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Optimization of the scan protocol for small-animal PET imaging: Effects on image quality, quantification accuracy, and radiation exposure

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Purpose: Positron emission tomography (PET) imaging performance is limited by a number of physical, acquisition, and dosimetric constraints. To gain a thorough understanding of this issue, multivariate analysis was used to investigate the simultaneous effects of changes in these factors. This study investigated the relationship among the small animal imaging protocol, imaging performance, and radiation dose to achieve optimal PET image quality and minimize potential damage caused by radiation and anesthesia in preclinical studies.
Methods: A small-animal PET system with a dual-layer phoswich detector was modeled based on a Monte Carlo simulation to generate the emission image and dose distribution. A multivariate approach was used to investigate the simultaneous effects of tumor size, target-to-background ratio (TBR), scan duration, and injected radioactivity on the contrast-to-noise ratio (CNR) and recovery coefficient (RC).
Results: The object size, TBR, injected activity, and scan time were crucial predictors, whereas TBR and scan time were the most relevant contributors of CNR and RC variations, respectively. In 1.86×10^5 Bq/ml injected activity, the absorbed dose for a body and tumor with TBR of 2 were 2.46 and 5.39 cGy, respectively. A substantial improvement in CNR or RC was not observed in images acquired with radiotracer activity larger than 9.3×10^4 Bq/ml and scan duration longer than 30 min. The coefficient of determination was greater than 0.93 for both regression models, indicating an excellent fit to the data.
Conclusions: Although the improvement of counting statistics by increasing scan duration and injected activity can reduce statistical noise and improve spatial resolution, it is crucial to maintain the radiation exposure and anesthetic dose received by animals as low as possible to reduce biological damage. The results of this study provide a practical guide to determining the radiotracer concentration and scan duration to detect and quantify focal lesions in small-animal PET imaging.

Keywords: PET; small animal; imaging performance; multivariate analysis

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