Monte Carlo Evaluation of Tissue Assignment Variation in Low-Energy Lung Brachytherapy

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INTRODUCTION

Purpose: To quantify the effect of tissue assignment variation on dose distributions for ^{103}Pd, ^{125}I, and ^{131}Cs seeds in lung brachytherapy.

METHODS AND MATERIALS

CT images from three patients with non-small cell lung cancer and the corresponding contours of the planning target volume (PTV), ipsilateral lung, and heart were investigated. As detailed in Table 1, three tissue assignment schemes were examined: coarse (5 categories), intermediate (12 categories), and fine (20 categories). TOPAS 1 Monte Carlo simulations were performed for each patient, source type, and tissue assignment scheme using identical implant geometries. Dose metrics including D90 and V100 for the PTV, mean lung and heart dose were calculated. Percent differences between tissue schemes were analyzed.

Table 1. Material assignment schemes used in this study.

Coarse	
HU value	Material
HU ≤ -950	Air
-950 < HU ≤ -200	Lung
-200 < HU ≤ -50	Adipose II
-50 < HU ≤ 250	Muscle II
HU > 250	Bone

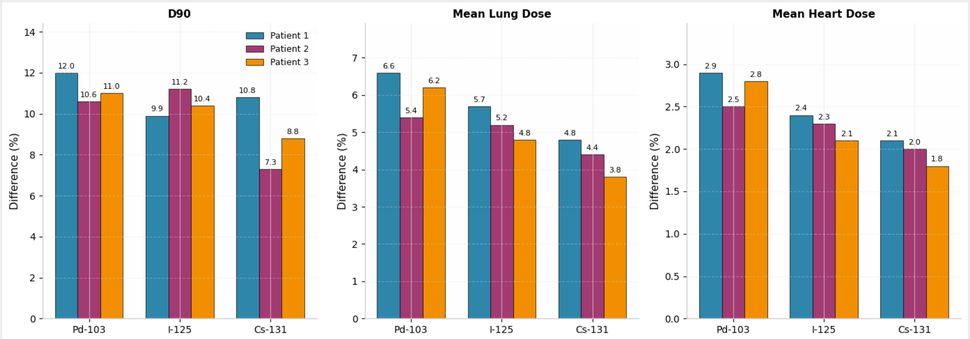
Intermediate	
HU value	Material
HU ≤ -950	Air
-950 < HU ≤ -200	Lung
-200 < HU ≤ -85	Adipose III
-85 < HU ≤ -65	Adipose II
-65 < HU ≤ -50	Adipose I
-50 < HU ≤ 50	Muscle II
50 < HU ≤ 65	Heart II
65 < HU ≤ 85	Skin II
85 < HU ≤ 250	Cartilage
250 < HU ≤ 750	Ribs II
750 < HU ≤ 1150	Ribs I
HU > 1150	Bone

Fine	
HU value	Material
HU ≤ -950	Air
-950 < HU ≤ -200	Lung
-200 < HU ≤ -85	Adipose III
-85 < HU ≤ -65	Adipose II
-65 < HU ≤ -50	Adipose I
-50 < HU ≤ -25	Soft Tissue III
-25 < HU ≤ 15	Soft Tissue II
15 < HU ≤ 25	Soft Tissue I
25 < HU ≤ 35	Muscle III
35 < HU ≤ 43	Muscle II
43 < HU ≤ 50	Muscle II
50 < HU ≤ 58	Heart II
58 < HU ≤ 65	Heart I
65 < HU ≤ 73	Skin III
73 < HU ≤ 80	Skin II
80 < HU ≤ 85	Skin I
85 < HU ≤ 250	Cartilage
250 < HU ≤ 750	Ribs II
750 < HU ≤ 1150	Ribs I
HU > 1150	Bone

RESULTS

As shown in figure 1, the low-energy sources, particularly ^{103}Pd, demonstrated the highest sensitivity to tissue assignment, with D90 varying by up to 12% between coarse and fine schemes. Mean lung dose differed by 6–7% for ^{103}Pd, while ^{131}Cs showed smaller variations (< 4%). Mean heart dose was only slightly affected (<3%), though slightly higher for finer tissue assignment scheme due to the more accurate modeling of soft tissue. Coarse tissue assignments overestimated the dose in low-density regions and underestimated it near high-density structures.

Figure 1. Percentage difference in D90, mean lung dose, and mean heart dose between coarse and fine material assignment methods for three patients using Pd-103, I-125, and Cs-131.



CONCLUSIONS

Tissue assignment variation can result in clinically significant differences in lung brachytherapy, particularly for low-energy sources. Model-based Monte Carlo calculations with refined tissue definitions are recommended for more accurate dose estimation.

REFERENCES

1. Perl J, Shin J, Schumann J, Faddegon B, Paganetti H. TOPAS: an innovative proton Monte Carlo platform for research and clinical applications. Med Phys. 2012;39(11):6818–6837. doi: 10.1118/1.4758060

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