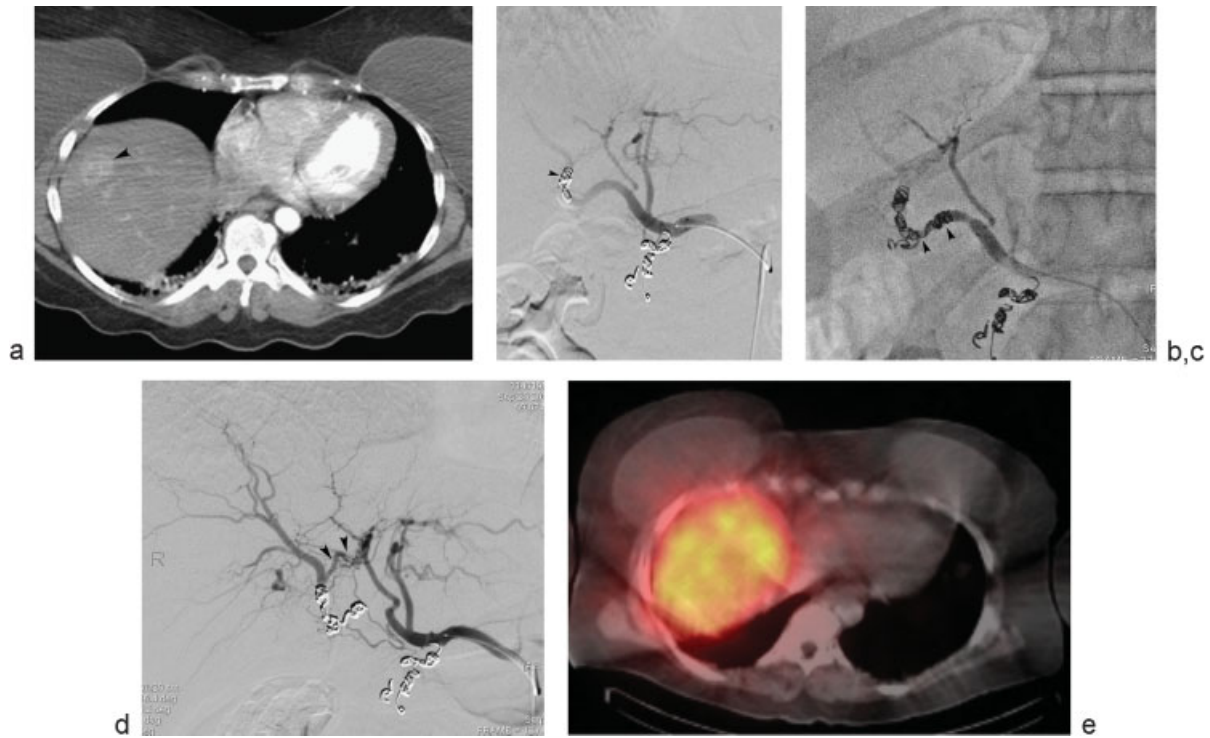
**Fig. 13** Coil migration. Celiac arteriogram (a) shows right hepatic lobe hypervascular liver tumor (arrowheads). Arteriogram (b) performed after inadvertent right hepatic artery coil migration (arrowhead) during gastroduodenal artery embolization displays poor tumor perfusion. Coil could not be retrieved. Nonetheless, arteriogram (c) performed during  $^{90}\text{Y}$  RE ~2 weeks later demonstrates tumor perfusion through coil pack and via collateral vessels;  $^{90}\text{Y}$  RE successfully performed.

controlled and directly monitored manner at present (although some operators inject  $^{90}\text{Y}$  resin particles as a suspension in iodinated contrast material). Furthermore, such treatment consolidation allows earlier completion of treatment cycle, as patients typically achieve whole liver therapy in 10 to 14 days over two procedures, as opposed to 5 to 6 weeks over three procedures for routine bilobar  $^{90}\text{Y}$  therapy (in which planning arteriography is performed at time zero followed by treatment of one liver lobe 10–14 days later and the second liver lobe 1 month after that).<sup>5</sup> Another potential theoretical benefit of this approach that may be exploited in research studies is the capability for within-patient comparison of locoregional treatment efficacy (chemoembolization vs.  $^{90}\text{Y}$  RE), although such a comparison could be confounded by factors such as therapy lead time bias as well as differences in baseline tumor characteristics, such as size. While the author does not have a substantial enough patient cohort on which to report at this time, this approach has anecdotally been found by the author to provide an efficient means to treat bilobar liver tumor patients. As a final note, intrahepatic flow

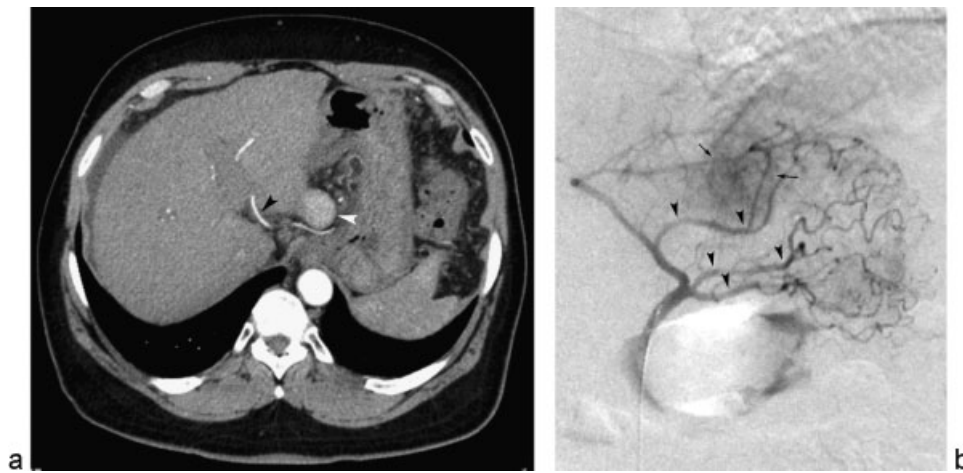
redistribution could also be used in the scenario described, with coil embolization of the left hepatic artery and whole liver treatment via the right hepatic artery.

#### **$^{99\text{m}}\text{Tc}$ -MAA Injection and Imaging, and LSF Calculation**

As a final step of the planning arteriogram procedure, 4 to 5 mCi of  $^{99\text{m}}\text{Tc}$ -MAA is administered to the whole liver for  $^{99\text{m}}\text{Tc}$ -MAA scanning.  $^{99\text{m}}\text{Tc}$ -MAA should be prepared and called to the IR procedure suite as close to the time of administration as possible, to avoid  $^{99\text{m}}\text{Tc}$ -MAA degradation and pulmonary transit that may lead to spurious LSF elevation.<sup>5</sup> To this end, at the author's institution,  $^{99\text{m}}\text{Tc}$ -MAA is typically requested from the nuclear medicine department approximately 5 minutes prior to injection.  $^{99\text{m}}\text{Tc}$ -MAA may be injected from the common or proper hepatic arteries (depending on whether the gastroduodenal and/or RGAs are embolized) in cases of standard liver vascular anatomy. In cases of aberrant arterial anatomy, the  $^{99\text{m}}\text{Tc}$ -MAA is fractionated into all liver feeding branches, which requires catheter and/or microcatheter repositioning between administrations. After  $^{99\text{m}}\text{Tc}$ -MAA injection, all devices are



**Fig. 14** Coil migration resolved with intrahepatic vascular flow redistribution (case courtesy of Brandon K. Martinez, MD, Corvasc MDs PC, Indianapolis, IN). Axial contrast-enhanced CT scan (a) shows right hepatic dome hepatocellular carcinoma (arrowhead), for which  $^{90}\text{Y}$  RE therapy planned. Arteriogram (b) reveals unintentional coil migration (arrowhead) into right hepatic artery from attempted gastroduodenal artery embolization. As coil could not be retrieved, right hepatic artery intentionally further coil embolized (arrowheads in image c) to induce left-to-right intrahepatic arterial collateralization (arrowheads in image d). Right hepatic lobe  $^{90}\text{Y}$  RE then successfully performed via left hepatic artery segment 4 branch, as depicted on Bremsstrahlung scan (e).

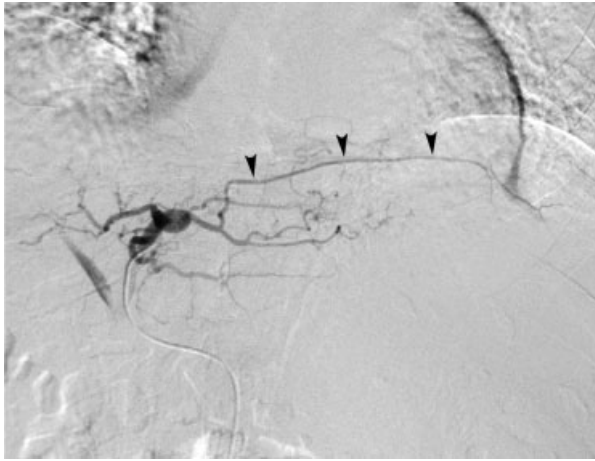


**Fig. 15** Gastrohepatic trunk. Axial contrast-enhanced CT scan (a) shows typical location of anomalous left gastric artery (black arrowhead) within fissure for ligamentum venosum; left hepatic lobe exophytic hepatocellular carcinoma also present (white arrowhead). Left gastrohepatic trunk arteriogram (b) depicts numerous gastric branches (arrowheads) at risk for nontarget  $^{90}\text{Y}$  microsphere deposition during hypervascular tumor (arrows) therapy.

removed, and hemostasis is achieved with manual compression or a vascular closure device.

For  $^{99\text{m}}\text{Tc}$ -MAA scanning at the author's institution, planar chest and abdomen images are performed within 30 minutes of  $^{99\text{m}}\text{Tc}$ -MAA intra-arterial injection. Patients are positioned supine under a dual-detector gamma camera (SkyLight; Philips, the Netherlands). Both anterior and

posterior projections are obtained until 1 million counts are collected for the abdomen, and scan time is recorded. The same scan time is applied to chest and total counts in the chest field-of-view are recorded. To calculate the percentage of hepatopulmonary shunting, regions-of-interest (ROIs) are drawn around the liver and both lungs. Geometric means for liver and lungs are obtained.



**Fig. 16** Left hepatic arteriogram reveals anomalous origin of left anterior phrenic artery (arrowheads) from left hepatic artery. Embolization of this vessel would be required prior to left hepatic lobe  $^{90}\text{Y}$  therapy.

Hepatopulmonary shunt ratio is calculated using the following formula:

$$\% \text{ LSF} = (\text{total lung counts} / \text{total lung} + \text{total liver counts}) \times 100$$

Abdominal shunt fraction, defined as total extrahepatic abdominal counts/total extrahepatic abdominal + total liver counts  $\times 100$ , is similarly calculated using ROIs drawn around the liver and extrahepatic abdomen.

In cases in which repeat  $^{90}\text{Y}$  RE treatment is planned in a relatively remote time frame (more than 6 months) after initial planning arteriography and  $^{99\text{m}}\text{Tc}$ -MAA scanning, repeat mapping arteriography and  $^{99\text{m}}\text{Tc}$ -MAA LSF calculation should be performed to identify any changes in hepatopulmonary shunt fraction that may impact  $^{90}\text{Y}$  RE dosimetry. As a final note, while a distinct planning arteriography session with  $^{99\text{m}}\text{Tc}$ -MAA scanning is currently considered mandatory for  $^{90}\text{Y}$  RE therapy, this approach may shift in the future, given recent reports of consolidated treatment protocol consisting of same day  $^{99\text{m}}\text{Tc}$ -MAA scanning and  $^{90}\text{Y}$  RE therapy,<sup>16</sup> and future studies aiming to assess the safety of  $^{90}\text{Y}$  RE treatment protocol excluding  $^{99\text{m}}\text{Tc}$ -MAA scanning in tumors known to have low LSFs.<sup>17</sup>

## Conclusion

Given the emergence of  $^{90}\text{Y}$  RE as a fundamental component of transarterial locoregional therapy for liver tumors, a thorough understanding and in-depth familiarity with therapeutic planning arteriography and  $^{99\text{m}}\text{Tc}$ -MAA scanning is vital to any IR with an interventional oncology practice. Although the procedure technique may vary between operators, with a spectrum of different individual, institutional, regional, and national practice patterns, a diligent approach of patient evaluation and arteriographic methodology enhances technical success and optimizes oncologic care for patients.

## Conflict of Interest

None.

## References

- Garrean S, Joseph E, Spat N. Yttrium-90 internal radiation therapy for hepatic malignancy. *Surg Oncol* 2005;14(4):179–193
- Salem R, Lewandowski RJ, Sato KT, et al. Technical aspects of radioembolization with  $^{90}\text{Y}$  microspheres. *Tech Vasc Interv Radiol* 2007;10(1):12–29
- Kennedy A, Nag S, Salem R, et al. Recommendations for radioembolization of hepatic malignancies using yttrium-90 microsphere brachytherapy: a consensus panel report from the radioembolization brachytherapy oncology consortium. *Int J Radiat Oncol Biol Phys* 2007;68(1):13–23
- Liu DM, Salem R, Bui JT, et al. Angiographic considerations in patients undergoing liver-directed therapy. *J Vasc Interv Radiol* 2005;16(7):911–935
- Salem R, Thurston KG. Radioembolization with  $^{90}\text{Y}$  microspheres: a state-of-the-art brachytherapy treatment for primary and secondary liver malignancies. Part 1: Technical and methodologic considerations. *J Vasc Interv Radiol* 2006;17(8):1251–1278
- Fischman AM, Resnick NJ, Fung JW, et al. Transradial approach for hepatic arterial embolization: initial results and technique. *J Vasc Interv Radiol* 2013;24:S93–S4
- Ray CE Jr, Gaba RC, Knuttinen MG, Minocha J, Bui JT. Multiple arteries supplying a single tumor vascular distribution: microsphere administration options for the interventional radiologist performing radioembolization. *Semin Intervent Radiol* 2014;31(2):203–206
- Gaba RC, Vanmiddlesworth KA. Chemoembolic hepatopulmonary shunt reduction to allow safe yttrium-90 radioembolization lobectomy of hepatocellular carcinoma. *Cardiovasc Intervent Radiol* 2012;35(6):1505–1511
- Hamoui N, Minocha J, Memon K, et al. Prophylactic embolization of the gastroduodenal and right gastric arteries is not routinely necessary before radioembolization with glass microspheres. *J Vasc Interv Radiol* 2013;24(11):1743–1745
- Lam MG, Banerjee S, Louie JD, et al. Root cause analysis of gastroduodenal ulceration after yttrium-90 radioembolization. *Cardiovasc Intervent Radiol* 2013;36(6):1536–1547
- McWilliams JP, Kee ST, Loh CT, Lee EW, Liu DM. Prophylactic embolization of the cystic artery before radioembolization: feasibility, safety, and outcomes. *Cardiovasc Intervent Radiol* 2011;34(4):786–792
- Atassi B, Bangash AK, Lewandowski RJ, et al. Biliary sequelae following radioembolization with Yttrium-90 microspheres. *J Vasc Interv Radiol* 2008;19(5):691–697
- Bilbao JI, Garrastachu P, Herráiz MJ, et al. Safety and efficacy assessment of flow redistribution by occlusion of intrahepatic vessels prior to radioembolization in the treatment of liver tumors. *Cardiovasc Intervent Radiol* 2010;33(3): 523–531
- Spreatico C, Morosi C, Maccauro M, et al. Intrahepatic flow redistribution in patients treated with radioembolization. *Cardiovasc Intervent Radiol* 2015;38(2):322–328
- Morante A, Romano M, Cuomo A, et al. Massive gastric ulceration after transarterial chemoembolization for hepatocellular carcinoma. *Gastrointest Endosc* 2006;63(4):718–720
- Gates VL, Marshall KG, Salzig K, Williams M, Lewandowski RJ, Salem R. Outpatient single-session yttrium-90 glass microsphere radioembolization. *J Vasc Interv Radiol* 2014;25(2):266–270
- Liu D, Cade DN, Worsley D, Klass D, Lim H, Arepally A. Single procedure Yttrium-90 (SPY90): pilot study of a consolidated single procedure selective internal radiation therapy without prior-MAA nuclear medicine scan or prophylactic embolization utilizing Yttrium-90 resin microspheres. *Cardiovasc Intervent Radiol* 2013;36:S321