Combination Ipsilateral Lobar and Segmental Radioembolization Using Glass Yttrium-90 Microspheres for Treatment of Multifocal Hepatic Malignancies

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ABSTRACT

Eight patients with primary (n = 6) and metastatic (n = 2) disease of the liver underwent yttrium-90 radioembolization with glass microspheres using a combination of segmental and ipsilateral lobar approach to treat multifocal tumors containing a single dominant tumor. The superselective dose was administered to the dominant tumor, whereas lobar infusion was used for smaller tumors. Assuming uniform distribution, median dose to the segment with dominant tumor was 412.3 Gy and to the remaining lobe was 117.5 Gy. No instances of radiation-induced liver disease occurred. Combined segmental and ipsilateral lobar radioembolization is a well-tolerated procedure to treat unilateral multifocal hepatic tumors including a single dominant tumor.

ABBREVIATIONS

TARE = transarterial radioembolization, ^{90}Y = yttrium-90

Transarterial radioembolization (TARE) with yttrium-90 (^{90}Y) glass or resin microspheres is a safe and efficacious treatment in patients with primary or metastatic malignancies of the liver (1,2). At the present time, glass microspheres use radiation doses of 80–150 Gy from a lobar approach to achieve effective tumor control (1,2). Recent data show that an optimal tumoricidal dose requires > 200 Gy based on technetium-99m macroaggregated albumin single photon emission computed tomography studies (3,4).

Superselective radioembolization, termed radiation segmentectomy, delivers a higher dose of radiation to a tumor-containing segment with the added benefit of decreased exposure to normal liver tissue. Riaz et al (5) achieved a median radiation dose of 521 Gy to tumor using a conservative uniform distribution assumption model. Although radiation segmentectomy has provided positive results, its application has been limited to tumors located within ≤ 2 hepatic segments sharing perfusion from a common catheter position (5). For multifocal tumors, the segmental approach remains technically unfeasible. In this scenario, treatment strategy is often limited to a lobar infusion with relatively lower radiation received by the tumor. In such situations, however, a combined ipsilateral lobar and segmental treatment may be beneficial by providing high-dose ^{90}Y delivery to the largest tumor using the segmental dose but also treating the remaining tumors with the second lobar dose. The purpose of this report was to assess the safety and feasibility of a combined segmental and ipsilateral lobar ^{90}Y infusion in the setting of multifocal lobar disease with 1 dominant tumor.

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MATERIALS AND METHODS

This Health Insurance Portability and Accountability Act–compliant study was approved by the institutional review board. All radioembolization cases using glass microspheres between October 2014 (the first combined treatment case date) and May 2016 were reviewed.

Patient Selection and Evaluation

There were 89 TARE treatments performed in 81 patients. Among this cohort, 8 patients received treatment with a combined ipsilateral lobar and segmental approach using glass microspheres for primary (n = 6) or metastatic (n = 2) liver cancer. Radiographic selection criteria for patients treated by the combined lobar and segmental approach included patients with a dominant (≥ 2.5 cm) tumor with additional smaller tumors in adjacent hepatic segments. Angiographic selection criteria included majority perfusion of the dominant tumor by a single segmental or subsegmental branch. All patients were Eastern Cooperative Oncology Group grade A (score 1 or 0) with serum bilirubin levels < 2.0 mg/dL.

Procedure Technique

Preparatory Angiography. All treatments were preceded by a mapping angiogram with injection of technetium-99m macroaggregated albumin to calculate the hepatopulmonary shunt fraction. Standard protocol for mapping included an abdominal aortogram to visualize variant hepatic arterial anatomy or parasitized flow to the liver. Next, angiograms of the superior mesenteric, celiac, and common hepatic arteries were obtained using a 5-F diagnostic catheter. Cone-beam computed tomography (CT) was performed in 4 instances to confirm arterial supply to the dominant tumor.

Next, lobar arteriography was performed through a high-flow microcatheter to assess the extent of disease involving the studied hepatic lobe. Subsequently, a microcatheter system was used to select distal (fourth order or greater) hepatic arterial branches from which the segmental delivery of ^{90}Y was planned to be performed. From this position, angiography with or without cone-beam CT was performed to confirm appropriate catheterization of the branch feeding the dominant tumor. Next, the microcatheter was withdrawn back into the lobar artery, and technetium-99m macroaggregated albumin was injected. On completion, the patient was transported to the nuclear medicine section for scintigraphy.

Dose Calculation and Radioembolization Administration. Radioembolizations were performed with glass ^{90}Y microspheres (TheraSphere; Biocompatibles UK Ltd, Farnham, United Kingdom). All doses were administered on Tuesday through Thursday. Two separate doses for lobar and segmental deliveries were prescribed to be given at 1 setting. The lobar dose was calculated within a range of 120–140 Gy based on liver volume.

A standard 3-GBq dose was used for segmental infusion with an intended target of ≥ 200 Gy to the dominant tumor. Given that all calculated segmental volumes were < 500 cm^3, a standard 3-GBq dose delivered anytime between Tuesday and Thursday after Sunday preparation was determined to provide a target dose of approximately ≥ 200 Gy.

On the day of administration, the intended branch was selected, and the prescribed segmental dose was infused as planned. After removing the first microcatheter per radiation safety protocols, a new microcatheter was placed into the ipsilateral lobar branch. Arteriography was repeated to verify catheter positioning. The prescribed lobar dose was then injected from this position. All procedures were performed by a board-certified interventional radiologist with certificate of added qualification in vascular and interventional radiology (B.A., S.M., J.T., O.A.). Patients with bilobar disease were scheduled for repeat treatment to the other lobe at a date 6–8 weeks from the initial administration.

Dosimetry. Estimated lobar and segmental volumes were obtained using three-dimensional liver processing software (AquariusNET; TeraRecon, Foster City, California) from a CT scan performed within 1 month before the procedure. The calculated exposure of the treated lobe was performed using the previously described uniform distribution model and complete ^{90}Y decay in situ assumptions (5). The actual cumulative dose received by the treated liver was estimated after accounting for losses from the lung shunt fraction as well as a 1% assumption for residual activity remaining in the treatment vial after delivery. As the dominant tumor was treated by both the segmental and the lobar deliveries, the total dose to this tissue was calculated as the sum of the actual segmental and lobar doses. The remaining tumor and lobe dose was calculated as the estimated lobar dose only.

Imaging and Clinical Follow-up

Follow-up consisted of liver function testing at 1 month with contrast-enhanced CT (n = 6) or magnetic resonance (MR) imaging (n = 2) and subsequent 3-month interval imaging using the same modality. Treatment response according to Modified Response Evaluation Criteria in Solid Tumors was determined by 6-month follow-up by a board-certified diagnostic radiologist (6). The individual response of the dominant tumor treated by both segmental and lobar delivery was also assessed using Modified Response Evaluation Criteria in Solid Tumors criteria. Adverse events were documented according to the research reporting standards for radioembolization of hepatic malignancies (7). Toxicity was determined at scheduled 1-month outpatient clinic visits using the Common Terminology Criteria for Adverse Events, version 4.0 (8).

Patient Demographics. Patient demographics, clinical characteristics, and imaging findings are presented in Tables 1 and 2. Mean dominant tumor size was 4.24 cm