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Perspective

Clinical Relevance of Inhomogeneity-Corrected Dose Calculation in Gynecological Brachytherapy

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DESCRIPTION

Gynecological Interventional Radiotherapy, commonly referred to as Brachytherapy (IRT or BT), plays a pivotal role in the curative management of pelvic malignancies, particularly cervical cancer. The ability of brachytherapy to deliver high doses of radiation directly to tumor sites while sparing surrounding healthy tissues is unmatched by other modalities. This precision stems from the proximity of the radioactive source to the tumor, enabling steep dose gradients and limited radiation exposure to adjacent organs. At our institution, standard clinical protocol for gynecological cancers includes four fractions of brachytherapy, with Computed Tomography (CT)-based simulation and individualized treatment planning for each fraction. Currently, the widely used and clinically approved dose calculation algorithm is TG-43, which simplifies patient geometry by assuming a homogeneous water-equivalent medium. While this method has served as a clinical standard for years due to its simplicity and reproducibility, it overlooks anatomical variations, such as tissue heterogeneities and the presence of air gaps[1]. The TG-186 algorithm, in contrast, represents a more sophisticated, model-based dose calculation approach that incorporates Monte Carlo-derived dose distributions, taking into account actual patient anatomy and the heterogeneity of tissues. Although TG-186 is not yet routinely used in clinical practice due to regulatory limitations, its potential to enhance dose accuracy is particularly relevant in complex clinical settings. This study aims to explore the dosimetric implications of implementing TG-186 in place of TG-43 in gynecological brachytherapy, with a focus on evaluating differences across varying anatomical conditions and applicator types[2].

MATERIALS AND METHODS

This retrospective dosimetric study was conducted using CT simulation and treatment datasets from patients undergoing brachytherapy for gynecologic cancers, primarily cervical carcinoma. Both intracavitary and hybrid interstitial treatments were included to capture a wide range of clinical scenarios. All CT images were contoured by an experienced radiation oncologist, who delineated the Clinical Target Volumes (CTV) and Organs At Risk (OARs) such as the bladder, rectum, and sigmoid colon, using the Oncentra Brachy v4.6.3 treatment planning system (Elekta). For each patient, two distinct treatment plans were developed: one using the conventional TG-43 formalism and another using TG-186, which integrates patient-specific tissue densities and applicator materials. The comparison focused on Dosimetric parameters such as D90 for the CTV and D2cc for the OARs, with particular attention paid to cases involving anatomical inhomogeneities like rectal air pockets or applicator positioning near bony structures[3].

RESULTS AND DISCUSSION

The comparative analysis revealed that in cases with relatively homogeneous anatomical configurations-where the tissues largely resembled water in density-the difference between TG-43 and TG-186 was minimal and not statistically significant. This finding validates the continued use of TG-43 in standard cases, given its clinical simplicity and reliability[4]. However, in scenarios involving significant anatomical irregularities, such as the presence of air in the rectum or close proximity to dense bone structures, the discrepancies between the two algorithms became more pronounced[5]. In some patients, the dose delivered to organs at risk, particularly the rectum, differed by up to 10%between TG-43 and TG-186 calculations. These variances raise concerns about the potential underestimation or overestimation of radiation doses to critical structures when relying solely on TG-43[6].

CONCLUSION

This study underscores the clinical relevance of adopting advanced dose calculation algorithms like TG-186 in gynecological brachytherapy. While TG-43 remains suitable for routine clinical use in standard anatomical settings, TG-186 offers substantial benefits in complex cases with inhomogeneities and air-tissue interfaces. Integrating such model-based algorithms into clinical workflows couldsignificantly improve treatment accuracy and potentially reduce toxicity in patients. As regulatory and technological

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advancements continue, the transition to TG-186 or similar algorithms may become an essential component of personalized radiotherapy planning in gynecological oncology.

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