NanoMASK: A Deep Learning Algorithm for Auto-Segmentation and Pharmacokinetic Quantitation for PET/CT Functional Imaging of Nanomedicines

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Multimodal imaging can provide important pharmacokinetic and dosimetry information during nanomedicine development and optimization. However, accurate quantitation is time-consuming, resource intensive, and requires anatomical expertise. We present NanoMASK: the first deep learning model capable of rapid, automatic organ segmentation of multimodal imaging data that can output key clinical dosimetry metrics without manual intervention. This model was trained on 350+ manually-contoured PET/CT data volumes of mice injected with a variety of nanomaterials and imaged over 48 hours. It produces 3-dimensional contours of the heart, lungs, liver, spleen, kidneys, and tumor with high volumetric accuracy (90-98%). Pharmacokinetic metrics including %ID/cc, %ID, and SUVmax achieved correlation coefficients exceeding R = 0.987 and relative mean errors below 0.2%. NanoMASK was applied to novel datasets of lipid nanoparticles and antibody-drug conjugates with a minimal drop in accuracy, illustrating its generalizability to different classes of nanomedicines. Furthermore, the fundamental dependencies of models built on the 3D U-Net architecture were explored through the development of subsetted models based on image modality, experimental imaging timepoint, and tumor status, showing highly consistent segmentation accuracy across significant changes in functional imaging contrast. NanoMASK is made publicly available to all readers for automatic segmentation and pharmacokinetic analysis applicable to a diverse array of nanoparticles, expediting agent development.