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The Evaluation of Hydrogel Rectal Spacer Movement and Absorbance during the Treatment of Prostate Cancer with Proton Therapy

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Abstract

Background: Hydrogel perirectal spacers are widely used to reduce rectal toxicity during prostate radiation therapy; however, their stability and degradation specifically during proton therapy remain poorly characterized. This study evaluated hydrogel spacer geometry and absorption throughout a course of intensity-modulated proton therapy (IMPT). Methods: Ten patients with localized or recurrent prostate cancer underwent hydrogel spacer placement before IMPT. Eight patients received SpaceOAR. All patients were treated to 70 Gy in 28 fractions using two lateral beams with single-field optimization. Baseline CT and contrast-enhanced MRI were obtained for radiation planning, followed by bi-weekly adaptive CT and MRI scans without contrast. Spacer thickness was measured at the prostate base, mid-gland, and apex on serial MRIs. Changes in spacer size were analyzed per patient and in aggregate. Results: Interpatient variability exceeded intrapatient changes over the treatment course. One patient demonstrated complete spacer disappearance by the third assessment, requiring rectal balloon placement. Three patients exhibited notable reductions in spacer size (18%, 33%, and 72% across all regions). The remaining patients showed a <10% reduction overall. Among the eight patients with SpaceOAR spacers, two experienced early spacer loss within four weeks, one demonstrated significant spacer displacement, and five maintained stable geometry. Conclusion: This study provides the first clinical characterization of hydrogel spacer stability during IMPT. While most patients maintained relatively stable spacer geometry, a subset experienced early degradation or displacement. The limited sample size constrains the interpretation of how often these events arise or whether they meaningfully affect rectal sparing. Our results indicate routine monitoring may help detect unexpected spacer changes; however, given the absence of a photon comparison group, the clinical significance during IMPT courses remains unclear. Larger, prospective research is warranted to define the determinants of hydrogel stability in proton therapy and to evaluate whether enhanced surveillance could improve outcomes.

Keywords

Rectal Spacer, Prostate Cancer, Proton Therapy, Hydrogel, SpaceOAR

1. Introduction

Prostate cancer is the second most common cancer in men worldwide, with risk factors being increasing age, family history of prostate cancer, and ethnicity [1]. The treatment for prostate cancer varies depending on the stage of disease, which is dependent on the T stage, PSA, and Gleason grade group, as well as lymph node and metastatic involvement. Radiation therapy is a common treatment modality used in prostate cancer, especially for those with intermediate to high-risk prostate cancer. A feared complication from treatment is rectal toxicity, which may present as diarrhea, hematochezia, tenesmus, rectal urgency, and more frequent or painful bowel movements. Rare complications, not typically seen with newer radiation techniques, include fistula or stricture formation and bowel obstruction or perforation.

Prostate cancer perirectal spacers, often composed of PEG-based hydrogels, are biodegradable, safe, and effective in reducing gastrointestinal radiation toxicities associated with the treatment of prostate cancer [2]. A prospective, multicenter, randomized clinical trial demonstrated that the use of hydrogel significantly reduces acute rectal discomfort and long-term rectal toxicities [3]. Hydrogel also significantly reduces the need to treat bowel symptoms and perform endoscopic examinations [4]. Since the placement of the spacer is a short procedure that patients generally tolerate well, hydrogel is widely used by radiation oncologists, especially when using stereotactic body radiation therapy (SBRT) [3]. Common hydrogel spacers include SpaceOAR and Cymetra (human collagen), both of which are injected under ultrasound guidance. Since Collagen does not require hydrodissection like SpaceOAR, theoretically, it could potentially provide more uniform space and reduce complications such as the risk of rectal fistula.

The biodegradability of the spacer is considered an advantageous feature, as it allows the patient to undergo only the initial insertion procedure without needing any removal procedures. However, very few studies have evaluated whether the absorption rate of the hydrogel affects the target volumes throughout more prolonged intensity-modulated radiation therapy (IMRT) courses, especially with the use of protons. One study of 52 patients using photons reported the space measured before treatment. After photon IMRT completion, it was nearly unchanged (<1 mm), and based on MR imaging, almost all of the spacers were fully absorbed 9 months after implantation [5].

Dosimetric analyses have confirmed that proton therapy results in superior organ-at-risk (OAR) sparing and adequate target coverage compared with photon therapy; however, clinical outcomes appear comparable in terms of efficacy. As for OAR sparing, proton therapy has been associated with reduced genitourinary toxicity based on patient and clinician assessments, although randomized controlled trials are needed to confirm the benefit. Regarding clinical efficacy, biochemical control rates are similar in high-risk prostate cancer patients treated with hypofractionated RT with either proton or photon therapy [6].

Despite the evidence of comparable clinical outcomes with increased cost, proton therapy is still considered in some patients with prostate cancer, often dependent on the individual radiation oncologist. Much like in photon RT, hydrogel perirectal spacers are often used in proton RT. Given this, it is important to continue to acknowledge the fundamentally distinct physicochemical properties protons and photons possess. Differences may result in markedly different interaction profiles within hydrogel systems.

Since the effect of proton therapy on the hydrogel degradation rate is not well studied and proton therapy possesses distinct properties, we evaluated the rate of perirectal spacer stability and absorption by measuring spacer size on MR imaging throughout intensity-modulated proton therapy (IMPT) in 10 patients treated at a single institution.

2. Methods

There were a total of ten patients; eight of whom were diagnosed with de novo localized stage T1-2, and two who presented with recurrent disease after prior RT. The first ten consecutive patients with localized prostate cancer who required a rectal spacer from January 2024 to February 2024 were included in the study. Each of the ten patients had the hydrogel inserted concurrently with three fiducial markers. SpacerOAR was used as the hydrogel in eight of the ten total patients, and human collagen hydrogel (Cymetra) was used for the rest. All patients underwent a computed tomography (CT) simulation and a magnetic resonance imaging (MRI) of the prostate with contrast. Rectal balloons were not used. Treatment was delivered with two beams (left and right laterals) using IMPT with the single field optimization (SFO) technique. The dose prescription was 70 Gy in 28 fractions. A bi-weekly adaptive simulation was done with a CT and MRI of the prostate without contrast. All patients were agreeable, signed a written informed consent form, and were enrolled in the IRB-approved Proton Collaborative Group data registry. Descriptive metrics were used, including mean and standard deviation. Inferential statistical analysis was not performed due to the small sample size. As shown in

Figure 1(A), the measurements, performed by one radiation oncologist and reviewed by another, were obtained from MR imaging (T2 sequence, sagittal and axial images). We measured spacer thickness at the base, apex, and mid-gland, which is defined as halfway between the base and apex. The measurements were tabulated for each patient and in aggregate (Figure 1(B)-1(C)).

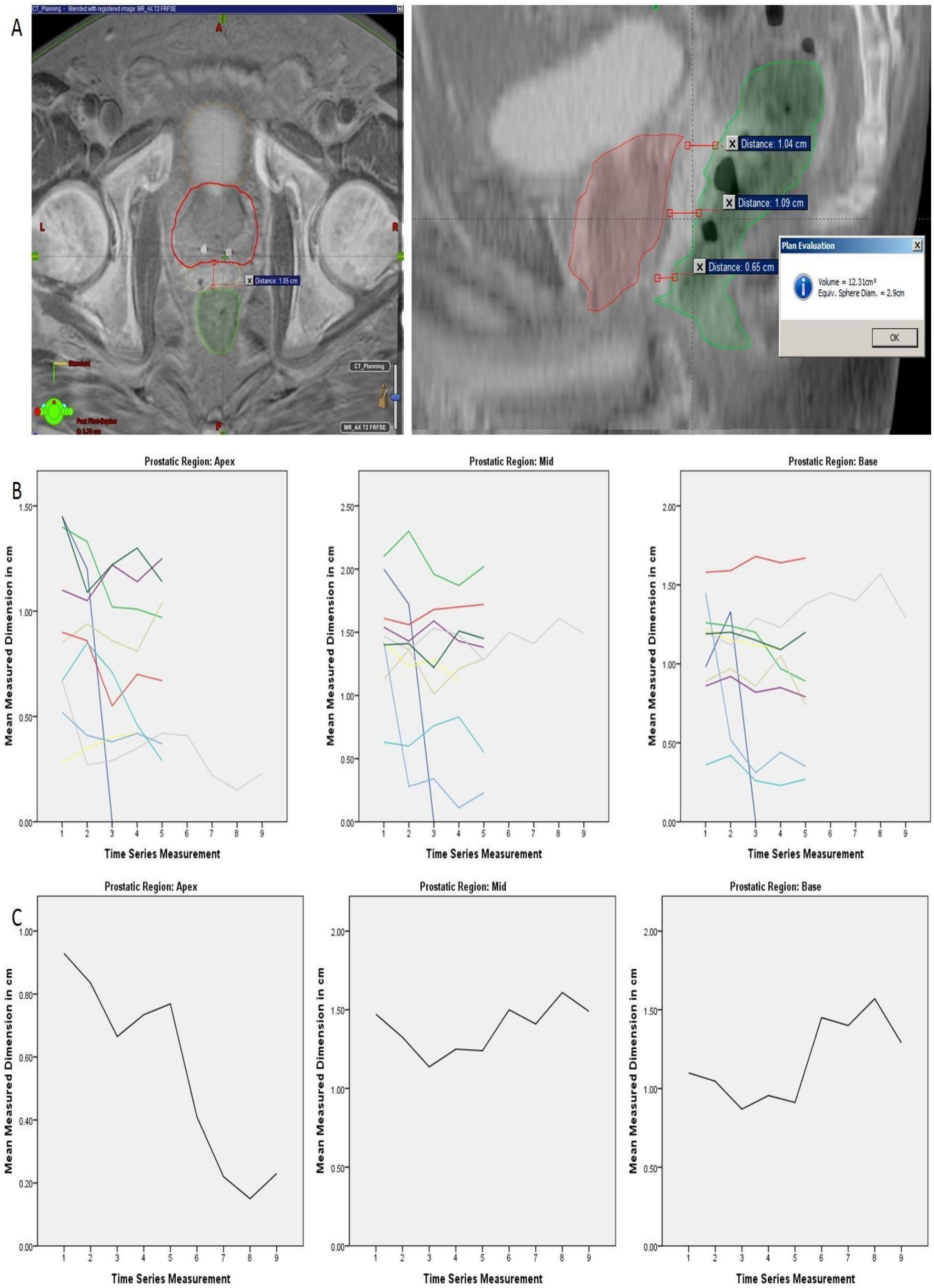

Figure 1. Prostatic Measurements & Degradation. A: An example of the measurements obtained from MRI: spacer thickness at base, apex, and mid-gland; B: Measurements of the apex, mid, and base tabulated for each patient in aggregate; C: The average of all of the patient measurements of the apex, mid, and base of the prostate.

3. Results

Variability between patients was more significant than variability over the treatment course. One patient had failure of the hydrogel with complete disappearance (*i.e.*, more than 95% of the hydrogel disappeared) on imaging by the third assessment and required a rectal balloon for the remainder of the treatment. Three patients had reductions in each of the three measured regions, with net reductions of 18%, 33%, and 72% across all regions. The remaining patients had reductions of less than 10% across all regions taken together. Specifically, in the SpacerOAR group, two of the eight patients experienced the disappearance of the spacer within four weeks from the time of insertion; one patient experienced a significant shift (ie, more than a 50% reduction in the hydrogel) in the SpaceOAR spacer; the other five had relatively stable geometry. Given that only two out of the ten patients were treated using the Cymetra hydrogel, a comparison between the hydrogels was not performed.

4. Discussion

4.1. Comparison Studies: Photons

This study is the first to clinically characterize spacer hydrogel stability and degradation in prostate cancer patients treated with proton therapy and to analyze how these changes affect treatment accuracy. Hydrogel spacers have been consistently shown to be effective in reducing rectal radiation toxicity. Only one study of 52 patients has been done to analyze the movement or degradation of hydrogel spacers. Photon IMRT was used, and results showed that there was nearly unchanged movement or degradation when compared to before and after treatment completion. Additionally, based on MR imaging, almost all spacers were fully absorbed 9 months after implantation [5].

4.2. Hydrogel Spacers and Proton Therapy

Hydrogel spacers have been shown to reduce interfraction prostate motion in patients treated with protons. Sato *et al.* performed a study on 22 patients with intermediate-risk prostate cancer who underwent proton therapy with androgen deprivation therapy; 11 patients had hydrogel spacer insertion, and 11 did not. As expected, the study confirmed a lower rectal dose across all dose parameters in patients with the spacer than in those without. Of note, the study investigated the interfraction prostate motion; they reported no significant differences in motion between groups in the left-right and superior-inferior directions. However, they did report a significant difference in the anterior-posterior direction ($p < 0.05$) between the groups. Of note, the maximum anterior displacement was higher in the no-spacer group (7.9 mm) compared to the spacer group (3.9 mm), indicating improved prostate stability in this direction when a spacer is used [7].

Hydrogel spacers have been shown to be effective in consistently reducing rectal dose throughout the course of image-guided proton therapy. To investigate this, Hedrick *et al.* analyzed quality assurance computed tomography (QACT) scans obtained during treatment in 41 patients with low- or intermediate-risk prostate cancer. These QACTs were compared to the treatment planning CT using dose-volume histogram metrics. The study found that variation in rectal dose was minimal with increases primarily attributed to rectal filling (e.g., gas or stool), rather than changes in the hydrogel spacer itself. Although the study did not directly monitor hydrogel volume or position over time (via MRI), the consistent rectal sparing observed suggests that the hydrogel remained stable throughout treatment [8].

Several limitations should be considered when interpreting the findings of this study. First, the sample size was small and drawn from a single institution; this limits generalizability and prevents meaningful subgroup analysis between de novo and recurrent cases. Additionally, although serial MRI provided high-quality visualization of the hydrogel, a single observer performed measurements, and inter-observer variability was not assessed. The study also did not incorporate dosimetric or toxicity correlations, preventing evaluation of whether spacer degradation or displacement had a measurable clinical impact. Finally, without a photon-treated comparison group, the differences in spacer behavior cannot be attributed specifically to proton-related effects or differing physicochemical interactions.

5. Conclusions

Hydrogel perirectal spacers remain an important tool for mitigating rectal toxicity during radiation therapy to the prostate, yet their behavior during proton therapy specifically has not yet been well described. In this preliminary clinical evaluation of hydrogel stability during an IMPT course, we observed that while most patients maintained relatively stable spacer geometry, a subset did experience early degradation, displacement, or complete loss of the hydrogel. Our observations suggest that spacer changes can occur during the course of IMPT, but the small sample size limits the ability to determine how frequently or predictably this occurs in clinical practice.

Throughout an IMPT course, routine monitoring of spacer integrity may help identify unexpected changes; however, the clinical significance of these findings remains uncertain. Comparisons to prior photon-based studies should be interpreted with caution, as our study lacked a photon comparison group and we did not assess mechanistic or dosimetric effects. Given the distinct physical properties of protons, larger prospective studies are warranted to clarify whether spacer behavior differs meaningfully between modalities and to determine whether additional monitoring or adaptive strategies may be beneficial in select patients.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Bergengren, O., Pekala, K.R., Matsoukas, K., Fainberg, J., Mungovan, S.F., Bratt, O.,

et al. (2023) 2022 Update on Prostate Cancer Epidemiology and Risk Factors—A Systematic Review. *European Urology*, **84**, 191-206.
https://doi.org/10.1016/j.eururo.2023.04.021

[2] Song, D.Y., Herfarth, K.K., Uhl, M., Eble, M.J., Pinkawa, M., van Triest, B., *et al.* (2013) A Multi-Institutional Clinical Trial of Rectal Dose Reduction via Injected Polyethylene-Glycol Hydrogel during Intensity Modulated Radiation Therapy for Prostate Cancer: Analysis of Dosimetric Outcomes. *International Journal of Radiation Oncology Biology Physics*, **87**, 81-87.
https://doi.org/10.1016/j.ijrobp.2012.12.019

[3] Mariados, N., Sylvester, J., Shah, D., Karsh, L., Hudes, R., Beyer, D., *et al.* (2015) Hydrogel Spacer Prospective Multicenter Randomized Controlled Pivotal Trial: Dosimetric and Clinical Effects of Perirectal Spacer Application in Men Undergoing Prostate Image Guided Intensity Modulated Radiation Therapy. *International Journal of Radiation Oncology Biology Physics*, **92**, 971-977.
https://doi.org/10.1016/j.ijrobp.2015.04.030

[4] Pinkawa, M., Berneking, V., König, L., Frank, D., Bretgeld, M. and Eble, M.J. (2016) Hydrogel Injection Reduces Rectal Toxicity after Radiotherapy for Localized Prostate Cancer. *Strahlentherapie und Onkologie*, **193**, 22-28.
https://doi.org/10.1007/s00066-016-1040-6

[5] Uhl, M., van Triest, B., Eble, M.J., Weber, D.C., Herfarth, K. and De Weese, T.L. (2013) Low Rectal Toxicity after Dose Escalated IMRT Treatment of Prostate Cancer Using an Absorbable Hydrogel for Increasing and Maintaining Space between the Rectum and Prostate: Results of a Multi-Institutional Phase II Trial. *Radiotherapy and Oncology*, **106**, 215-219. https://doi.org/10.1016/j.radonc.2012.11.009

[6] Wu, C., Chen, W., Wu, Y. and Chen, M. (2025) Hypofractionated Radiotherapy for Prostate Cancer: A Comparative Study of Clinical Outcomes and Dosimetry between Proton and Photon Therapy. *Cancer Management and Research*, **17**, 2589-2599.
https://doi.org/10.2147/cmar.s546959

[7] Sato, H., Kato, T., Motoyanagi, T., Takemasa, K., Narita, Y., Kato, M., *et al.* (2020) Preliminary Analysis of Prostate Positional Displacement Using Hydrogel Spacer during the Course of Proton Therapy for Prostate Cancer. *Journal of Radiation Research*, **62**, 294-299. https://doi.org/10.1093/jrr/rraa115

[8] Hedrick, S.G., Fagundes, M., Case, S., Renegar, J., Blakey, M., Artz, M., *et al.* (2016) Validation of Rectal Sparing throughout the Course of Proton Therapy Treatment in Prostate Cancer Patients Treated with Spaceoar. *Journal of Applied Clinical Medical Physics*, **18**, 82-89. https://doi.org/10.1002/acm2.12010