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Technical notes

Quantitative comparison between the commercial software STRATOS® by Philips and a homemade software for voxel-dosimetry in radiopeptide therapy

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ABSTRACT

Background: Targeted radionuclide therapy is a rapidly growing modality. A few commercial treatment planning systems are entering the market. However, some in-house systems are currently developed for a more flexible and customized dosimetry calculation at voxel-level. For this purpose, we developed a novel software, VoxelMed, and performed a comparison with the software STRATOS.
Methods: The validation of both of them was undertaken using radioactive phantoms with different volume inserts. A cohort of 10 patients was also studied after a therapeutic administration of ^{177}Lu-labelled radiopeptides. The activity, number of disintegrations, absorbed dose and dose-volume histogram (DVH) were calculated for the phantoms and the kidneys in patients, which were the main critical organs at risk in this study.
Results: In phantoms the absorbed doses computed with VoxelMed and STRATOS agree within 5%. In patients at the voxel-level the absorbed dose to kidneys (VoxelMed: mean 0.66 Gy/GBq) showed a limited difference of 5%, but with a remarkable range (−40%, +60%) between the two software packages. Voxel-dosimetry allows to estimate the dose non-homogeneities in volumes, which may be evaluated through DVHs.
Conclusion: This study demonstrates that a fully 3D voxel-dosimetry with multiple SPECT images is feasible by using home-made or commercial software package and absorbed dose results obtained are similar. The main difference between the studied tools was observed in the activity integration method (effective vs physical half-time to time activity curve tail). We believe that an effective half-time integration method produces a more accurate approximation of clinical uptake and resultant dosimetry.

Introduction

In the last decade, peptide receptor radionuclide therapy (PRRT) with somatostatin analogues has been increasingly used for the treatment of metastasized neuroendocrine tumours. On the other hand patient-specific dosimetry can provide information to assess both organ-specific and tumour absorbed doses, and to avoid healthy organ toxicity [1]. An accurate dosimetry is so necessary to understand the radiobiological considerations that affect treatment response [2]. Different dosimetric methods can be applied. They are generally based on the MIRD (Medical Internal Radiation Dose) indications.

The MIRD scheme [3] may be employed through either hybrid (3D SPECT plus serial planar) or fully 3D SPECT-CT-based dosimetry. Organ and equivalent dose values may be then calculated with MIRDose or the OLINDA/EXM software (Vanderbilt University, Nashville, USA).

MIRD no. 23 [4] describes a voxel-level approach, in which the absorbed dose is computed at voxel-level, accounting for the non-uniformity at a maximum level of detail accessible *in vivo*. This produces dose-volume-histograms (DVHs) and radiobiological parameters of great interest for radionuclide therapy.

The voxel-based methods are not widely used in clinical practice and only two commercial software packages are available:

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STRATOS (Philips Technologie, Aachen, Germany) [11] and VoxelDose (DosiSoft, Cachan, France) [5].

Despite this, for a more flexible and customized dosimetry calculation at voxel-level, in-house software packages were developed by many groups, using 3D information from PET/CT or SPECT/CT [6,7].

The aim of the present work is to compare the results obtained with two different software packages for voxel-dosimetry when processing the same image sets: 1) the software package VoxelMed (VM) developed at our institute; 2) the STRATOS research module.

Material and methods

Phantoms

All activity measurements were performed with an accurate activity calibrator (Aktivimeter Isomed 1010, Nuklear Medizintechnik, Germany), specifically calibrated for ^{177}Lu measurements. All phantoms features are summarized in Table 1.

All phantoms were acquired through a SPECT-CT scanner (Symbia T2, Siemens Medical, Germany, 3/8" NaI(Tl)-detector). The energy windows (EW) of ^{177}Lu photopeaks were set at 113 keV ± 7.5% and 208.4 keV ± 7.5%. For the lower EW, the TEW scatter correction was employed (lower scatter window 87.58 − 104.53 keV, weight = 0.5; the upper scatter window 121.47 − 130.51 keV, weight = 0.9375). For the higher EW, the DEW scatter correction was employed (lower scatter window 171.60 − 192.40 keV, weight = 0.75).

Two cylindrical phantoms were used. The home-made 'Phantom-B' was filled with a homogeneous radioactive solution of ^{177}Lu, while 'Phantom-D' (Data Spectrum Corporation, USA) was provided with six spheres filled with a ^{177}Lu solution in a hot background.

'Phantom-D' was acquired with the standard clinical SPECT-CT protocol for brain studies.

It was used to study the accuracy and the distribution of the activity (A), number of disintegration (ND) and absorbed dose (D) at the voxel-level in the ideal case of only physical decay, at 5, 164, 333 and 500 h after phantom preparation.

'Phantom-B' was acquired with the standard clinical SPECT-CT protocol for body studies.

It was used to study the accuracy and the distribution of the dosimetric values A, ND and D at the voxel-level. The acquisition of the phantom in air was repeated 5 times (30 min, 4 h, 24 h, 48 h and 60 h after injection) at activity concentrations that were intended to simulate a clinical time activity curve.

To extrapolate a single calibration factor CF (expressed in Bq/counts unit, i.e. independent on voxel size of images) shared by both voxel-dosimetry tools, the cylindrical plastic 'Phantom-A' (Data Spectrum Corporation, USA) and 'Phantom-C' (that is 'Phantom-D' essentially without inserts), were filled with a homogeneous ^{177}Lu solution.

The absolute CF for body protocol was determined from 'Phantom-A' (0.065 MBq/ml), while for brain protocol it was determined from 'Phantom-C' (0.40 MBq/ml).

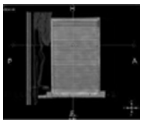
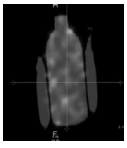
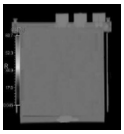
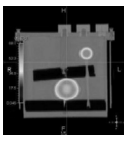
Multiple volumes of interest (VOIs) were manually drawn on one of the CT images and the total counts were extrapolated from the corresponding SPECT images for each object inside the phantoms and for each phantom.

The SPECT-CT scanner was characterized for PVE (Partial Volume Effect) by extrapolation of recovery curves for ^{177}Lu, as a function of volume. All data (A; ND/A and D/A, that are ND and D ratio to activity A), were shown already corrected for PVE.

Acquisition and reconstruction clinical protocols

The standard Siemens clinical protocol for brain studies used: two MEHR collimators; matrix = 128 × 128; zoom = 1.23; views = 60 × 2; time/view = 30 s; step and shoot mode; degree of rotation = 180°; non-circular orbit; detector configuration = 180°. The SPECT projections were reconstructed by an iterative algorithm with compensations for attenuation from CT images, scatter, and full collimator-detector response in Siemens E-Soft workstation (Flash 3D iterative algorithm: 12 iterations; 8 subsets; gaussian filter cut-off = 3.9 mm; 3.9 mm cubic voxel for brain protocol).

Table 1
Description of phantoms used in the study.

Acquisition protocol	Index	Picture	Vol. (ml)	Geometry h = height d = diameter	Insert (ml)	Aim	Activity concentration (MBq/ml)
Body	A		9580	Cylinder h:30, d:20 (internal values)	–	CF calculation	homogeneous solution: 0.065
	B		500	Plastic bottle + water bags h:18, d:6	–	effective decay test	refilled homogeneous solution (× 10^{-3}): 2.2, 2.7, 1.89, 0.94, 0.13
Brain	C		5640	Jaszczak Cylinder (no insert) h:18, d:21 (internal values)	–	CF calculation	homogeneous solution: 0.40
	D		5640	Jaszczak Cylinder (personalized inserts) h:18, d:21 (internal values)	7 fillable spheres (98, 26.5, 19, 11.5, 5.6, 2.57) + extruded polystyrene foam support	test CF and physical decay test	hot background: 0.38, spheres:3.44