PO0311: Clinical Outcome Modelling Indicates Minimum Dose to be a Good Predictor in Evaluating Cervical Cancer HDR Brachytherapy Plans

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Purpose: Drug-eluting stents are the first-line therapy for in-stent restenosis. However, intravascular brachytherapy (IVBT) is used to treat patients whose drug-eluting stents fail. Current clinical dosimetry for IVBT is water-based, i.e., the absorbed dose in the target volume is calculated by assuming that the patient's artery, calcified plaques, metallic stents, and off-centred guidewire from the IVBT delivery system are all water with unit mass density. We have previously developed a Monte Carlo-based dosimetry software, RapidBrachyIVBT, to account for these heterogeneities and allow for dose calculations on optical coherence tomography images (OCT). This study examines the impact of off-centred guidewires on dose inhomogeneity during irradiation, considering scenarios with multiple guidewires, often overlooked in previous studies. Multiple guidewires are used in cases where the source train passes through a bifurcation of blood vessels.

Materials and Methods: RapidBrachyIVBT, a Monte Carlo dosimetry software based on the Geant4 toolkit, including the Novoste Beta-Cath 3.5F IVBT device with a $^{90}Sr^{90}Y$ source train, was used. OCT images from a patient undergoing coronary IVBT for recurrent in-stent restenosis treated at Brigham and Women's Hospital (Boston, Massachusetts) were used to calculate the absorbed dose considering all heterogeneities compared to the dose calculated in water. The patient artery was segmented as water (lumen), fibrotic plaque (around the lumen), calcified plaque (behind the fibrotic plaque), smooth muscle (tunica media) and cobalt-alloy (stents). The source position was assumed to be at the origin of the image, where the OCT imaging device was placed. The guidewire positions were assumed to be at the exact locations used during imaging. Simulations were performed on the Digital Research Alliance of Canada Cedar computing cluster with 200 million decay events to yield less than 1% uncertainty on absorbed dose in the target volume, 2 mm from the source center. The absorbed dose was scored in rectangular voxels of $0.1 \times 0.1 \times 1.0$ mm^3 along a 42 mm length, which includes the stents, source train and an additional 2 mm margin. The prescribed dose was 23 Gy to the target volume. The dose homogeneity index, the maximum to minimum dose ratio in the target volume, was calculated in both water and patient cases.

Results: The dose difference between the water and patient-specific cases was up to 56.2%, 55.8%, and 64.6% in the target volume with one, two, and three guidewires, respectively. The mean dose at the target volume was reduced by 3.4% and an additional 4.1% when adding the second and third guidewire, respectively. The dose homogeneity index was 1.29 in water and 2.96, 2.94, and 3.33 for the respective patient-specific cases. Each guidewire added a cold spot around the IVBT source at the target volume.

Conclusions: The dose at the target volume in IVBT is significantly reduced when three guidewires are present. Limiting the number of guidewires present during irradiation would reduce cold spots and dose inhomogeneity at the target volume.

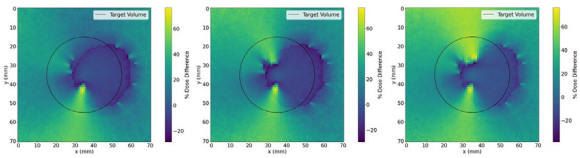

Figure 1: The percent dose difference between water-based and patient-specific dosimetry on an example slice of the patient OCT images. Dose reduction is seen around the stents, calcified and fibrotic plaques and each added guidewire. Each guidewire introduced a cold spot, as shown with one (left), two (middle), and three (right) guidewires present in the lesion area The target volume is shown as a black circle.

PO0311

Clinical Outcome Modelling Indicates Minimum Dose to be a Good Predictor in Evaluating Cervical Cancer HDR Brachytherapy Plans

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Purpose: High-dose-rate brachytherapy (HDR-BT) of cervical cancer is characterised by a highly non-uniform dose distribution in the target region and organs-at-risk (OARs). Dose-volume histogram (DVH) parameters used for plan evaluation may not accurately reflect the biological impact of delivered dose. In this work, we extend radiobiology-based outcome models to study dose non-uniformity in locally advanced cervical cancer (LACC) BT and highlight implications for treatment planning.

Materials and Methods: Tumour control probability (TCP) models were derived considering the linear-quadratic model, independence of subvolume responses, and inter-patient heterogeneity in radiosensitivity (α and β normally distributed with means α and β, and standard deviations σ_α and σ_β). An expression for the equivalent uniform dose (EUD) was derived with similar assumptions. Model parameters were estimated based on in vitro data, and other modelling studies: $\alpha = 0.3$ Gy^{-1}, $\alpha/\beta = 10$ Gy, $\sigma_\alpha = [0.05, 0.10, 0.15]$ Gy^{-1}, $\sigma_\beta = [0.005, 0.010, 0.015]$ Gy^{-2}, and clonogen density $\rho = 10^7$. To check if resulting TCP and EUD models were reasonable, two phenomenological models were fitted: TCP_{prob} (probit TCP, parameterised by slope γ_{50} and dose TCD_{50} at 50% response) and gEUD (generalised EUD, parameterised by power-law parameter a). DVHs of the first fraction of 16 LACC patients that were in accordance with EMBRACE II aims were extracted (EBRT: 25×1.8 Gy, BT: 3 fractions). TCPs and EUDs were calculated for these DVHs to show: (1) the relationships with CTV_{HR} DVH-parameters, and (2) the effects of dose boosting or underdosing. For the latter, DVHs were manipulated such that in case of boosting the total D_{90} was increased without changing the D_{100}. For cold spots, the D_{98} was lowered, whilst keeping the D_{90} constant.

Results: CTV_{HR} DVHs were similar for all patients, with a mean ($\pm$SD) D_{90} and D_{98} of respectively 90.0 ($\pm$0.2) and 78.0 ($\pm$2.9) Gy $EQD2_{\alpha/\beta=10\text{ Gy}}$. TCP curves resembled clinically observed curves, with TCP_{prob} parameters $\gamma_{50} = [2.6, 1.5, 0.97]$ and $TCD_{50} = [55.1, 55.0, 55.4]$ Gy. The gEUD a-parameter ranged from -26.5 to -10.6 across analysed DVHs, indicating that the EUD tends to the minimum dose. Figure 1a shows relationships between DVH-parameters and modelled TCP and EUD for the patient cohort. Simulated TCPs are sensitive to variations in the input parameters, which is less the case for the EUDs. For similar D_{90} values, the predicted TCPs and EUDs vary, whereas the D_{98} and D_{100} seem to be more indicative for predicted biological effects. Moderate underdoses in the CTV_{HR} can notably decrease the modelled TCP and EUD, which is more pronounced than the potential for dose boosts of the D_{90} within planning aims (Figure 1b).

Conclusions: This study illustrates how dose non-uniformity might affect treatment outcome. EUD is more robust than TCP, and hence more suited for plan evaluation. The studied TCP and EUD models are less related to the D_{90} than to the minimum dose, suggesting that the D_{98} may be emphasised more in treatment planning.

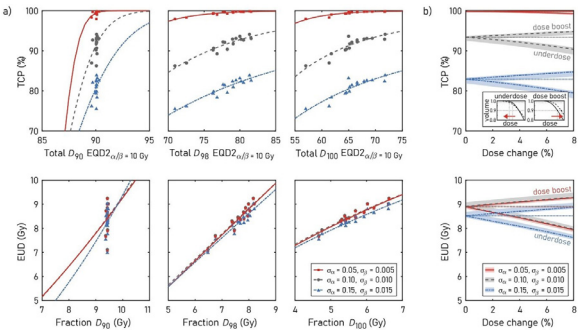

Figure 1. Graphs illustrating: a) the relationship between DVH-parameters and modelled TCP and EUD, and b) the effect of dose boosting and underdosing. Treatment plans for 16 patients were generated aiming at 90 Gy EQD2$_{\alpha/\beta=10\ \mathrm{Gy}}$ and 75 Gy EQD2$_{\alpha/\beta=10\ \mathrm{Gy}}$ for the CTV$_{\mathrm{HR}}$ D_{90} and D_{98} respectively. Variations in radiosensitivity were considered to make TCP slopes consistent with clinical data.

PO0312

Single Fraction Low Energy Superficial X Ray Radiation for Conjunctiva Kaposi Sarcoma, a Case Report

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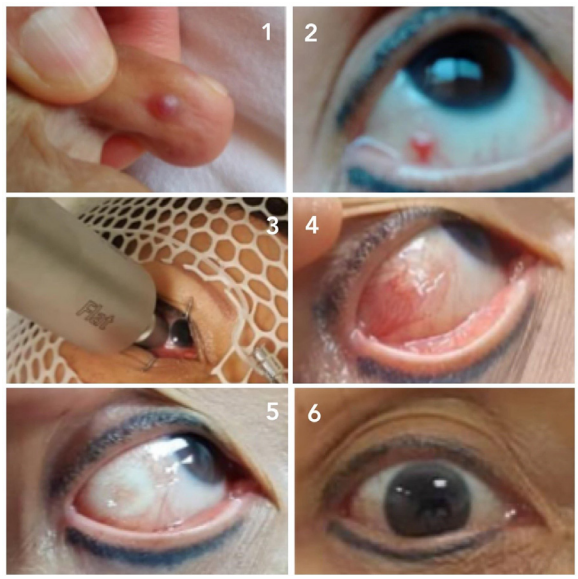
Purpose: We present a case of conjunctival Kaposi's sarcoma in a patient without HIV. This patient was treated with superficial radiation at 1400 cGy in a single fraction with low-energy X-ray equipment.

Materials and Methods and Results: A 57-yo Peruvian woman with no evidence of HIV infection without a significant medical history. Our patient reported small purple and painless skin lesions (approx. 5 mm) appeared in the left-hand middle finger and left ear, in November 2011. These lesions received the diagnosis of classic KS non-HIV associated without immunosuppression after performing an incisional biopsy. treated with a Paclitaxel every 3 weeks for six months, disappearing skin lesions. In 2013, New lesions appeared in lower limbs and were treated with surgery. In 2015, a new lesion (<5 mm) in the fifth left toe was treated with Doxorubicin every 3 months in 5 courses (Fig 1). In August 2016, a new lesion in the manubrium (approx. 7mm) received superficial RT at 1,600 cGy in four fractions (Dermopan 50-KV and mA power by SIEMENS, Germany). After these events, the diagnosis was dispersed and aggressive stage IV classic KS, according to Brambilla et al staging of classic KS (9).After the disease's progression, our patient was not a candidate for systemic therapy due to the high toxicity risk and non-response. In April 2017, the patient presented at the Department of Radiation Oncology with a 1-month history of eye redness (right eye), and foreign body sensation (Fig. 2). The physical exam showed a salmon-colored mass (approx. 4mm-diameter) on the right eye lateral canthus. The patient did not mention any pain or visual changes. The best corrected visual acuity was 20/20 in both eyes (by Snellen chart); ocular motility was preserved, pupils were reactive to light, and the fundoscopic exam was normal. An ocular ultrasound revealed a lesion thickness of 2 mm. The biopsy was compatible with KS non-HIV-associated without immunosuppression. After an internal organs' evaluation, the treatment to control the disease suggested was external RT. The application procedure consisted of fixing the head with a thermoplastic mask, fenestrated over the right eye. For superficial RT, a low-energy X-ray device (50 kV maximum energy; Intrabeam, Carl Zeiss Meditec AG, Jena, Germany) equipped with a small spherical applicator was placed with light pressure to flatten the tumor. Irradiation with 1,400 cGy (with 2 mm depth) in a single fraction was applied (Fig. 3). The dose was chosen according to Sarria et al calculation for a conjunctival lymphoma (10). In the evaluation post-treatment (one week later), conjunctivitis (grade I-II) was observed in the radiation field. Symptomatic, anti-inflammatory, and topical corticosteroids were indicated for three days (Fig. 4). A month later, the patient does not manifest discomfort (foreign body sensation, pain, photosensitivity, ocular motility, among others), changes in visual acuity, or other symptoms or signs of toxicity (Fig. 5). Currently, five years later, the patient continues without any difference at the visual level and there is no recurrence in the conjunctival area (Fig. 6).

Conclusions: RT improves the quality of life in patients with classic KS carrying minimal toxicity; however, there is no standardized RT dose or technique (18, 19). To the best of our knowledge, there is no antecedent with superficial R in a single session in classic KS. The decision to use 1,400 cGy in one fraction was based on the KS radiation sensitivity and previous experience published in the literature (10). A single administered dose is well documented (17), causing the relief of symptoms and improvement in her life quality. The use of RT as a single treatment in classic Kaposi's sarcoma is rare, especially in conjunctiva KS. However, RT was an effective treatment for relieving symptoms, recurrence, and local control in our patient.



PO0314

GEC-ESTRO Survey of ^{106}Ru Eye Applicator Practice for Ocular Melanoma - Physicist Survey

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Purpose: ^{106}Ru eye plaque brachytherapy is an eye-preserving treatment for uveal melanoma performed in about 100 clinics worldwide. Despite this relatively low number, there is a considerable variation in clinical practice. In 2022, the BRAPHYQS and Head & Neck and Skin GEC-ESTRO working groups conducted a survey to map the current clinical practice. The survey consisted of a physicist and a physician part. This