Project title: Challenges in dose surface measurement

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Dermal toxicity has occurred frequently during radiotherapy treatments. Its incidence varies according to the tumour site treated and the dose prescribed. It can compromise the achievement of radiotherapy at the planned dose or induce treatment interruptions necessary for tissue repair but harmful in terms of tumor control (through inter-fraction tumor repopulation mechanisms). The surface dose, and therefore the dose to the skin in an irradiated patient, is a difficult parameter to assess because of the absence of the "build up effect" in the first few millimeters of the dose deposit in the tissues. Several parameters can influence the surface dose distribution, including contamination electrons (related to machines, accessories, materials implanted in the patient or the patient himself) as well as the possible use of masks and boluses for treatment. Dose measurement requires suitable detectors. The surface dose and contribution of the secondary particles produced are imperfectly modelled, with variations according to the dose calculation algorithms used in radiotherapy planning systems (TPS). The performance of TPS optimization algorithms can also have consequences on skin dose distribution ("hot spots" of overdose) and tumor volumes. The surface dose problem is common to all irradiation techniques, from orthovoltage to proton therapy, IMRT (intensity modulation radiotherapy) and brachytherapy. Dermal toxicity can compromise radiotherapy, induce interruptions necessary for tissue repair but harmful to tumor control. The problem of surface dose (skin) is present from IMRT to hadrontherapy/proton therapy. 1/ Dose measurement requires appropriate detectors. 2/ The surface dose and the contribution of secondary particles are poorly modelled (calculation algorithms). 3/ Optimization algorithms guide the skin and tumor dose. 4/ The parameters are clinical, technical, physical (database available).

Part 1: Surface physical dose measurement

The build-up effect is either used in certain therapeutic irradiations (using uncharged particles such as 6 MV photons) where we want to preserve the skin (breast cancer, head and neck cancers, etc.), or involuntarily compensated by contamination radiation (bolus effect of restraints, backscatter, secondary electrons of accessories positioned in the beam and machines) or voluntarily compensated by introducing an equivalent tissue on the skin (skin cancers). The depth reference is at 0.07mm below the surface. The surface dose can vary from 6% to 27% due to secondary electron contamination for fields of 5X5cm and 40X40cm, respectively.

Objectives: definition of an irradiation protocol (scanner, application conditions, cutting thickness, voxel size, etc.) common to the different techniques (IMRT, brachytherapy, protontherapy, etc.) / particles / energies. Surface dose measurement on simple skin models (simplified "solid water" type models with modular thicknesses and anthropomorphic phantoms) with suitable detectors (ionizer chamber, films, thermoluminescent dosimeters etc.) for absolute and relative dose. This is a still active field of investigation based on previous methodology at our department. Evaluation of the build up with 6MV photons in a beam perpendicular to the surface or tangent, with machine accessories (equalizing cone, multiblade collimators, jaw, etc.). Two students of the Erasmus Master's Degree Mundi 2018 contributed to the development of the study protocol

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The air-tissue interface at the skin surface makes the TPS calculation less reliable. An overdose of more than 7% may lead to serious complications and an underdose of more than 5% reduces the effectiveness of the treatment and local control of the tumor. Surface dose modelling is not well taken into account in radiotherapy planning software, sometimes leading to overdoses. Several studies have described a difference between the dose estimated by the TPS and the dose measured. In addition, new radiotherapy techniques are based on the multiplication of the number of beams delivered. It has been shown that the many tangential fields, used in IMRT's plans for the treatment of head and neck cancers, contribute to increase in skin dose. Calculation algorithms incorporating Monte Carlo code allow better consideration of the contribution of secondary particles and are more efficient in situations of tissue heterogeneities, and will be used.

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Part 2: Skin dose in hadrontherapy (protontherapy)

The Normandy region is equipped with innovative patient care facilities. Patients treated in proton therapy are included in the PMRT program for modelling the effects of proton therapy (RGPD compliant). The problem of build-up is also present in proton therapy. Patient-specific bolus for range shifter air gap reduction in intensity-modulated proton therapy of head-and-neck cancer studied with Monte Carlo based plan optimization. in the input channel before the abrupt dose deposition represented by the Bragg peak, which is generally spread to cover the entire thickness of the tumor. Two sources of secondary radiation are identified in this input channel and are not necessarily taken into account in current practice: there is an accumulation of electrons δ in the first few millimeters of the tissue until an equilibrium state of the electrons δ diffused in front is reached. In addition, there is an accumulation effect of fragments created by inelastic interactions between the protons of the native beam and the target nuclei of the tissues traversed. These fragments may have low kinetic energies and/or high atomic numbers relative to the protons of the incident beam. As a result, the target fragments have high linear energy transfer values and therefore increased biological efficiency.

Objectives: These experiments will be reproduced in our treatment conditions on phantoms, anthropomorphic phantoms and patient dosimetries, also using a cartographic modeling tool for linear energy transfer and biological efficiency available in our team

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