^{177}Lu-DOTATATE Dosimetry for Normal Organs and Tumors with Multiple Voxel S-Value Approach

Purpose– ^{177}Lu-DOTATATE therapy is regarded as a proper option for neuroendocrine tumor (NET) because ^{177}Lu has good targeting performance and suitable decay time for therapeutic purposes. However, individual internal dosimetry is required for the protection of organs at risk and quantification of dose delivery to tumor region. The multiple voxel S-value (VSV) approach is an accurate and fast voxel-based dosimetry method compared to the conventional single VSV method [1]. In this study, ^{177}Lu-DOTATATE internal dose estimations for kidneys, bone marrow and tumors were performed using the multiple VSV method.

Methods– The SPECT/CT data used for this study consists of two sets: the first data set is obtained at Seoul National University Hospital and another set is obtained at Malaysia Sunway Medical Centre. The mean administered activity was 200.22 ± 26.86 mCi. The SPECT/CT images were acquired at 4, 24, 48, 120 hours after injection for the first data set, and 0.5, 4, 24, 48 hours for the second data set. We first generated VSV of ^{177}Lu in mediums with various density using GATE v.8.2 for multiple VSV approach. Then, the dose map for each medium was generated by convoluting VSV kernel and time-integrated activity map. Finally, the dose maps were properly masked with medium-specific binary mask maps derived from CT images and summed into the final dose map. Four different VSV sets were tested for multiple VSV approach (single, 4, 10, and 20 VSVs). Dose maps obtained by Monte Carlo simulation were regarded as ground truth. The absorbed doses in kidneys, bone marrow and tumors were analyzed and the relative error between the VSV method and ground truth was estimated.

Results– For dosimetry of kidneys, 20 VSV provided the smallest mean absolute error (MAE) but not very significant (MAE: 4.00, 4.40, 4.80, and 1.04 % for single, 4, 10, and 20 VSVs, respectively). However, the MAE decreased considerably when 20 VSV was applied to the bone marrow (MAE: 8.41, 8.40, 8.42, and 1.67 % for single, 4, 10, and 20 VSVs, respectively). In dose estimation of tumor regions, similar tendency was observed (MAE: 10.76, 6.71, 8.20, and 0.69 % for single, 4, 10, and 20 VSVs, respectively) and this discrepancy was remarkable when only the bone metastatic tumor was considered (MAE: 15.87, 5.40, 8.83, and 1.31 % for single, 4, 10, and 20 VSVs, respectively). Furthermore, multiple VSV approach took shorter computation time compared to Monte Carlo simulation (1% simulation with Monte Carlo: 81 hr, 20 VSVs: 12 min)

Conclusion– The conventional single VSV method provides accurate dose estimation where density distribution is uniform (e.g. kidneys). However, in bone marrow and tumor, the single VSV method yields large error because it does not consider other mediums than water. However, the multiple VSV method allows precise dose estimations in the bone marrow and bone metastatic tumors where the medium property is heterogeneous.

Reference

[1] Lee MS et al. “Whole-body voxel-based personalized dosimetry: the multiple voxel S-value approach for heterogeneous media with nonuniform activity distributions”, J. Nucl. Med. 59, 1133-1139 (2018).