Commissioning of Brachytherapy TPS Using a 2D-Array of Ion Chambers

Mammo Yewondwossen and Jim Meng
Department of Radiation Oncology, Dalhousie University, Halifax, Nova Scotia, Canada
mammo.yewondwossen@cdha.nshealth.ca

Abstract. Purpose/Objective(s): Unlike external beam treatment planning system (TPS) commissioning, a brachytherapy TPS requires little input, no modeling with most brachytherapy TPS calculations are based on the AAPM TG-43 formalism. The dose distribution using the AAPM TG-43 dose formalism is usually compared with the calculations using the Sievert summation, Monte Carlo simulation or dose distributions measured by with GAFCHROMIC film. These methods have shown an agreement of within 5% compared to the AAPM TG-43 dose formalism. The purpose of this study is to report our experience of using a 2D-array of ion chambers (MatriXX Evolution, IBA Dosimetry) for dosimetric verification of conformal CT-based high dose rate (HDR) brachytherapy.

Material/Methods: After benchmarking the new TPS against the old TPS used in the clinical for several years and comparing with MATLAB calculated dose distribution, the dose calculation accuracy of TPS systems was investigated by measuring dose distributions experimentally using MatriXX Evolution. The phantom used for this technique consists of multiple catheters, the IBA MatriXX detector and a slab of RW3 to provide full scattering conditions. The TPS dose distribution was calculated on the CT scan of this phantom. The measured and TPS calculated distributions were compared in IBA Dosimetry OmniPro-I’mRT software.

Results: The average absolute dose difference over the ROI was 1.67% and the gamma agreement index computed for a distance to agreement of 3 mm and a dose difference of 3% showed agreement for 98.7% of all pixels, with gamma ≤ 1.

Conclusion: We have found that MatriXX 2D dosimetric technique provides a fast and accurate way to validate a brachytherapy TPS for both commissioning and quality assurance.

1. Introduction
High-dose-rate (HDR) brachytherapy has proven to be a highly successful radiation treatment in the management of different types of cancers. The brachytherapy Treatment Planning System (TPS) is an important component of radiation treatment process. Commissioning and quality assurance of a commercially available brachytherapy TPS is essential to ensure accurate dose delivery. External beam TPS commissioning requires measurement and input of the beam characteristics into the TPS followed by some kind of modeling or fitting. Unlike external beam TPS, brachytherapy TPS requires little input and no modeling. The radiation source types used in HDR brachytherapy TPS are well characterized and documented in scientific literature. The common algorithm employed by brachytherapy TPSS is the AAPM TG-43 approach [1], greatly simplifying the effort required in commissioning.
One of the challenges encountered during implementation of a new brachytherapy TPS into a clinical environment is verifying the dose calculation accuracy. The complex and variable nature of the treatment planning process makes it essential to verify delivered absolute dose distributions, especially during commissioning and quality assurance. The dose distribution generated by the TPS using the AAPM TG-43 dose formalism is usually compared with the calculations using the Sievert summation, Monte Carlo simulation or dose distributions measured by with Gafchromic film. Gafchromic film is an excellent tool for dosimetry but is a costly consumable, requires careful calibration and specific methods for digitization with sufficient signal-to-noise characteristics. Recently, two-dimensional ionization chamber arrays have become increasingly popular for intensity-modulated radiation therapy (IMRT) plan verification. The MatriXX Evolution (IBA Dosimetry, Germany), an array of 1020 ionization chambers[2,3] has been developed and used widely for this purpose. The aim of this study is to evaluate the applicability of MatriXX Evolution to brachytherapy TPS plan verification.

2. Materials and methods
A kilovoltage X-ray therapy unit (Gulmay D3300, Gulmay Ltd., Chertsey, UK) was used to calibrate the matrix detector, according to the procedure detailed in the Radiation Therapy Committee Task Group 61 of American Association of Physics in Medicine (AAPM TG-61 protocol) [4]. Before patient specific dose verification can be carried out, absolute calibration of the detector response (quantified by the factor $k_{user}$) must be determined experimentally by the user. This factor converts the charge collected by the internal electrometer to the dose deposited in the detector plane at a given calibration depth and field size [2]. Absolute calibration of the detector was performed by irradiating the detectors with a normally incident 300 kV field, to a known dose using a circular 5 cm diameter open-ended applicator at 30 cm focus-to-surface distance.

The new Oncentra Brachy version 3.2 TPS was commissioned by: 1) benchmarking test plans against the Nucletron Plato system, v 14.3.7 which was used in the clinical routine for several years in our department, and 2) comparing the dose distribution generated by the TPS with MATLAB calculated (using calculation algorithms of AAPM TG-43) dose distribution. We then evaluated the TPS experimentally using MatriXX Evolution. To generate a brachytherapy treatment plan for the experimental conditions, Nucletron Freiburg Flap Applicator Set was used. The Freiburg Flap Applicator Set is a flexible mesh style surface mold made of a flexible silicone rubber with 36 channels for flexible implant tubes with a separation of 10 mm and a channel length of 24 cm. The Freiburg Flap maintains a fixed distance of 5 mm from the applicator to skin. This apparatus was positioned to cover the detector area of the matrix detector (Figure 1, left). Slabs of Solid Water were added above and below the matrix detector and Freiburg Flap to provide full scattering conditions. A Cone Beam CT (CBCT) scan for the treatment planning was obtained with 2.5 mm slice thickness.

Based on the CBCT data of this phantom, a treatment plan were calculated using the TPS (Nucletron Oncentra Brachy version 3.2.) The plan consisted of 3 active channels to mimic the Fletcher GYN applicator set (Figure 1, right) and was set to deliver 2 Gy at 2cm lateral to tandem axis. The matrix detector was irradiated according to this plan, which was exported directly to the console from the TPS. The data acquisition on the matrix detector was done in the movie mode at the sampling frequency of 1 sample per second.

The planned dose matrix in the detector plane was exported from the planning system for comparison with measurement using the Gamma index method. A gamma value greater than 1 was considered as outside tolerance range, using dose difference and distance criteria of 3% and 3 mm, respectively.
3. Results and discussion
Figures 2 show the comparison between the measured and planned planar dose distributions. The ROI shown in the figure includes 10% of the delivered dose. The average absolute dose difference over the ROI was 1.67% and minimum and maximum being 0 and 11.35%, respectively. The result shows agreement for 98.7% of all pixels, with gamma ≤ 1. These preliminary results demonstrate that the matrix detector can be used for rapid and convenient verification of brachytherapy plans with similar dose tolerances as for IMRT plan verification.

Figure 2. Comparison calculated and the measured dose distribution.

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4. References
[1] Nath, R., Anderson, L.L., Luxton, G., Weaver, K.A., Williamson, J.F., Meigooni, A.S., Dosimetry of interstitial brachytherapy sources: Recommendations of the AAPM Radiation Therapy Committee Task Group No. 43, Med. Phys. 22 (1995) 209–234.
[2] Herzen J., Todorovic, M., Cremers, F., Platz, V., Albers, D., Bartels, A., Schmidt, R., Dosimetric evaluation of a 2D pixel ionization chamber for implementation in clinical routine Phys. Med. Biol. 52 (2007) 1197–208

[3] Lessard E, Pouliot J. Inverse planning anatomy-based dose optimization for HDR-brachytherapy of the prostate using fast simulated annealing algorithm and dedicated objective function. Med Phys 2001; 28:773e779.

[4] Ma, C. M., Coffey, C. W., DeWerd, L. A., Nath, R., Liu, C., Seltzer, S. M., and Seuntjens, J., AAPM protocol for 40 - 300 kV x-ray beam dosimetry in radiotherapy and radiobiology: Report of Task Group 61, Med. Phys. 28 (2001), 868 - 893