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Miscalculated Lung Shunt Fraction for Planning of Hepatic Radioembolization

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Abstract:

Yttrium-90 radioembolization is a safe and efficacious treatment option for many patients with unresectable hepatocellular carcinoma. Potential candidates for radioembolization, based on clinical criteria, undergo technetium-99m labeled macroaggregated albumin imaging to determine the extent of hepatopulmonary shunting. Dose selection is based on results from shunt imaging and can exclude patients from radioembolization therapy. We present a case of miscalculated lung shunt fraction and the circumstances that led to the critical error.

Keywords: Yttrium-90 radioembolization; lung shunt fraction; technetium-99m labeled macroaggregated albumin, hepatocellular carcinoma

Introduction:

Millions of individuals worldwide suffer from hepatocellular carcinoma (HCC), the most common primary liver malignancy. In addition to resection, transplantation, radiofrequency ablation, chemoembolization, and systemic chemotherapy, radioembolization has been shown to be a safe and effective treatment option for many patients (*1*). In Yttrium-90 (^{90}Y) radioembolization, glass or resin beads fixed with the beta-particle emitting radioisotope ^{90}Y are selectively injected via microcatheter to deliver high doses of radiation to the tumor. Prior to treatment, patients undergo important planning studies, including mapping angiography and technetium-99m labeled macroaggregated albumin (^{99m}Tc-MAA) imaging. Information from these studies is used to minimize the risk of non-target radiation injury to the gastrointestinal tract and lungs (*2*).

Radiation pneumonitis is a known complication of ^{90}Y radioembolization, and the risk of this complication is related to radiation delivered unintentionally to pulmonary tissue via hepatopulmonary shunting (*3*). ^{99m}Tc-MAA imaging is therefore critical for ^{90}Y patient selection, requirement for shunt reduction intervention and radioembolization dosing. After ^{99m}Tc-MAA injection, anterior and posterior planar imaging is obtained. The geometric mean is calculated as the square root of the product of counts for regions of interest (ROI) from anterior and posterior planar images (Fig. 1). Many vendors' software generates a single geometric mean image, which is a composite of the anterior and (flipped) posterior image, and from this the geometric mean counts for each ROI are obtained. The lung shunt fraction (LSF) is calculated as the counts from the lung ROI divided by the total counts for the lung and liver ROI (from the geometric mean image) (Fig. 1). For radioembolization therapy an LSF greater than 20% or an LSF that results in an estimated lung radiation exposure of > 30 Gy (based on the planned ^{90}Y dosage) is considered a contraindication (*4*) or requires a significant dose reduction at the risk of reduced treatment efficacy.

Case Report:

A 65-year-old male with multifocal HCC (Fig. 2) underwent evaluation for potential treatment with ^{90}Y radioembolization. Pre-treatment ^{99m}Tc-MAA imaging was performed to assess hepatopulmonary shunting. ROI determination and post-processing were completed per standard procedure and the LSF was initially calculated as 29.5% (Fig. 3). The nuclear medicine physician noted a potential error in shunt fraction based on visual assessment and requested the image be reprocessed. After reprocessing, the LFS was recalculated as 7.9% (Fig. 4). The patient ultimately received a successful ^{90}Y radioembolization.

Discussion:

This case highlights a critical source of error that can occur during LSF calculation by ^{99m}Tc-MAA imaging. Initially, the nuclear medicine technologist mistakenly labeled the raw data from a posterior flipped view as the geometric mean image and thus the ROI only contained counts from the posterior view. The initial incorrect LSF (by using only the flipped posterior planar image) was 159,7289 ÷ (159,7289 + 380,618) = 0.295 (Fig. 2). The correct LSF (based on counts from the geometric mean image) was 282,930 ÷ (282,930 + 3,284,000) = 0.079 (Fig. 4).

The initial shunt fraction of 29.5% would be a contraindication to ^{90}Y radioembolization and thus the error would have mistakenly precluded the patient from therapy. While differences in region of interest size can alter count totals, the variance in this case was too large to be attributed to this factor alone as the error led to a 3.5 greater LSF discrepancy between the calculated LSFs. The initial artifactually low liver count was especially exacerbated by the anterior position of the tumor (Fig. 5) as only the (flipped) posterior planar image was used for the initial LSF calculation. Our nuclear medicine laboratory has scanners from multiple vendors, and this error likely occurred due to confusion with how the geometric mean is displayed or calculated among different vendors.

To overcome this potential error, the nuclear medicine technologist may be benefit from having easy access to a vendor-specific guide for the accurate calculation of LSF. Labelling the images with “geometric mean” instead of “ROI” or “counts”, as in our case (Fig. 3) and (Fig. 4), may act as a reminder for using the correct data source. Further, if the nuclear medicine technologist (or nuclear medicine physician) needs to actively window the raw data in order to discriminate the lung ROI (or liver ROI) from the background then the LSF should be low. Nuclear medicine technologists and nuclear medicine physicians may also use the provided LSF visual reference (Fig. 6) as a guide when visually assessing the adequacy of the LSF from the raw data images.

Conclusion:

^{99m}Tc-MAA imaging and LSF calculations are important steps in pre-treatment assessment for patients prior to ^{90}Y radioembolization for HCC. Confirming the visual assessment and calculated LSF are concordant ensures the LSF has been calculated appropriately from the geometric mean image during processing.

Disclosure:

The authors have no potential conflict of interest relevant to this article to disclose.

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Figures:

$$Geometric\ mean = \sqrt{Anterior\ view\ counts \times Posterior\ view\ counts}$$

$$Lung\ shunt\ fraction\ (LSF) = \frac{Lung\ geometric\ mean}{(Lung\ geometric\ mean\ + Liver\ geometric\ mean\ )}$$

FIGURE 1: Formulas used for calculating the geometric mean (for a designated region of interest) and lung shunt fraction.

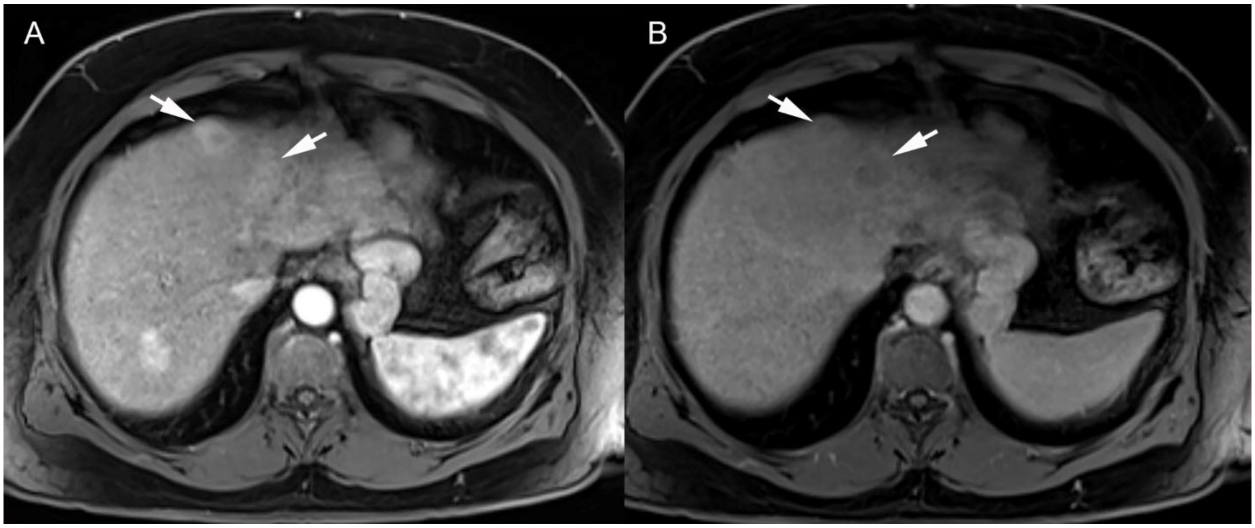

FIGURE 2: Post-contrast axial T1-weighted images during the arterial (A) and delayed (B) phases demonstrate washout within two adjacent hepatocellular carcinomas (white arrows) located anteriorly within segment 4A of the liver.

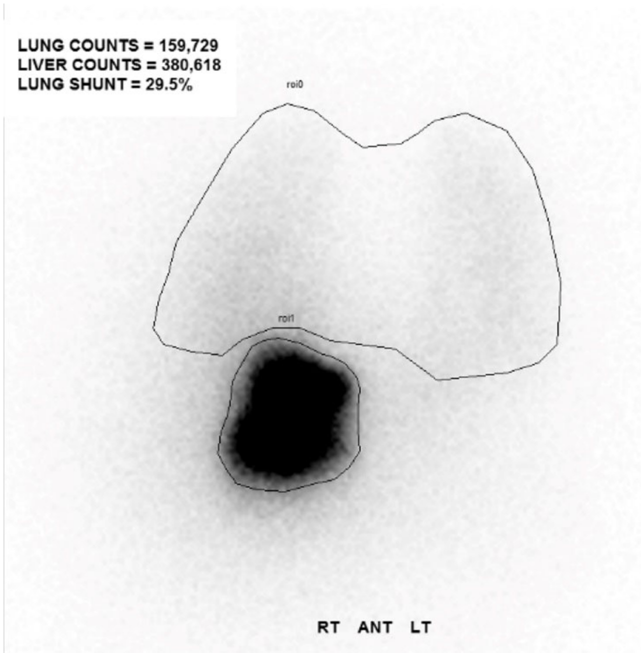

FIGURE 3: The initial ^{99m}Tc-MAA (flipped) posterior planar image with lung and liver regions of interest. The incorrect lung shunt fraction calculated was 29.5%.

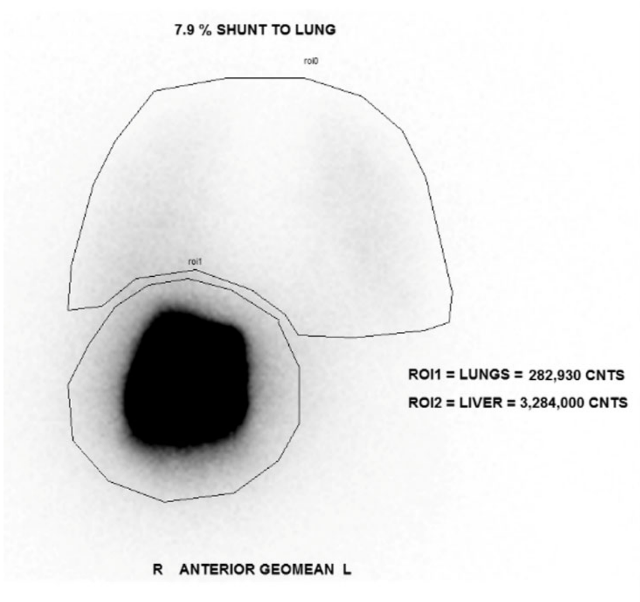

FIGURE 4: The ^{99m}Tc-MAA geometric mean image with lung and liver regions of interest. The correct lung shunt fraction calculated was 7.9%.

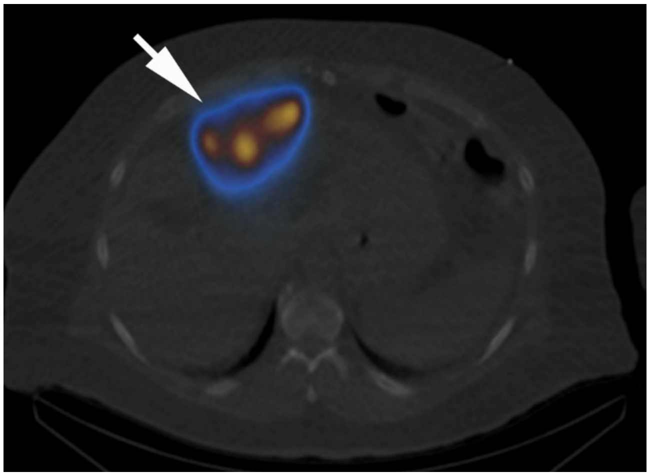

FIGURE 5: Selected axial ^{99m}Tc-MAA SPECT/CT image confirming radiotracer delivery to the anteriorly positioned hepatocellular carcinomas (white arrow).

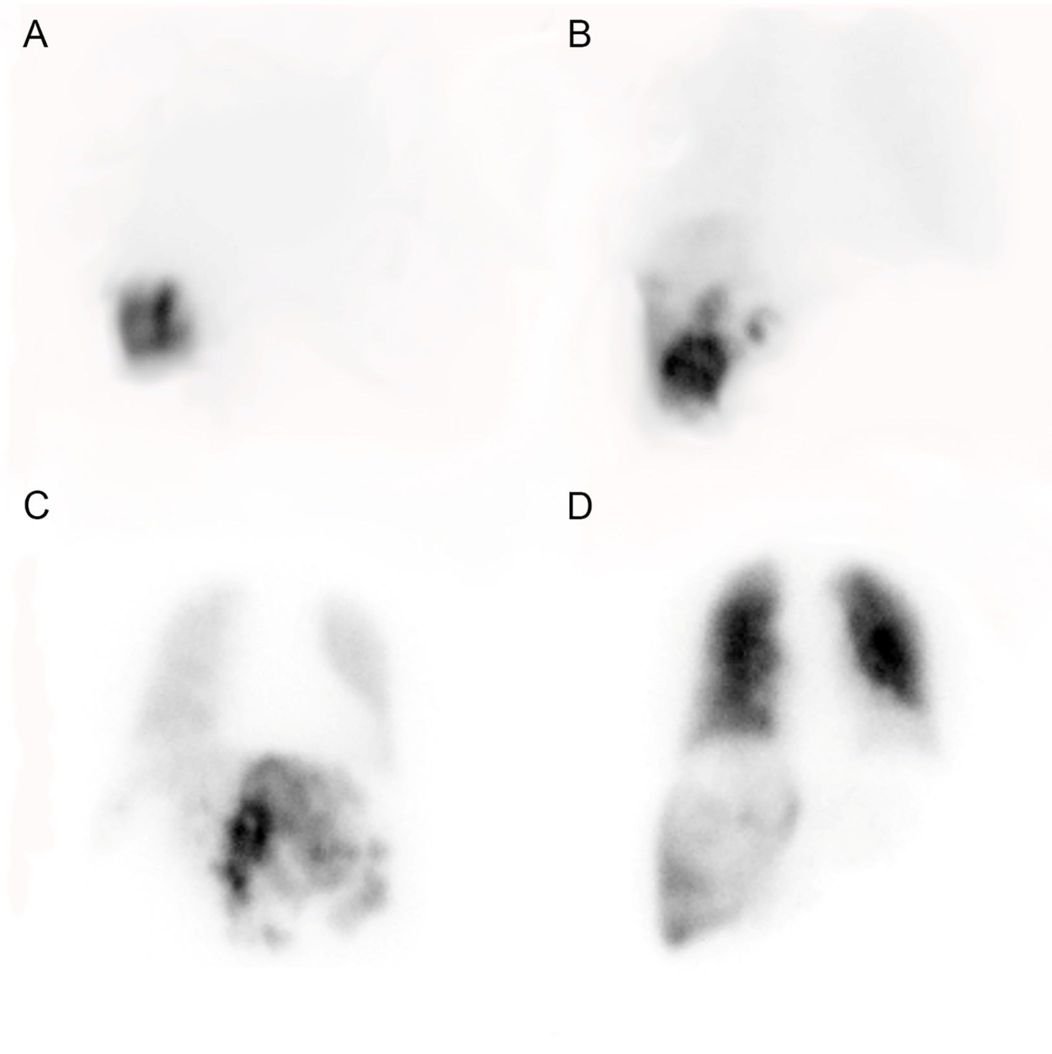

FIGURE 6: Lung shunt fraction visual reference for lung shunt fractions of 3% (A), 15% (B), 37% (C) and 79% (D).