Clinical Dosimetry Workflow comparison: implementation and evaluation in OpenDose3D

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Résumé

Introduction: Image-based dosimetry is a multistep procedure where each step can be implemented with various methods, leading to variability in dosimetric results. This lack of standardization is a major challenge in molecular radiotherapy (MRT) dosimetry. OpenDose3D (OD3D) is an open-source software designed to perform image-based, patient-specific dosimetry, which enables the comparison of different clinical dosimetry workflows (CDWs). OD3D allows absorbed dose (AD) calculations based either on time-integrated activity (ACT-CDW) or on absorbed dose rates (ADR-CDW), the latter at the voxel level. This study investigates the variability introduced by these workflows and the impact of componing steps (registration, absorbed dose calculation algorithm, etc.), contributing to the effort of dosimetry standardization.
Material and Methods: This study used OD3D to compare ADR-CDW and ACT-CDW. Seven patients treated with (^{1}Lu)Lu-DOTATATE were analyzed, along with patient A from the 2021 Society of Nuclear Medicine and Molecular Imaging (SNMMI) Dosimetry Challenge (Uribe et al. 2021).

First, both workflows were tested under equivalent conditions: rigid registration, LED algorithm, and homogeneous density medium.

Second, the comparison between ADR and ACT was repeated while modifying one variable at a time in both workflows, such as changing the registration method (which affects volume variability) or switching between homogeneous or heterogeneous density media.

Third, each workflow was evaluated separately using three image processing strategies: rigid registration, elastic registration, and segmentation at each time point without registration.

Fourth, homogeneous and heterogeneous media assumptions were compared within each workflow to assess the impact of tissue density correction.

Statistical analysis considered $p \leq 0.05$ as significant, with $r \geq 0.7$ indicating correlation.

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Results: Under ideal conditions, both CDWs provided identical ADs. When replacing rigid with elastic registration, differences of up to 5% were observed. Segmenting at each time point without registration showed a statistically significant difference for bone marrow: although the mean values differed by only 0.02 Gy, this corresponded to a 10% relative difference due to the low baseline AD. The trend toward lower AD values in ACT-CDW was consistent across patients for the bone marrow.

In the heterogeneous media, differences between ADR and ACT workflows emerged, with relative differences ranging from 0.8% to 3.3%.

When comparing registration types within each CDW, significant differences were found in most VOIs, with relative mean differences reaching 15%.

For the comparison of homogeneous vs. heterogeneous media within each workflow, statistically significant differences were observed in nearly all VOIs.

These findings were consistent with the results from patient A in the dosimetry challenge. A strong correlation ($r = 0.9$) was observed between the variation of VOI volume over time and the difference in AD between the two CDWs, with the spleen showing the highest variability up to 15.2%.

Conclusions: The choice of registration method and medium density significantly impacted dosimetric results, regardless of whether the calculation was based on the integration of ADR or activity. OD3D allows testing clinical dosimetry software by benchmarking individual CDW steps and end-to-end procedures.

References

1. Uribe C. et al. e. Nucl Med. 2021;32:36S-47S