Technical aspects of clinical dosimetry

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While in external beam radiotherapy (XRT) each treatment is preceded by a treatment planning session, this is seldom performed in nuclear medicine therapy (targeted therapy TRT). However in the last years, both the Therapy and Dosimetry Committee of EANM made effort to push toward a dosimetry based TRT [1], [2].

The large gap of dosimetric technique between XRT and TRT has many reasons, but the most important one is the following. While an accelerator beam is completely under the technologist's control, the biokinetics of a radiopharmaceutical in a patient body is completely out of control, except for the administered activity. So the question is which is the optimal administered activity, i.e. which well be simultaneously safe and effective, if possible. The answer to this problem should be regarded as the treatment planning in TRT. Dosimetry after therapeutic injection is also a useful source of information's, while cannot be used for lesion, but only for healthy organ treatment planning in repeated administrations schema. Since dosimetry in TRT was not performed systematically, we are facing an unexplored scenario, where very few data and demonstrated scientific facts are available.

The absorbed dose seems to be the main, but not the only physical parameters correlated to the biological effect (toxicity and efficacy). Values currently used in XRT were unsuccessfully applied to TRT, and the introduction of Biological Effective Dose (BED) was necessary to explain renal toxicity following 90Y DOTATOC therapy. New liver treatment performed with intra-arterial administration of radioactive microspheres indicates another major difference between XRT and TRT: the non uniformity of dose distribution. For these reasons, large research efforts are necessary to fully understand the relation between dose and effects in TRT.

The starting point is the fact that the absorbed dose in an organ or tumor is proportional to the number of decay in an organ, which, in a simplified approach is given by two factors:

a) the initial uptake by the organ;

b) the time the activity resides in the organ.

This means that any dosimetric evaluation has to QUANTIFY the uptake and to describe its variation along the time (Time-Activity curve: TACT). These two basic concepts make a huge conceptual difference between a diagnostic scan and a dosimetric scan, while in practical they are similar. Since for instance, in radioiodine therapy of thyroid carcinoma, lesion clearance times are of the order of many days, data acquisitions have to follow a similar time schedule.

Data collection is performed not only by imaging. For a safety oriented dosimetry, the total body TACT is the first source of information. It is acquired by external probe (spectroscopic NaI probe used for thyroid uptake measurement, or portable monitor). Blood activity concentration versus time is the second necessary information. This requires blood sampling and well counter or gamma counter counting. Total body and blood TACT are sufficient for a safety oriented, i.e. red marrow dosimetry, in all systemic treatment except than radio-peptides, where kidney is the critical organ and lung diffuse metastases from thyroid carcinoma, where lung itself could be the critical organ.

Imaging is necessary for lesion and organ dosimetry. So a sequence of planar, SPET or PET scintigram is necessary to evaluate the tumor dose. Unfortunately gamma camera is not meant to be quantitative, for a series of physical effects effect:

Photon attenuation in patient body

Background of overlapping structures

Scatter

Self absorption of source object

Partial volume effect for small objects

Dead time count losses (only after therapeutic activity administration)

Calibration of gamma camera (conversion of cps to MBq)

Since absorbed dose is define as deposited energy per unit mass, the exact organ mass is necessary to improve the dosimetric evaluation. This requires a volumetric determination on CT scan.

The whole body probe and blood sample counting, scintigrams with particular technique, the correction of some physical effect, as well as the volume determination of studied organ, are professional knowledge of trained technologists.

References

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