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Scientific Article

Validation of a Quality Metric Score to Assess the Placement of Hydrogel Rectal Spacer in Patients Treated With Prostate Stereotactic Radiation Therapy

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Purpose: To evaluate the quality of the interspace between the prostate and rectum and assess the effect on the dose to the rectum by measuring the spacer quality score (SQS) before and after implanting a hydrogel rectal spacer.

Methods and Materials: Thirty patients with prostate cancer were treated with stereotactic ablative body radiation therapy as part of the SPORT clinical trial. Each patient had a 10 mL polyethylene glycol hydrogel spacer inserted transperineally. Computed tomography scans were acquired before and after spacer insertion, 10MV flattening filter free (FFF) stereotactic ablative body radiation therapy (SABR) treatment plans were generated using each image set. To calculate the SQS, the prostate-rectal interspace (PRI) was measured in the anterior-posterior orientation, parallel to the anatomic midline at the prostate base, apex, and midgland on the prespacer and postspacer computed tomography. Measurements were taken in 3 transverse positions between the prostate and the rectum, and PRI scores of 0, 1, and 2 were assigned if the interspace between prostate and rectum was <0.3, 0.3 to 0.9, or ≥ 1 cm, respectively. The overall SQS was the lowest of the PRI scores. Differences between prespacer and postspacer PRIs and SQS were investigated by performing Fisher's exact test and differences between doses to the rectum were investigated by performing the paired samples Wilcoxon rank-sum test and Student *t* test.

Results: Statistically significant differences between prespacer versus postspacer patients were found when grouping patients according to their overall SQS. The PRI summary score did not reach statistical significance between prespacer and postspacer at the base but was significantly higher for the prostate midline and apex. Statistically significant differences in some rectum dose-volume metrics were found when grouping patients according to their PRIs and SQS.

Conclusions: SQS before and after the spacer insertion was evaluated and was found to be correlated with pre- and postspacer rectal dosimetry. Sources of improvement of the SQS scoring metric and limitations are discussed.

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Introduction

There is significant interest in stereotactic ablative body radiation therapy for the treatment of low- and intermediate-risk prostate cancer, demonstrated by the many large randomized clinical trials investigating this approach for treating prostate cancer.[1-6] However, increased rectal toxicity has been reported in SABR trials with doses greater than 40 Gy to the CTV in 5 fractions.[5,7,8]

Several solutions have been developed to reduce this toxicity, including the insertion of anatomic modulators (such as hydrogel spacers, hyaluronic acid, or saline-filled balloons[9,10]) that increase the separation between the anterior rectal wall and the prostate gland.[11] Rectal spacers have been incorporated into a number of clinical trials,[9,12,13] and it has been demonstrated that they are well tolerated and can reduce the radiation therapy dose to the rectum and toxicity.[9,10,13-15] However, these advantages need to be weighed against possible risks of complications such as acute grade 3 rectal perforation, which occurred in 1.49% of patients during the implantation procedure in a previous study.[16]

Initial evaluation of spacer quality was conducted by Eckert et al,[17] where the hydrogel spacer distance from the prostate to the rectum was measured (in millimeters) at prostate apex, center, and base before and after spacer insertion on T2-weighted magnetic resonance images (MRIs) in 10 men. No spacer score was generated in this study. The first spacer scoring system based on the hydrogel spacer symmetry was published by Fischer-Valuck et al.[18] The symmetry between spacer and prostate was evaluated by assigning a score between 0 and 3 on 3 axial slices (midgland, 1 cm superior to midgland, 1 cm inferior to midgland) in the anterior-posterior orientation, parallel to anatomic midline on T2-weighted MRIs in a cohort of 149 patients. A limitation of this study was that the calculation of the symmetry score was not possible if the spacer was not visible in one of the slices. More recently, another scoring system was developed by Grossman et al.[19] The interspace between prostate and rectum was measured on T2-weighted scans at the prostate base (axial slice 0.5-0.8 cm caudal to the most superior slice of the prostate base), apex (axial slice 0.5-0.8 cm cranial to the most inferior slice of the prostate apex), midgland (axial slice midway between base and apex) in 3 positions (rectal midline, 1.0 cm to the right, 1.0 cm to the left) in 42 patients with prostate cancer across 2 institutions. A score between 0 (low space) and 2 (high space) was given to each position and an overall spacer quality metric score (SQS) was computed based on these 9 measurements.

The purpose of the present study was to evaluate the effect of the interspace between the prostate and rectum on the dose to the rectum by measuring the SQS before and after implanting a hydrogel rectal spacer, examining if the SQS is appropriate to use prospectively and retrospectively. These values were correlated with the dose received by the rectum. This is the first direct comparison with the SQS scores from an independent center, effectively validating the original implementation of the SQS score.

Methods and Materials

Patient cohort

The patients included in this study (n = 30) were enrolled in the SPORT clinical trial evaluating SABR to prostate or pelvic lymph nodes (NCT03253978) at the Northern Ireland Cancer Centre. Ethical approval for the trial was granted by the Office of Research Ethics Committees (reference 15/NI/0192). The SPORT trial included patients with National Comprehensive Cancer Network unfavorable intermediate- or favorable high-risk localized prostate cancer who were suitable for radical external beam radiation therapy and long-term androgen deprivation therapy.[20] Patients were eligible for the trial if they had one of the following features: stage T3a N0 M0, Gleason score 7 (4+3) or above, or prostate specific antigen (PSA) >20. Patients with clinical T stage $\geq$ T3b/T4 were excluded from the trial. Patients on the trial received 3 months neoadjuvant androgen deprivation therapy as standard of care with it continuing for a minimum of 12 months in total.

A 10 mL polyethylene glycol hydrogel spacer (SpaceOAR, Boston Scientific, Inc) was inserted transperineally under transrectal ultrasound guidance in each patient.[20] This procedure was performed by different 3 consultants for the full cohort. The SpaceOAR hydrogel rectal spacer is a material composed of water and a polyethylene glycol hydrogel that is injected between the Denonvilliers' fascia and the anterior rectal wall under ultrasound guidance.[21] Upon insertion, the hydrogel solidifies and creates an anatomic separation between the prostate and the rectum, thereby reducing the volume of the rectum present in the high dose region surrounding the prostate. The spacer remains in the patient for approximately 3 months before breaking down and being absorbed and removed from the body through urine within 6 months of insertion.

CT scans were acquired using a General Electric Optima CT580 helical CT-simulator (512 $\times$ 512 field of

view, 1.0 mm axial pixel resolution, 2.5 mm slice width) before the hydrogel insertion (referred as "prespacer CT") and a week after the spacer insertion (referred as "postspacer CT"). The same day, a postspacer T2-weighted MRI was also acquired for each patient. MRI and postspacer CT were fused using the Eclipse treatment planning system versus 15.6 (Varian Medical Systems) to assist in the delineation of anatomic features and hydrogel spacer. Structures of interest were contoured manually in Eclipse by consultant clinical oncologists on the prespacer CT and postspacer CT images by following the volume definitions for target and OARs specified in the SPORT clinical trial,[20] with trial protocol emphasizing the definition of the prostate apex with MRI.

Although the patients were randomized to prostate only and prostate and pelvic node radiation therapy, treatment plans for all 30 patients in this study were created to include the prostate, including any extraprostatic extension, and proximal 10 to 20 mm of the seminal vesicles in the clinical target volume (CTV). A 5 mm margin was extended isotropically from the CTV to create the planning target volume (PTV). Radiation therapy prescription was 36.25 Gy to the prostate PTV with 40 Gy to the CTV delivered in 5 weekly fractions over 29 days. Volumetric modulated arc therapy (VMAT) plans were generated on the Eclipse treatment planning system using the VMAT photon optimizer (v.15.6) and Acuros External Beam planning dose calculation algorithm (v.13.6.23) and delivered using a 10 MV FFF photon beam with a maximum dose rate of 2400 MU min^{-1}. Plans were evaluated in terms of target, rectum, and bladder dose-volume histogram (DVH) metrics. The target and organ at risk (OAR) planning dose constraints are summarized in King et al.[14]

To evaluate the effect of the spacer it was necessary to standardize the method of optimization between the pre- and postspacer plans. To do this, full PTV coverage was prioritized to give coverage of the 100% isodose along the posterior edge of the PTV. However, in our center, and international clinical trials such as PACE-NODES, the rectal tolerance of V36 Gy <2 cc would be prioritized. which may require the 100% isodose to be "peeled" back around the rectum while still maintaining D95% >100%.

Normal tissue complication probability (NTCP) was calculated to evaluate the dosimetric effect of the spacer on the rectal toxicity. DVH dose bins were modified using the linear-quadratic model to express the dose as the equivalent dose in 2-Gy fractions, using an $\alpha/\beta = 3$. Code was adapted to calculate the equivalent uniform dose and NTCP.[22] Quantec NTCP parameters for grade 2+ rectal bleeding were used for these calculations.

Hydrogel rectal spacer quality metric

Although the method is presented in the paper by Grossman et al,[19] it is briefly described here for completeness. The interspace between prostate and rectum was measured in the anterior-posterior orientation, parallel to anatomic midline on the prespacer and postspacer CT scans available for each patient. The prostate-rectal interspace (PRI) was measured at the prostate base (axial slice 0.75 cm caudal to the most superior slice of the prostate base), apex (axial slice 0.75 cm cranial to the most inferior slice of the prostate apex), and midgland (axial slice midway between base and apex) as shown in Fig. 1. Measurements were taken in 3 positions between the prostate and the rectum: rectal midline, 1.0 cm to the right, and 1.0 cm to the left of the midline, as shown in Fig. 2. PRI thickness values of 0, 1, and 2 were assigned if the interspace between prostate and rectum was <0.3 cm, between 0.3 and 0.9 cm, or ≥1 cm, respectively. A PRI row summary score was calculated as the mode of the 3 PRI thickness values per axial position from 9 PRI thickness values. The SQS was calculated as the lowest value of the 3 row PRI scores.

Differences between prespacer and postspacer dose to the rectum were investigated by performing paired samples Wilcoxon rank-sum test and Student *t* test; the normality of the data samples was tested with the Shapiro-Wilk test. After grouping the patient according to the final SQS score, we tested whether the grouped distributions were identical using the Kruskal-Wallis Test with Bonferroni correction. Differences between prespacer and postspacer PRI summary scores at the prostate base, apex and midgland, as well as the SQS values were investigated by

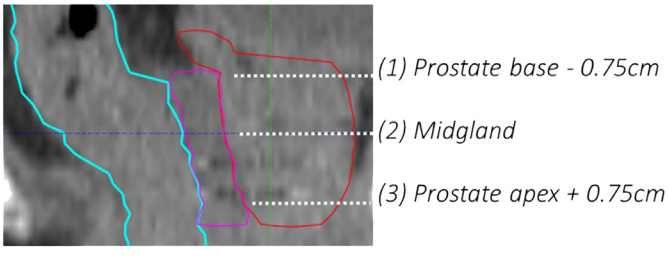

Figure 1 Positions where the prostate-rectal interspace were measured following the method presented in Grossman et al.[19] Prostate (red), rectum (cyan), and spacer (magenta).

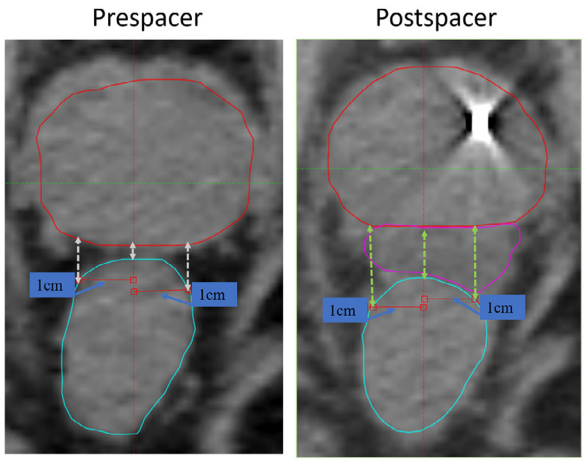

Figure 2 Example of prostate-rectal interspace thickness values measured between the prostate (red) and the rectum (cyan) on prespacer computed tomography (CT) and postspacer CT scans at midgland position. The prostate-rectal interspace thickness values were measured in 3 positions (left, middle, and right) as shown by the gray and green dashed arrows in pre- and postspacer CT, respectively. The spacer is contoured in magenta.

performing the Fisher exact test. Statistical analysis was performed using a statistics software package (R, http://www.R-project.org/); all tests had significance set at P value < .05. Comparisons were then made to the study by University of Texas Southwestern Medical Center (UTSW) involving a 42-patient cohort.[19]

Results

The percentage of prespacer, postspacer, and UTSW patients corresponding to each PRI and SQS score is presented in Fig. 3 with a more detailed comparison between the SQS measured for prespacer and postspacer presented in Table E1. Most of the patients had a maximum PRI summary score of 2 at the prostate base (83.4% prespacer vs 96.7% for postspacer) with no significant difference observed between the 2 groups. At the midgland, most of the patients in the prespacer group had a PRI summary score of 0 (46.7%) or 1 (50.0%), while in the postspacer group 33.3% and 60.0% had PRI row summary scores of 1 and 2, respectively. Similar results were measured at the

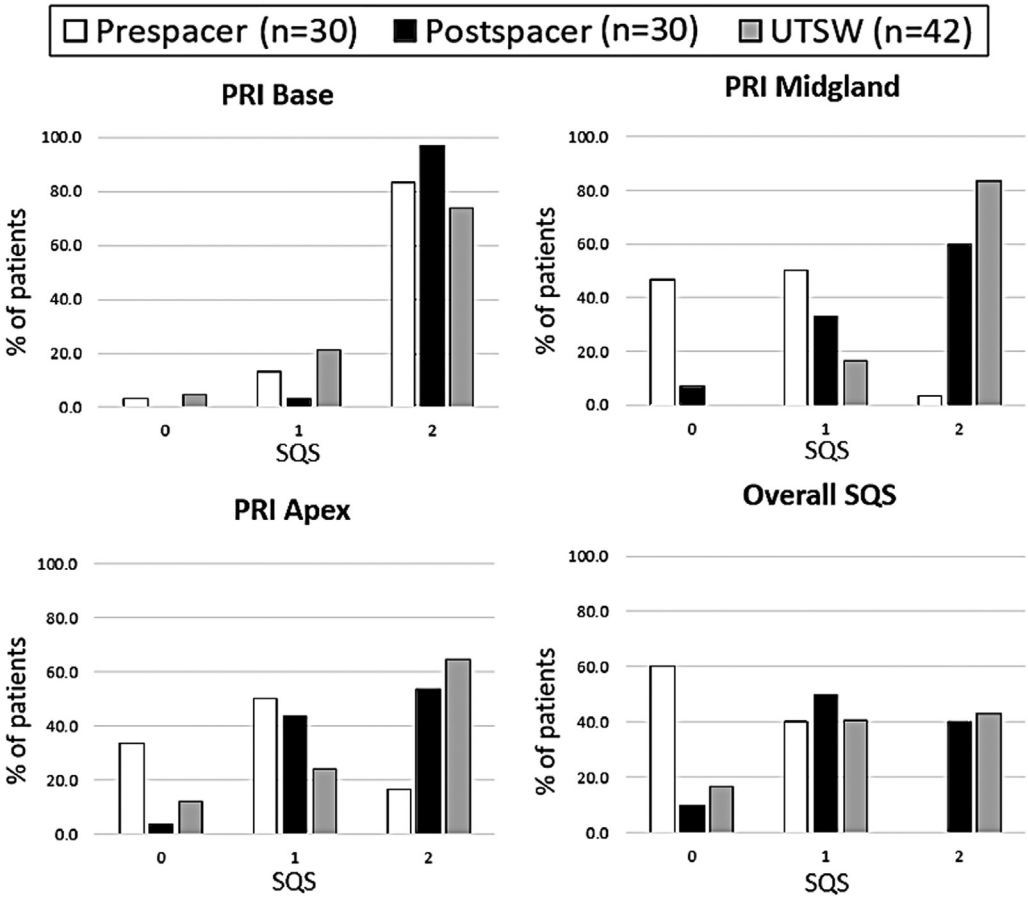

Figure 3 Percentage of patients with prostate-rectal interspace between of 0, 1, and 2 at the (a) prostate base, (b) prostate midgland, (c) prostate apex, and with (d) overall spacer quality score scores between of 0, 1, and 2 in the prespacer, postspacer, and UTSW groups. *Abbreviations:* PRI = prostate-rectal interspace; SQS = spacer quality score; UTSW = University of Texas Southwestern Medical Center.

Table 1 Summary of the rectum dosimetric results for prespacer and postspacer patients

Metric	Measure	Prespacer n = 30	Postspacer n = 30	*P* value	UTSW n = 42
Rectal Dmax [Gy]	Median (range)	41.4 (39.9-43.3)	39.5 (27.8-42.2)	<.001	44.2 (29.3-50.9)
	Mean (SD)	41.5 (0.7)	38.8 (3.1)		42.9 (5.4)
Rectal D0.035 cc [Gy]	Median (range)	40.7 (38.7-42.6)	38.5 (24.7-41.4)	<.001	41.8 (27.1-49.9)
	Mean (SD)	40.8 (0.8)	37.5 (3.7)		40.7 (6.2)
Rectal D1 cc [Gy]	Median (range)	38.8 (36.8-40.4)	35.1 (19.5-37.2)	<.001	33.4 (14.7-46.2)
	Mean (SD)	38.7 (1.0)	33.1 (4.8)		33.7 (7.8)
Rectal V40 Gy [cc]	Median (range)	0.3 (0.0-1.6)	0.0 (0.0-0.3)	<.001	0.1 (0.0-6.5)
	Mean (SD)	0.4 (0.4)	0.0 (0.1)		0.8 (1.3)
Rectal V30 Gy [cc]	Median (range)	6.4 (3.6-13.6)	3.3 (0.0-7.9)	<.001	2.5 (0.0-22.3)
	Mean (SD)	7.1 (2.6)	3.5 (2.4)		3.3 (4.0)
Rectum volume in PTV [cc]	Median (range)	2.3	0.2	<.001	
	Mean (SD)	2.6 (1.5)	0.54 (0.72)		
Rectal V36 Gy [cc]	Median (range)	2.7 (1.4-6.0)	0.7 (0.0-2.2)	<.001	
Objective <2 cc	Mean (SD)	3.1 (1.4)	0.7 (0.7)		
Rectal V29 Gy [%]	Median (range)	12.7 (7.2-19.5)	4.2 (0.0-8.8)	<.001	
Objective <20%	Mean (SD)	13.0 (3.1)	4.1 (2.7)		
Rectal V18.1 Gy [%]	Median (range)	29.8 (19.3-47.9)	25.7 (3.2-49.1)	.004	
Objective <50%	Mean (SD)	30.6 (7.5)	24.9 (12.0)		
Grade 2+ rectal bleeding NTCP [%]	Median (range)	8.9 (2.3-25.8)	1.4 (0.0-15.9)	<.001	
	Mean (SD)	9.7 (4.7)	2.3 (3.2)		

Abbreviations: NTCP = normal tissue complication probability; PTV = planning target volume; UTSW = University of Texas Southwestern Medical Center.
The statistical differences are calculated by performing the paired samples Wilcoxon rank-sum test and Student *t* test. The UTSW results presented in Grossman et al[19] are also included in this table but because a different dose is prescribed in the trials presented in Folkert et al[13] and King et al,[14] no statistical analysis was conducted.

apex where in the prespacer group PRI row summary scores of 0 and 1 were measured for 33.3% and 50.0% of the patients, respectively, while in the postspacer group 43.3% and 53.4% had a PRI row summary score of 1 and 2, respectively. Significant differences were observed between groups both at midgland and apex. When the overall SQS was computed by combining these results, the difference between prespacer versus postspacer patients was statistically significant ($P < .05$): 60.0% versus 10.0%, 40.0% versus 50.0%, and 0.0% versus 40.0% had a scores of 0, 1, and 2, prespacer versus postspacer patients, respectively.

Figure 3 additionally shows that the results measured for the postspacer SPORT cohort, are consistent with the results reported by Grossman et al,[19] from a cohort of 42 patients with prostate cancer from UTSW.[13] SPORT PRI row summary scores were higher than UTSW at the prostate base (PRI = 2, +22.4%) but lower than UTSW at the midgland (PRI = 2, −22.9%). At the apex, the SPORT scores were higher for PRI equal to 1 (+17.6%), but lower for PRI equal to 2 (−6.6%). The overall SQS showed almost identical results between the 2 cohorts, with a slightly better outcome for the cohort being studied (SQS = 0, −10.0%; SQS = 1, +7.1%; and SQS = 2, +2.9%).

Table 1 presents a summary of the dosimetric results (maximum dose to the rectum, Dmax; dose to 0.035 cc of the rectum, D0.035 cc; dose to 1 cc of the rectum, D1 cc; volume of rectum receiving 40 Gy, V40 Gy; volume of rectum receiving 30 Gy, V30 Gy) of prespacer and postspacer patients, and the differences are statistically significant for all the dosimetric measurements presented ($P < .05$). The prescribed dose and treatments were different in the 2 clinical trials (45 Gy over 5 fractions prescribed to cover >95% of the PTV for the UTSW cohort[19] vs 40 Gy for the CTV and 36.25 Gy for the PTV, delivered simultaneously, in 5 fractions for the cohort being studied[14]); therefore, the results are here reported for completeness, but no statistical comparison was performed. The mean dose to 0.035 cc and 1 cc of rectum were 37.5 Gy versus 41.3 Gy and 33.1 Gy and 34.9 Gy, for our study compared with Grossman et al.[19]

Statistical differences between prespacer and postspacer were evaluated for the dosimetric rectum constraints (volume of rectum receiving 18.1 Gy, V18.1 Gy;

volume of rectum receiving 29 Gy, V29 Gy; volume of rectum receiving 36 Gy, V36 Gy). The plan constraints were V18.1 Gy <50.0%, V29 Gy <20.0%, and V36 Gy <2 cc, respectively. Mean and median volumes measured show that the constraints were achieved with both plans, except for V36 Gy, for which the volume of rectum receiving 36 Gy was <2 cc only with the postspacer plans. The mean percentage of rectum receiving 29 Gy and 18.1 Gy decreased by approximately 9.0% and 5.5% in the postspacer plans. The mean difference between postspacer and prespacer rectal bleeding NTCP was −7.4%, a similar trend to initial data previously published for the first 6 patients.[14] As can be seen in Fig. 4, all patients except for patient 29 had a decrease in NTCP postspacer.

The variation in the SQS and PRI scores for each patient is shown in Fig. 4, focusing on the variation of dose delivered to the rectum before and after the spacer implantation (Δscore = (postspacer score) − (prespacer score)). As expected, patients with smaller dose to the rectum variations after the spacer was implanted, also have a negative Δscore (ie, the postspacer score was lower than the prespacer score), such as patient 29 and patient 18 (SQS = −2 and PRIs = −2 for all the dosimetric measurements here presented).

Prespacer and postspacer distributions are presented in Fig. 5. The results clearly show that a decrease in the dose received by the rectum corresponds to a better (higher) SQS score, ie, patients with SQS = 2 received the lowest dose to the rectum. Two outliers were found in the postspacer group: 2 patients who had SQS = 2 also had 44.4% and 49.1% of rectal volume receiving 18.1 Gy (plan constraint: V18.1 Gy <50%). The latter patient is also an outlier for the constraint V29 Gy because 18.1% of its volume received 29 Gy (plan constraint: V29 Gy <20%). This could be explained by prioritizing the achievement of the target dose constraints rather than keeping a lower dose to the OARs.

A summary of the dosimetric results for prespacer and postspacer patients grouped according to the SQS scores is presented in Table E2. For the prespacer group, only SQS = 0 and SQS = 1 were compared because no patients had a score of 2. Although the median and mean dose difference among the 3 groups was small, statistically significant differences (P <.05) were found for rectal Dmax, D0.035 cc, D1 cc, and V36 Gy for both prespacer and postspacer patients. Rectal V29 Gy differences were significant among different SQS groups only for the postspacer plans. Finally, differences in rectal V18.1 Gy were not statistically significant, neither for prespacer nor for postspacer plans.

Discussion

To evaluate the quality of the rectal spacer implantation, several studies have been focusing on long-term follow-up after radiation therapy for prostate cancer with and without rectal hydrogel spacer.[13,17-24] As highlighted in a recent review,[25] accurate spacer placement is essential, suggesting the need for quantitative measures evaluating the spacer quality. This study quantitatively measured, using the SQS score, the quality of the hydrogel rectal spacer score placed in the patients and by retrospectively analyzing the dose received by the rectum during prostate SABR treatments. Prespacer and postspacer CT scans of 30 patients treated with prostate SABR as part of the SPORT clinical trial were analyzed in this study and the dose to the rectum was measured to investigate the effect of the spacer on the final dose received by the OAR. The overall SQS score improved after spacer implantation for 76.7% of the patients, and the postspacer results are in line with those presented in the original SQS work.[19]

The dosimetric benefits associated with injection of hydrogel rectal spacers are well documented within the literature,[12,15,17,26-29] demonstrating the efficacy of the spacers in reducing the rectal dose during external beam radiation therapy. The value of being able to identify the quality of the inserted hydrogel spacer was mentioned in the review by Drabble et al.[25]

When grouping the results according to the SQS, statistically significant differences were measured both in the prespacer and postspacer plans (Table E2) and the volume of the rectum receiving 18.1 Gy, 29 Gy, and 36 Gy was significantly reduced from the prespacer to postspacer plans, particularly when going from SQS = 0, to 1 and 2 as shown in Fig. 5. During treatment planning, priority was given to achieving the target dose constraints, therefore the dose to OARs increased in some cases, thus generating outliers such those presented in Fig. 5 for the dose to the rectum for V29 Gy and V18.1 Gy. However, it is important to note that in our study isotropic margins of 5 mm were extended from the CTV to create the PTV while in other studies alternative margins were utilized.[12,13,28]

In the review by Drabble et al,[25] it was highlighted that there is a correlation between placement symmetry and reduced rectal dose. A spacer thickness of 5.0 mm was determined to be a guide to creating a clinically significant reduction in rectal V70 dose. It was also reported from the Pivotal trial[28,30] in which clinicians reported a success rate in terms spacer placement of 99.0%. The Pivotal success rate for optimal spacer placements was significantly lower (62.0%-72.0%) and the spacer was covering both the apex and base of the prostate in only 32.0% of patients. Although in this study the evaluation of the quality of the spacer implantation was purely qualitative. The need for quantitative measures of spacer quality was addressed for the first time by Fischer-Valuck et al,[18] where the symmetry of the spacer insertion was investigated on 149 patients. The spacer was found to be symmetrical to the rectum in 49.0% of the patients and asymmetrical lateral hydrogel distributions of 1.0 or 2.0 cm based on the medial aspect of the spacer were measured.

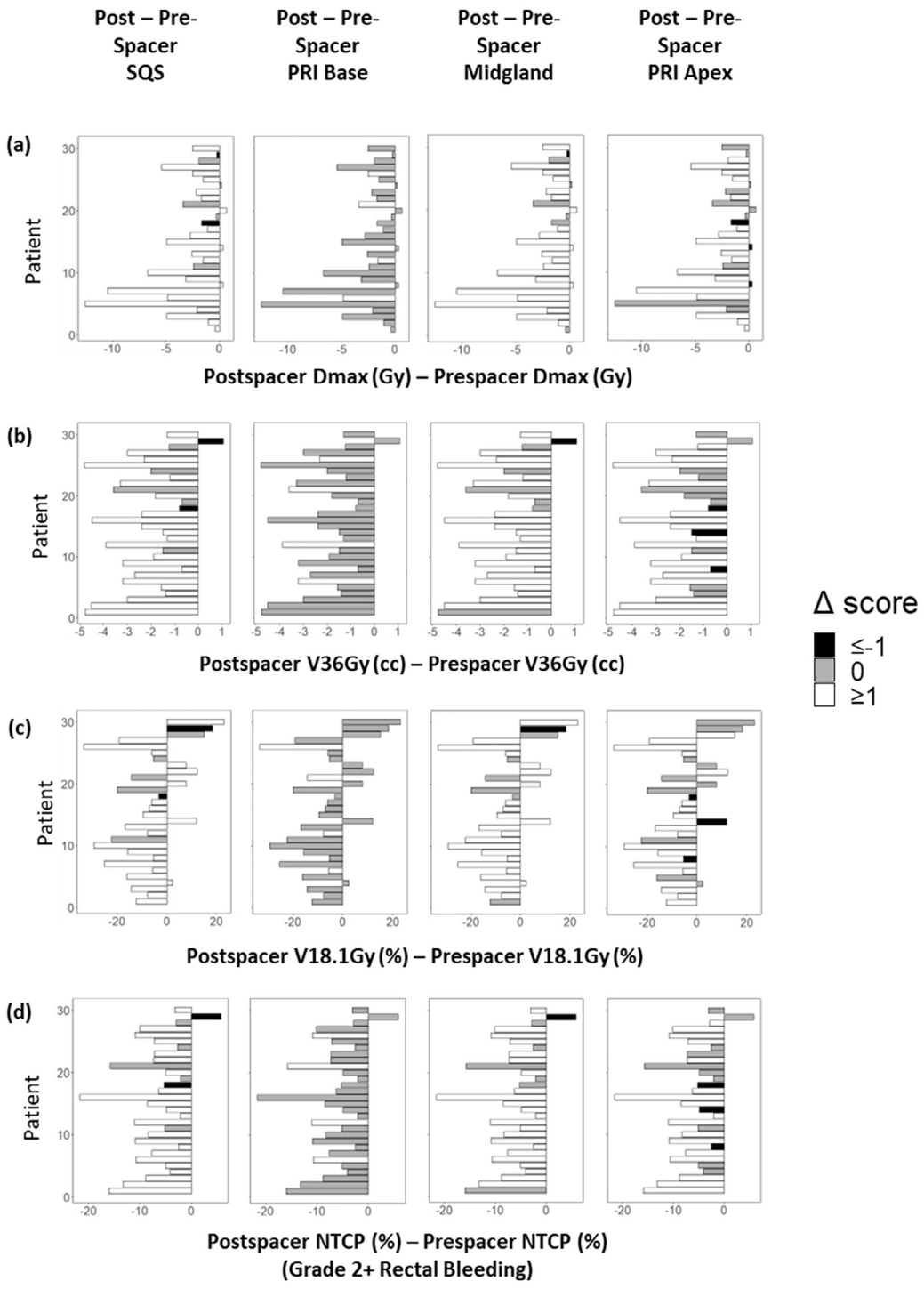

Figure 4 Variation in the spacer quality score and prostate-rectal interspace scores (Δscore = [postspacer score] − [prespacer score]) for each patient versus the variation in the rectum dosimetric results for (a) Dmax, (b) V36 Gy, (c) V18.1 Gy, (d) grade 2+ rectal bleeding NTCP. Changes in scores are coded black for a negative change, gray for no change, and white for a positive change. Abbreviations: NTCP = normal tissue complication probability; PRI = prostate-rectal interspace; SQS = spacer quality score.

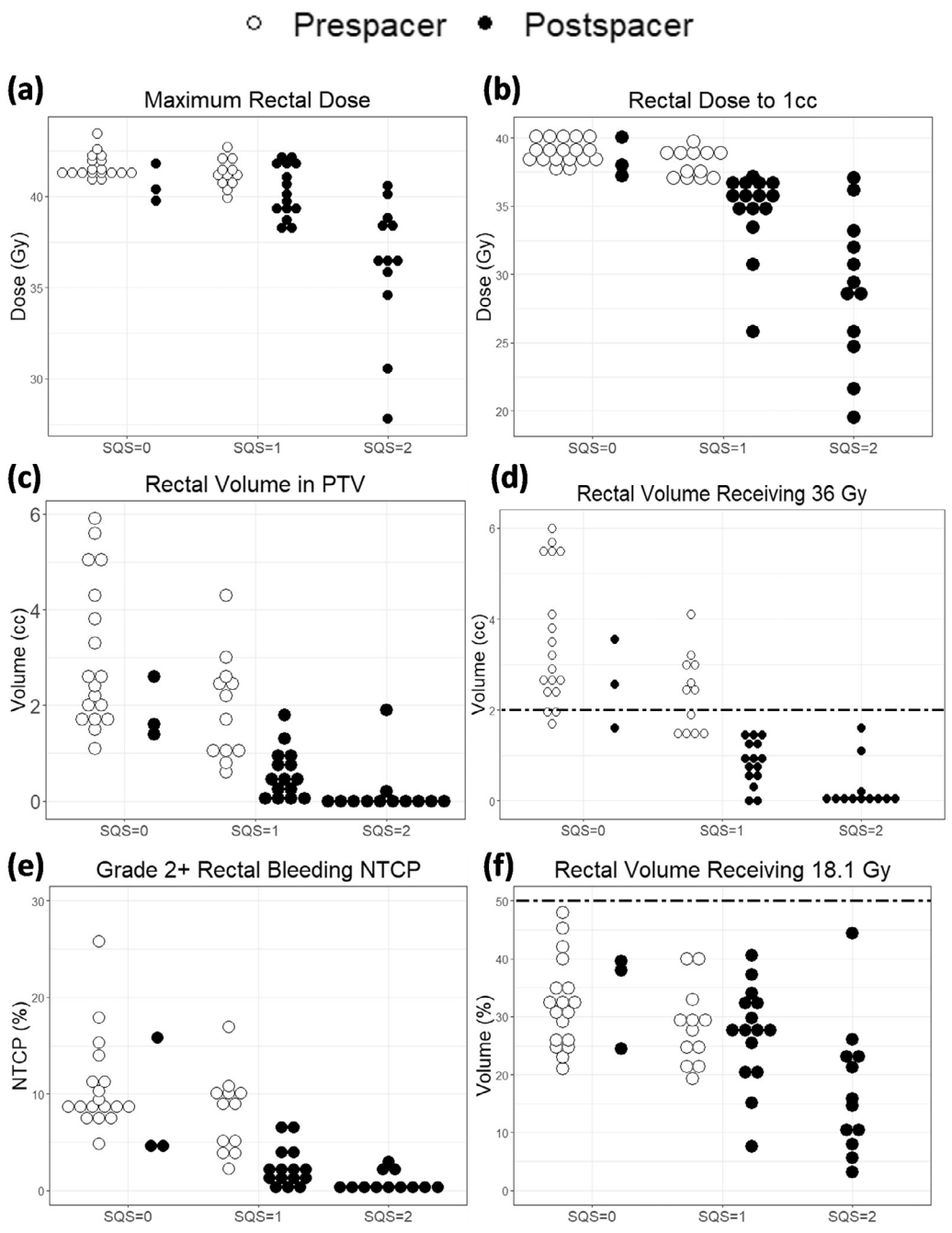

Figure 5 Prespacer and postspacer (a) maximum dose received by the rectum, (b) dose to the most irradiated 1 cc of the rectum, (c) volume of the rectum in the planning target volume, (d) rectal volume receiving 36 Gy, (e) normal tissue complication probability of rectal bleeding, (f) rectal volume receiving 18.1 Gy. Metrics are grouped according to the different spacer quality score scores measured (0, 1, or 2). The dashed black line shows the plan constraints for the rectal volume. *Abbreviation:* NTCP = normal tissue complication probability; PTV = planning target volume.

Both in the study presented by Grossman et al[19] and in the work presented here, the focus was the direct measurement of the distance between rectum and spacer. Note that the symmetry of the rectal placement is indirectly taken into consideration by combining the PRI thickness values into PRI row summary scores: if a spacer is inserted asymmetrically, different PRI thickness values would be measured in each axial slice, and the PRI row summary score would be lower. The percentage of postspacer patients with PRI summary scores of 0, 1, and 2 at the prostate base, midgland, and apex is presented in the Fig. E1, the highest scores were measured at the prostate

base. At the prostate apex the results are similar to those presented in Grossman et al[19] while a difference of 20% was observed at the prostate midgland for PRI summary scores of 2. The overall SQS results reported in this study were in line with the work presented in Grossman et al[19] with 10.0%, 50.0%, and 40.0 of patients having SQS of 0, 1, and 2, respectively.

Potential limitations of the study must be also acknowledged. The data set here presented is relatively small (n = 30). Motion of the seminal vesicles could be a cause of error in the measurements that can affect the reproducibility of the study. Eckert et al[17] suggested that the prostate base should be selected 3.0 mm below the origin of the seminal vesicles to avoid artifacts (option not implemented in this study to be consistent with Grossman et al[19]). The volume of prostate and spacers should be considered when evaluating the SQS. In particular, the measurements 1.0 cm to the right and to the left from the rectal midline, in some cases had to be adjusted because the prostate was too small, and the distance could not be measured. Finally, even if the PRI summary scores takes indirectly into consideration the symmetry between spacer and rectum, investigating the correlation between the SQS score presented in Grossman et al[19] and the symmetry score presented in Fischer-Valuck et al[18] should be considered for further studies.

A refinement of the metric is also suggested by the fact that some of the postspacer plans with lower SQS/PRI scores are better than the prespacer corresponding plans with higher SQS/PRI scores, as shown in Fig. 3. In these cases (eg, patient 11 and 21), a negative ΔSQS score is measured but the dose to the rectum is lower after the spacer implantation. Therefore, weighting one of the slices is a possible solution that should be investigated. The SQS metric may be further adjusted to take an alternative to the minimum score, as the overall score may be effected more heavily than it should if the overall implant is good, but one of the 9 regions is not. The inclusion of the rectal volume in the PTV in scoring may also be investigated as this was found to correlate with NTCP with a Pearson coefficient of 0.8. This study will lead on to a method being developed to identify patients, using diagnostic imaging and a scoring metric, who would benefit from a spacer in the first place. The identification of a robust scoring metric is key to this.

Conclusion

This study investigated a scoring method[19] measuring the insertion quality of a polyethylene glycol hydrogel spacer in a cohort of patients with high-risk prostate cancer treated with SABR.

Our work is the first external validation of this method and demonstrates that the SQS can provide further insight beyond simple DVH metrics by showing the spatial component of spacer and rectum.

Significant differences in the rectum dose-volume metrics between the prespacer and postspacer plans were correlated with the SQS score measured, thus demonstrating the reliability and feasibility of this scoring method.

Disclosures

Suneil Jain reports consulting fees from Boston Scientific, honoraria from Janssen, Astellas, Bayer, Astra Zeneca, Pfizer, and Accord; support for attending meetings from Janssen and Bayer; and research support from Boston Scientific.

Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.adro.2023.101396.

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