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Physics Contribution

Selective Internal Radiation Therapy With Yttrium-90 Glass Microspheres: Biases and Uncertainties in Absorbed Dose Calculations Between Clinical Dosimetry Models

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Summary

Relative to external beam, currently used standard (SM) and partition (PM) dosimetry models for ^{90}Y SIRT are simplistic. We show that large differences exist in calculated mean absorbed doses when voxel-level Monte Carlo (MC) calculations are compared with SM and PM absorbed doses. The SM is unable to predict individual mean MC tumor absorbed dose. The PM is

Purpose: To quantify differences that exist between dosimetry models used for ^{90}Y selective internal radiation therapy (SIRT).

Methods and Materials: Retrospectively, 37 tumors were delineated on 19 post-therapy quantitative ^{90}Y single photon emission computed tomography/computed tomography scans. Using matched volumes of interest (VOIs), absorbed doses were reported using 3 dosimetry models: glass microsphere package insert standard model (SM), partition model (PM), and Monte Carlo (MC). Univariate linear regressions were performed to predict mean MC from SM and PM. Analysis was performed for 2 subsets: cases with a single tumor delineated (best case for PM), and cases with multiple tumors delineated (typical clinical scenario). Variability in PM from the ad hoc placement of a single spherical VOI to estimate the entire normal liver activity concentration for tumor (T) to nontumoral liver (NL) ratios (TNR) was investigated. We interpreted the slope of the resulting regression as bias and the 95% prediction interval (95%PI) as uncertainty. MC_{NL}^{single} represents MC absorbed doses to the NL for the single tumor patient subset; other combinations of calculations follow a similar naming convention.

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statistically correlated to mean MC absorbed dose but with large uncertainties in predicted values.

Results: *SM* was unable to predict MC_T^{single} or $MC_T^{multiple}$ (p>.12, 95%PI >±177 Gy). However, SM^{single} was able to predict (p<.012) MC_{NL}^{single}, albeit with large uncertainties; SM^{single} and $SM^{multiple}$ yielded biases of 0.62 and 0.71, and 95%PI of ±40 and ± 32 Gy, respectively. PM_T^{single} and $PM_T^{multiple}$ predicted (p<2E-6) MC_T^{single} and $MC_T^{multiple}$ with biases of 0.52 and 0.54, and 95%PI of ±38 and ± 111 Gy, respectively. The TNR variability in PM_T^{single} increased the 95%PI for predicting MC_T^{single} (bias = 0.46 and 95% PI = ±103 Gy). The TNR variability in $PM_T^{multiple}$ modified the bias when predicting $MC_T^{multiple}$ (bias = 0.32 and 95%PI = ±110 Gy).

Conclusions: The SM is unable to predict mean MC tumor absorbed dose. The PM is statistically correlated with mean MC, but the resulting uncertainties in predicted MC are large. Large differences observed between dosimetry models for ^{90}Y SIRT warrant caution when interpreting published SIRT absorbed doses. To reduce uncertainty, we suggest the entire NL VOI be used for TNR estimates when using PM.

Introduction

Selective internal radiation therapy (SIRT) with ^{90}Y microspheres has been shown to be an effective treatment option for unresectable hepatocellular carcinoma or metastatic colorectal cancer in the liver (1, 2). Dose calculations in radiation oncology have been at the voxel level since the turn of the century (3, 4). In contrast, clinical dosimetry models for SIRT absorbed dose calculations currently provide only mean absorbed dose to volumes of interest (VOIs). An obvious limitation of such models is the lack of spatial dose information (Fig. 1). Unlike radiation oncology, clinical absorbed dose calculations for SIRT (undesirably) depend explicitly on delineated VOI masses. To be clear, radiation transport, and hence dose calculation, should not depend on a user-specified VOI superimposed on a patient. The mean absorbed dose calculations using partition model (PM) (5) and standard model (SM) (6) for glass microspheres require VOI segmentation, which leads to additional variability in absorbed dose. Equations 1-3 describe mean absorbed doses (in Gy) using PM (5) and SM (6), where A is the administered activity to the liver volume (in GBq), M_T and M_{NL} represent the masses (in kg) of tumor (T) and nontumoral liver (NL), respectively, and

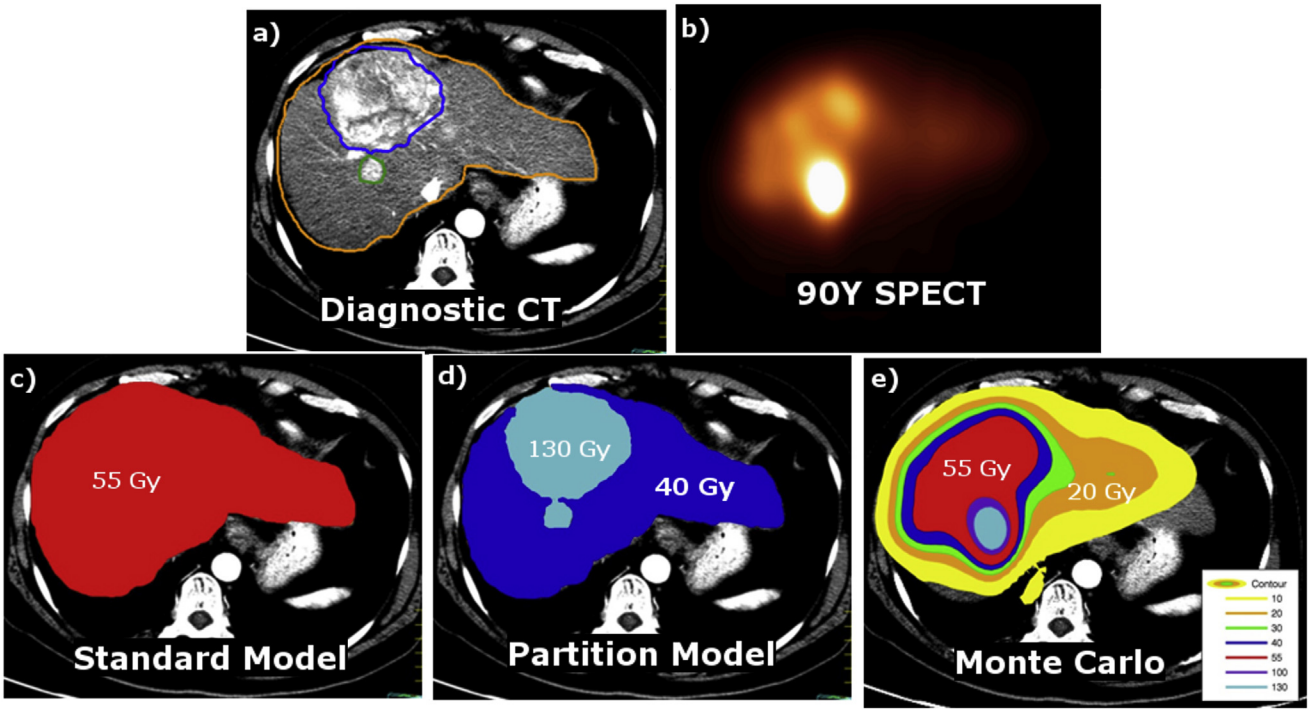

Fig. 1. Spatial representation of the dosimetry models. (a) Diagnostic computed tomography (CT), (b) ^{90}Y single photon emission computed tomography (SPECT), (c) standard model, (d) partition model, (e) Monte Carlo. Gold, blue, red, and cyan color washes represent 20, 40, 55, and 130 Gy, respectively. (A color version of this figure is available at www.redjournal.org.)