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Erich A Schnell

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HIGH DOSE RATE BRACHYTHERAPY FOR THE TREATMENT OF GYNECOLOGIC CANCERS

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ABSTRACT: Brachytherapy is utilized for treating many types of cancer, particularly gynecologic varieties. Brachytherapy technology has undergone rapid development, with increasing complexity in physical apparatus and computer based systems. This change has led to inconsistent adoption of the newest developments across brachytherapy centers, due to financial restriction and unease or inexperience on the part of physicians. The purpose of this study is to evaluate the benefit of utilizing the newest technologies in the treatment of cervical cancer, and other gynecologic malignancies. We compare dosimetric benefit in contrast to practicalities of implementation, between the original standard of practice and the advanced methods, and for popular alternative modalities. The hypothesis being tested is that the advanced, updated methods of individually tailored brachytherapy treatment provide a real dosimetric and overall patient benefit that outweighs the time and effort required to implement them, and should be the standard of patient care.

Materials and Methods: **1.** Utilizing six patients treated with a tandem and ring and three patients treated with a cylinder, we compare the dosimetry of plans generated using a standard optimization to those created with inverse optimization. Standard dosimetric metrics were utilized. **2.** Thirty-one patients had CT-delineated target volume compared with MR-delineated volumes, with comparing geometric similarity. Six additional patients had plans optimized and compared to each of the CT target and MR target. Dosimetric results were compared between both plans, with the MR volume considered as the "true" target. **3.** Sixty-four original plans from 18 patients, each treated with one of four advanced applicators were evaluated. The applicators were the Rotte double tandem, the Capri multi-channel cylinder, the tandem and ring with needle channels (TRN), and the Venezia multichannel applicator. The plans were compared based on equivalent dose delivered in 2 Gy fractions. **4.** Three patients that originally received tandem and ring brachytherapy plans were re-planned using either photon and proton plans attempting to either deliver a uniform dose or to emulate the brachytherapy distribution. Resultant plans were compared with standard dosimetric metrics, and low and high-dose volumes. **5.** A set of three materials including cork, tissue equivalent bolus gel, and metallic marker seeds were combined in different configurations with a MapCheck 2 detector system and scanned with CT. A brachytherapy plan was produced for each material setup and measured with the array. Each plan was calculated using homogeneous and heterogeneous models. Resultant doses were compared for different calculation settings. Additionally, six patients had their original clinical plans re-calculated and compared using the heterogeneity model.

<u>Results</u>: **1.** Target volumes on CT were not always consistent with the standard Point A treatment volume. Smaller targets do not sacrifice disease coverage but sacrifice additional critical structure sparing. A target volume much larger than the standard distribution leads to extreme under-dosing. Two patients were slightly under-dosed, but were restricted by normal tissues. One patient was adequately planned by the standard distribution. The cylinder patients were adequate with either optimization. **2.** The similarity index of the MR volume with the CT was on average 0.55 for the six patients evaluated dosimetrically. For the 31 patients compared between fractions, the similarity index was 0.596. For two patients evaluated dosimetrically, the HRCTV from the MR was not sufficiently covered when planning to the CT volume. **3.** Conformation number improvement when using advanced applicators instead of simple had a mean of 0.104 for TRN and 0.251 with Venezia. Capri and Rotte had mean improvements of 0.043 and 0.025. Critical structure doses showed the least benefit with the Rotte, with changes less than 12 cGy, and significant change only for the bladder and sigmoid. The Capri showed significant but small improvement using the advanced applicator across all structures. The TRN also showed significant improvement across all structures, with a high standard deviation. The Venezia had the largest improvement, though with extremely high standard deviation. **4.** Both proton and photon plans covered target volumes with uniform dose coverage. Single or multiple field proton optimization had little effect on the target coverage. Higher robustness distance increased the target coverage and critical structure doses for proton plans. Photon plans achieved good emulated brachytherapy distributions, with a better result for the 200% volume than the 300%. Escalated Photon and proton plans did not achieve the same high dose coverage as brachytherapy, and proton entry path doses rose to over 150% of the prescription. **5.** Measured doses were greater than calculated doses for most setups. Heterogeneity corrected calculations yielded values between 3%-20% lower than measurements, while homogeneous calculations yielded doses 12-34% lower. Utilization of uniform material density definition rather than HU based correction for metals improved the comparison by 17%. For cork and tissue equivalent materials, uniform definition improved the comparison by 7% and 3%. On average, clinical treatment plans calculated with heterogeneity correction yielded doses 3.7% lower for critical structures and 4.7% for the dose to 90% of the target.

<u>Conclusions</u>: **1.** Three-dimensional planning for brachytherapy improves the dosimetric knowledge we have while planning and flexibility to tailor the dose to an individual's anatomy. Volumetric planning, in particular inverse planning, enables more consistent organ sparing, and better disease coverage. **2.** MR imaging allows greater confidence in target volume delineation, approximately equivalent normal tissue sparing, and improved accuracy for inverse optimized techniques. **3.** For any type of applicator, the biggest factors influencing dose distributions are the number of channels and their separation from each other within the target volume. Similar coverage can be obtained with lower normal tissue doses by tailoring the distribution using advanced applicators for most patients. **4.** Brachytherapy is able to achieve the highest target dose heterogeneity while still protecting organs at risk. External beam photon plans are superior to proton plans when emulating the brachytherapy dose heterogeneity. **5.** Heterogeneity corrected dose calculations perform well when compensating for dose changes due to materials with an electron density that differs substantially from water or soft tissue. The calculation performs better when the materials are defined uniformly rather than based on HU values. Under normal treatment conditions, materials different enough to water are not generally present in the treatment region, and may not warrant the use of heterogeneity correction.