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Scientific Report

Minimum Required Interval Between Hydrogel Spacer Injection and Treatment Planning for Stereotactic Body Radiation Therapy for Prostate Cancer

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Abstract

Purpose: The present study evaluated the short-term characteristics (<3 days) of a hydrogel spacer from the time of injection during stereotactic body radiation therapy (SBRT) for prostate cancer.

Methods and Materials: Fifteen patients treated with SBRT via the CyberKnife system (36.25 Gy/5 fractions) were enrolled in this retrospective study. Two magnetic resonance (MR) images were obtained with a hydrogel spacer: one on a computed tomography (CT) simulation day (MR pretreatment [MR_{pre}]) and the other on the last treatment day (MR posttreatment [$MR_{post]}$). Two medical physicists contoured the hydrogel spacer on each MR image. The changes of the shapes and the volume for the hydrogel spacer between 2 MR images were evaluated.

Results: The median period between hydrogel spacer injection and CT simulation was 1 day (range, 1-9 days). The median period between CT simulation and the last treatment was 17 days (range, 14-25 days). Regarding the volume change of the hydrogel spacer, the 2 observers observed significant differences between the volumes of the hydrogel spacer on the MR_{pre} and MR_{post}. However, the average volume difference between them was less than 1 cm^3. The average dice similarity coefficient between the MR_{pre} and MR_{post} to compare the shape was more than 0.83. In addition, no clear correlation was confirmed between the volume change and the period from hydrogel spacer injection to CT simulation.

Conclusions: A single day is an acceptable interval between hydrogel spacer injection and treatment planning for SBRT for prostate cancer.

Introduction

A hydrogel spacer (SpaceOAR System, Augmenix Inc, Waltham, MA) was recently introduced and used for external beam radiation therapy in patients with prostate cancer. A phase 3 trial for image-guided intensity

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modulated radiation therapy showed the benefit of a hydrogel spacer in reducing the rectal dose, toxic effects, and decline in quality of life.[1] In addition, a hydrogel spacer has a dosimetric benefit for patients treated with almost all external beam radiation therapy techniques.[2] In clinical settings, imaging for treatment planning should ideally be performed shortly after the hydrogel spacer injection for better time management. However, this is not recommended because the position and volume of a spacer can change shortly after the injection. Waiting for a period of 3 to 5 days after the injection before acquiring treatment planning computed tomography (CT) scans was previously recommended, based on a comparison between obtaining the first CT scan shortly after the injection of a hydrogel spacer and the second CT scan after 1 to 2 weeks.[3] However, the characteristics of only 3 patients were evaluated in that previous study, and no studies have investigated the short-term characteristics (<3 days) of a spacer. Therefore, the current study aimed to evaluate the short-term characteristics of a hydrogel spacer from the time of injection during stereotactic body radiation therapy (SBRT) for prostate cancer.

Materials and Methods

Study design

The current retrospective study was approved by the institutional review board of our hospital (receipt number: 1946). Between March 2020 and November 2020, 15 patients who underwent prostate SBRT with the hydrogel spacer were enrolled. All the patients were treated with SBRT (36.25 Gy/5 fractions, dose delivered to 95% of the planning target volume) using the CyberKnife system. The eligibility criteria for hydrogel spacer injection in the current study were as follows: (1) patients receiving treatment with SBRT, (2) patients with a high risk of hemorrhage, such as those with diabetes mellitus or receiving anticoagulants, and (3) patients with a large prostate volume near the rectum.

Procedure for hydrogel spacer injection and the timing of obtaining CT scans

Details of the method for hydrogel spacer injection have previously been described.[4,5] In our institute, radiation oncologists inserted the spacer. In brief, the patient is positioned in the dorsal lithotomy position, with a transrectal ultrasound probe positioned in the rectum. Then, a needle is subsequently advanced to the midpoint (base to apex) of the prostate gland, and the spacer is injected between the rectum and prostate under transrectal ultrasound guidance and by using a stepper device. The spacer solidifies in seconds and maintains a space between the prostate and the rectum for approximately 3 months. Finally, the spacer is absorbed by the body during a period of approximately 6 months.

To evaluate the changes in the characteristics of the hydrogel spacer, 2 magnetic resonance (MR) images were obtained with a hydrogel spacer: one on a CT simulation day (MR pretreatment [MR_{pre}]) and the other on the last treatment day (MR posttreatment [MR_{post}]). In routine clinical settings at our institution, an MR image and simulation CT are usually acquired 1 day after hydrogel spacer injection.

Evaluation of the changes in the characteristics of the hydrogel spacer

To evaluate the changes in the characteristics of the hydrogel spacer on both MR_{pre} and MR_{post} images, 2 experimental medical physicists for prostate treatment planning contoured the hydrogel spacer on each CT image by using MIM Maestro software (MIM Software Inc, Cleveland, OH). We measured the volume (cm^3) in each MR image and calculated the dice similarity coefficient (DSC) to evaluate the difference of the shapes. Statistical analysis was performed using JMP Pro, version 16.0 (SAS Institute Inc, Cary, NC), with a level of significance of $P < .05$.

Results

Table E1 shows the characteristics of the patients enrolled in this study. The mean patient age was 71.9 ± 7.80 years, the mean prostate-specific antigen level was 9.12 ± 5.30 ng/mL, the mean Gleason score was 6.62 ± 1.00, and the mean clinical target volume was 38.0 ± 10.9 cm^3. The mean period between hydrogel spacer injection and CT simulation was 2.87 ± 2.47 days, and the median period was 1 day (range, 1-9 days). Similarly, the mean period between CT simulation and the last treatment was 18.2 ± 3.28 days, and the median period was 17 days (range, 14-25 days).

Figure 1 shows the typical volume changes considering the contours of a hydrogel spacer on an MR image obtained 1 day after hydrogel spacer injection (MR_{pre}) and the MR image obtained 18 days after acquisition of the first image (MR_{post}) for both the observers. The volume difference of the hydrogel spacer before and after CT for this patient was 1.18 cm^3 (9.41 cm^3 [MR_{pre}] − 10.59 cm^3 [MR_{post}]) and 2.56 cm^3 (10.75 cm^3 − 13.31 cm^3) for observers 1 and 2, respectively. Table 1 shows the changes in the hydrogel spacer volume for all patients and the DSC between 2 MR images. Regarding the volume change of the hydrogel spacer, the 2 observers observed significant differences between the volumes of the hydrogel spacer on MR_{pre} and MR_{post}. However, the average

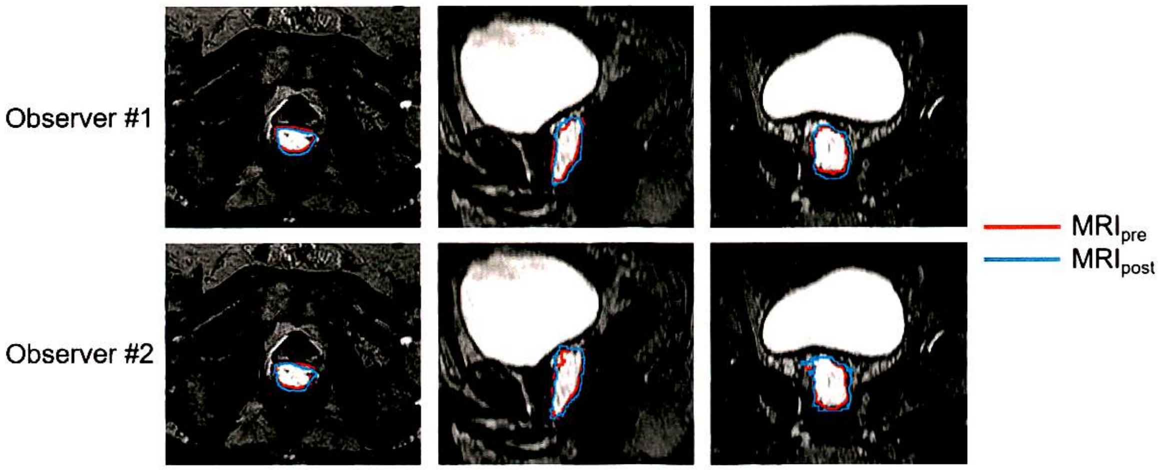

Fig. 1 Volume change of the hydrogel spacer between the magnetic resonance (MR) image obtained 1 day after hydrogel spacer injection (MR_{pre}) and the MR image obtained 18 days after the acquisition of the computed tomography simulation scan (MR_{post}). Each color illustrates the contour of the hydrogel spacer observed on both images for 2 observers (MR_{pre}, red; MR_{post}, blue).

Table 1 Changes in hydrogel spacer volume measured by MRI*

	Spacer volume (cm^3), mean ± SD (N = 15)				
Observer	MRI_{pre}	MRI_{post}	Difference (MRI_{post} − MRI_{pre})	*P* value	DSC
1	11.9 ± 1.15	12.8 ± 1.74	0.87 ± 1.09	.0107	0.83 ± 0.04
2	12.2 ± 1.29	13.2 ± 1.78	0.89 ± 1.74	.0096	0.85 ± 0.04

Abbreviations: DSC = dice similarity coefficient; MRI = magnetic resonance image; post = posttreatment; pre = pretreatment; SD = standard deviation.
* Results for both observers are shown. Each *P* value was calculated using the Wilcoxon test and is considered statistically significant.

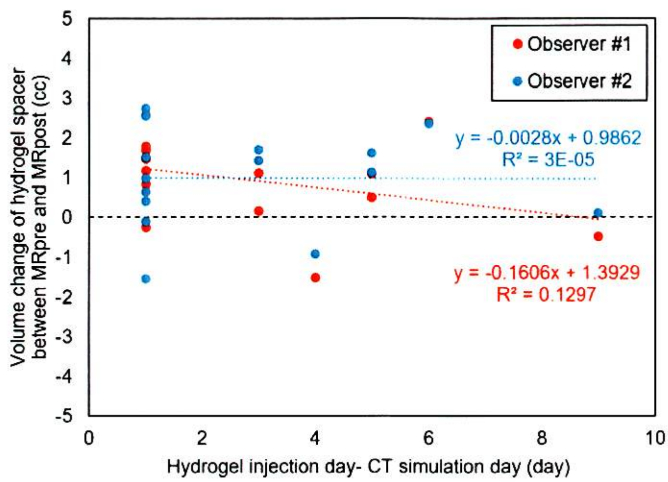

Fig. 2 A scatter plot showing the volume change of the hydrogel spacer between the magnetic resonance (MR) images pretreatment (MR_{pre}) and posttreatment (MR_{post}) versus the period from hydrogel spacer injection to computed tomography (CT) simulation (days). Each color plot illustrates the result for each observer (observer 1, red; observer 2, blue).

volume difference between them was less than 1 cm^3. The average DSC between MR_{pre} and MR_{post} to compare the shape was more than 0.83.

Figure 2 shows a scatter plot of the volume change of the hydrogel spacer (cm^3) versus the period from hydrogel spacer injection to CT simulation (days). From the figure, no clear correlation was confirmed between the volume change and the period from hydrogel spacer injection.

Discussion

In the current study, 2 observers contoured the hydrogel spacer to ensure consistency in the results. Regarding the volume change of the hydrogel spacer, the 2 observers observed significant differences between the volumes of the hydrogel spacer on MR_{pre} and MR_{post}. However, the average volume difference between them was less than 1 cm^3. In addition, there was no correlation between the volume change of the hydrogel spacer and the period from hydrogel spacer injection. Therefore, the results suggest that prostate SBRT can be performed using a simulation CT for treatment planning that is performed more than 1 day after injection. In general, changes in the volume and shape of the hydrogel spacer are considered to be caused by changes in the contained gas volume, but no changes of this were observed in this study. In the current study, we had some limitations as follows. First, this study was performed by only 2 observers. Second, the misalignment of body position and bladder volume between MRI_{pre} and MRI_{post} may have affected the accuracy of measurement. Third, CT evaluation of the same case was not performed, so the difference between the 2 on CT images and the dosimetric effect could not be evaluated.

Conclusion

We evaluated the short-term characteristics of a hydrogel spacer for prostate cancer. The change in volume and shape for the hydrogel spacer were clinically negligible when the simulation CT was performed more than 1 day after injection. Our results suggest that an interval of just 1 day is acceptable between hydrogel spacer injection and treatment planning for SBRT of prostate cancer.

Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.prro.2022.01.004.

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