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RESEARCH

Rectal spacer use and bowel, urinary, and sexual dysfunction diagnosis and related procedures among men receiving prostate radiotherapy: US county-level analysis

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Abstract

Purpose Clinical studies demonstrate the protective function of rectal spacers to mitigate side effects of radiotherapy (RT) in prostate cancer (PCa) patients. However, large-scale real- world evidence is lacking. This study evaluates the association between rectal spacer use and the prevalence of bowel, urinary, and sexual dysfunction diagnoses and related procedures among PCa patients receiving RT in the US at the county level.

Methods Medicare 5% and 100% Standard Analytic Files were used to analyze county-level data from January 2015 to March 2024. The sample included adult PCa patients receiving RT. The primary outcome was the county-level proportion of RT patients diagnosed with bowel, urinary, or sexual dysfunctions or undergoing related procedures. The primary explanatory variable was rectal spacer use 1–5 years before diagnosis. Zero-inflated Poisson regression models were used, controlling for county-level characteristics.

Results Among 318,911 PCa patients across 3,168 US counties, the annual prevalence of dysfunction was 2.0% (bowel), 5.6% (urinary), and 1.1% (sexual). Rectal spacer use increased from 4.4 to 18.1% over the study period. A 100-percentage point increase in rectal spacer use at the county level was associated with a 7.1–55.1% reduction in any of three dysfunctions after 1–5 years (all $p<0.05$), with similar but weaker trends for related procedures. The strongest association was observed for bowel dysfunction, followed by urinary dysfunction.

Conclusion This large-scale, county-level analysis identifies an association between rectal spacer use and lower prevalence of bowel, urinary, and sexual dysfunction, suggesting potential population-level benefits in PCa RT patients.

Keywords Rectal spacer · Prostate cancer · Radiotherapy · Dysfunction · Real world data

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Introduction

Radiotherapy (RT) is a standard treatment strategy for clinically localized prostate cancer (PCa). Innovations in technology have enabled oncologists to deliver higher doses of radiation to the prostate with improved precision while minimizing damage to surrounding tissues. Despite these advancements, the rectum, bladder, penile bulb, and neurovascular bundles remain vulnerable to radiation exposure due to their proximity to the prostate. Adverse side effects, such as bowel, urinary and sexual dysfunction impact patients' quality of life (QOL) [1, 2]. Side effects can manifest acutely in 45–65% of patients; however, a subset of patients develop chronic symptoms that persist or emerge years later, causing serious complications [3–12].

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Rectal spacers have been developed to mitigate radiation exposure to the anterior rectum [13–15]. Clinical trials demonstrate that rectal spacers are safe and effective in expanding the prostate-rectal distance and decreasing RT exposure [1, 16, 17] and help preserve QOL in the bowel, urinary, and sexual domains [18–20]. However, only a limited number of clinical studies have assessed the long-term association between rectal spacing and bowel, urinary, and sexual toxicities and quality of life [14, 18–22]. While controlled clinical trials show promising efficacy for rectal spacing in terms of preserving quality of life, they may not fully reflect the comparative effectiveness of rectal spacing in real-world populations. Large, real-world data may complement trial findings, providing a broader understanding of the long-term effects of rectal spacing on the reduced bowel, urinary, and sexual dysfunction [23].

In addition to measuring the effectiveness of rectal spacing under real-world conditions, county-level analysis enables the evaluation of pooled changes in health outcomes over time, reducing sensitivity to individual health variations. Observing changes and trends using Medicare claims at the county level offers greater reproducibility and minimizes the influence of factors such as migration, provider-specific practices, and variations in provider expertise or volume. Additionally, county-level evaluations facilitate the quantification of rare, long-term changes, such as the incidence of late complications from prostate radiation. This study leverages large-scale administrative data, specifically Medicare claims, to explore the real-world uptake of rectal spacers and their association with diagnosis prevalence of bowel, urinary, and sexual dysfunction as well as prevalence of related procedures among PCa patients undergoing RT over time at county level.

Materials and methods

Data and analytical sample

This study used aggregated county-level data from the Medicare 5% and 100% Standard Analytic Files (SAFs) to examine the association between rectal spacer use among PCa patients receiving RT and the average annual prevalence of bowel, urinary, and sexual dysfunction and related procedures [24]. The Medicare 5% SAFs contain demographic and enrollment information, as well as billing claims from all health encounters regardless of the location of service among the representative 5% sample of all Medicare patients. The Medicare 100% SAFs include information for all Medicare patients but are limited to claims from hospital settings. Data from both datasets were combined for this analysis, excluding patients in the 5% Medicare who received prostate cancer diagnosis at hospital to avoid double counting with Medicare 100% dataset.

County-level characteristics of the general population data were obtained from the 2020 Agency for Healthcare Research and Quality Social Determinants of Health (SDOH) Database [25]. These factors were included as potential confounders that could influence both the outcome (prevalence of bowel, urinary, and sexual dysfunction and related procedures) and explanatory variables (rectal spacer use).

The study population included adult males aged≥65 years diagnosed with PCa cancer between January 1, 2015 and March 31, 2024 (First quarter; Q1) who underwent RT after diagnosis. RT modalities included stereotactic body radiation therapy (SBRT), intensity-modulated radiation therapy (IMRT), proton beam radiation therapy (PBT), brachytherapy (BT), and 3D conformal radiation therapy (3DCRT). Patients who received combinations of the above modalities were also included. Individuals were required to have continuous Medicare enrollment for 1 year prior to RT (baseline period).

Rectal spacer use during RT was identified using Current Procedural Terminology (CPT®) codes 0438T and 55,874. CPT code 0438T was used prior to 2018, after which it was replaced by CPT code 55,874. Most patients were administered SpaceOAR™ Hydrogel system (Boston Scientific) rectal spacers at the time of their RT treatment. SpaceOAR was approved by the FDA in 2015 and available for clinical use in the United States several years before other products, e.g., Barrigel® Rectal Spacing (Teleflex Incorporated) and BioProtect Balloon Implant™ System (BioProtect), which were cleared in 2022 and 2023, respectively. Given the period of analysis (2015-2024Q1), only events involving administration of SpaceOAR generated sufficient data to track outcomes beyond 2 years.

Outcomes and measures

The primary outcome was the percentage of patients with diagnosis bowel, urinary, and sexual dysfunction among PCa patients with RT each year during the study period, measured at the county level. Similarly, the percentage of patients undergoing procedures related to bowel, urinary, and sexual dysfunction was also examined. Each dysfunction and procedure were identified using diagnosis or procedure codes based on Pan et al. [26]. In that study, International Classification of Diseases, 9th Edition, Clinical Modification (ICD-9-CM) diagnosis codes were used to identify dysfunction. The current study uses the same codes for diagnosis after converting the ICD-9-CM codes to ICD-10-CM codes using conversion tables provided by the Centers for Medicare & Medicaid Services. Due to the use

of Medicare 100% claims data, dysfunction-related events may be underestimated, particularly if such care was delivered in non-hospital settings not represented in the dataset. Moreover, the complications captured in our study are limited to those that necessitated medical intervention or were formally documented by healthcare providers. As such, our findings may be less sensitive than toxicity data obtained through clinical trials or patient-reported outcomes. Nonetheless, the complication rates we report appear to align with those observed in other analyses based on claims data.

The primary explanatory variable was the percentage of rectal spacer use among PCa patients receiving RT at the county level in the previous 1–5 years (years t-5 to t-1) before dysfunction diagnosis (year = t).

Statistical analysis

Zero-inflated Poisson (ZIP) regression models were used to assess the association between rectal spacer use and diagnosis of bowel, urinary, and sexual dysfunction and related procedures at the county level. The models controlled for potential confounding variables among patients at the county-level (median age, percentage White patients, and RT modalities) and in the general population (median age, % White, and median household income) that might influence treatment decisions, outcomes, and interpretations of QOL after RT. To account for population differences across counties, the total number of prostate cancer (PCa) patients undergoing RT in each county was included as an inflation factor in the ZIP regression model. State-level fixed effects were employed to account for regional variation. Two sensitivity analyses were conducted (Online Appendix 1).

Results

The study sample included 318,911 PCa patients residing in 3168 US counties and equivalents treated with RT, with or without rectal spacers, between 2015 and 2024 Q1. Overall, 19.7% of counties did not have any RT patients in a year. Among counties that had at least one patient undergoing RT in a year, the median number of RT in a country in a year was 5 (IQR 2–11) (table not shown). Patient demographic characteristics at the county level are presented in Online Appendix Table 1. A small proportion of patients had diagnoses of bowel dysfunction (3.2%) and sexual dysfunction (3.6%) during the baseline period of 1 year prior to RT while 24.7% of patients had urinary dysfunction at baseline. Only a small proportion of patients with the baseline diagnosis had undergone procedures: 0.1% for bowel and sexual, 3.7% for urinary.

Online Appendix Table 2 presents county-level summary statistics for main outcome and explanatory variables. The average annual prevalence of each diagnosis at the county level was 2.0% for bowel dysfunction, 5.6% for urinary dysfunction, and 1.1% for sexual dysfunction. The average annual prevalence of procedures related to each diagnosis at the county level was 0.3% for bowel dysfunction, 1.1% for urinary dysfunction, and 0.1% for sexual dysfunction. The percentage of patients using rectal spacers increased at the county level over time from 4.4% (5 years prior to diagnosis) to 18.1% (1 year prior) and 19.8% (in the same year).

Table 1 and Fig. 1 display regression results examining the association between rectal spacer uptake in prior years and the average annual prevalence of diagnosis on bowel, urinary, or sexual dysfunction. After adjusting for confounders, counties with higher rectal spacer use 1–5 years prior had significantly lower diagnosis prevalence of bowel, urinary, or sexual dysfunction: a 100-percentage points increase in spacer use at the county was associated with 7.1–55.1% reduction in the prevalence of dysfunction diagnosis at 1–5 years prior, with gradual increase in the effect size over time (incidence rate ratio (IRR) at 1 year: 0.929, 95% confidence interval (CI) [0.869, 0.994]; IRR at 3 years: 0.808, 95% CI [0.741, 0.882]; IRR at 5 years: 0.449, 95% CI [0.377, 0.535]) (Fig. 1; Table 1; Panel A). A 55.1% reduction associated with a 100-percentage point increase in spacer use translates to a 6.7% reduction for a 10-percentage point increase.

Similar but weaker results were observed for the prevalence of procedures related to bowel, urinary, or sexual dysfunction: a 100-percentage point increase in spacer use at the county was associated with 32.3–42.6% reduction in the prevalence of procedures related to bowel, urinary, or sexual dysfunction at 4 and 5 years prior (IRR at 4 year: 0.677, 95% CI [0.539, 0.850]; IRR at 5 years: 0.574, 95% CI [0.397, 0.830]) (Fig. 1; Table 1; Panel B). For procedures, effects of higher rectal spacer use at 2- and 3-year prior were not significant, but a decrease in procedures also was observed (IRR at 2 years: 0.858, 95% CI [0.718, 1.025]; IRR at 3 years: 0.989, 95% CI [0.822, 1.190]).

Regression results for each diagnosis: bowel, urinary, and sexual dysfunction were presented in the form of the forest plot in Online Appendix Fig. 1 Panel A. Counties with higher rectal spacer use 1–5 years prior had significantly lower diagnosis prevalence of bowel dysfunction (IRR at 1 year: 0.799, 95% CI [0.701, 0.910]; IRR at 5 years: 0.407, 95% CI [0.302, 0.549]). Higher rectal spacer use 2–5 years prior had lower diagnosis prevalence of urinary dysfunction (IRR at 2 years: 0.871, 95% CI [0.797, 0.952]; IRR at 5 years: 0.418, 95% CI [0.343, 0.509]). And counties with higher rectal spacer use 3–5 years prior had lower diagnosis prevalence of sexual dysfunction (IRR at 3 years:

Table 1 Association between percentage rectal spacer use in the past and % diagnosis and related procedures around bowel, urinary, or sexual dysfunction at present

Panel A: Diagnosis					
% bowel, urinary, or sexual dysfunction diagnosis at year = t (IRR)					
	(1)	(2)	(3)	(4)	(5)
%Spacer adoption					
At year = t-1	0.929** [0.869,0.994]				
At year = t-2		0.855*** [0.795,0.920]			
At year = t-3			0.808*** [0.741,0.882]		
At year = t-4				0.672*** [0.597,0.757]	
At year = t-5					0.449*** [0.377,0.535]
N	11,342	11,294	11,263	11,202	11,062
Panel B: Procedure					
% procedures related to bowel, urinary, or sexual dysfunction at year = t (IRR)					
	(1)	(2)	(3)	(4)	(5)
%Spacer adoption					
At year = t-1	0.846** [0.724, 0.989]				
At year = t-2		0.858 [0.718, 1.025]			
At year = t-3			0.989 [0.822, 1.190]		
At year = t-4				0.677*** [0.539, 0.850]	
At year = t-5					0.574*** [0.397, 0.830]
N	11,342	11,294	11,263	11,202	11,062

The table shows IRR [with 95% confidence interval] based on zero-inflated Poisson regression with controls: patient characteristics at the county-level (median age, percentage white patients, percentage RT type) and characteristics of the general population (median age, % white, and median household income). "At year = t" in the outcome variable means that the outcome was measured at the present year. "At year = t-1" in the independent variable means that the spacer use rate was captured 1 year prior to the observation of the outcome; "at year = t-2" means 2 years prior etc

IRR incidence rate ratio, *RT* radiotherapy

**Statistically significant at < 0.05; ***statistically significant at < 0.01

0.813, 95% CI [0.671, 0.985]; IRR at 5 years: 0.598, 95% CI [0.392, 0.913]). Effect sizes for all dysfunction diagnoses increased as the year lag grew longer.

Online Appendix Fig. 1, Panel B presents the forest plot based on regression results for procedures related to each dysfunction diagnosis, separately. Results were consistent with diagnosis prevalence for each dysfunction, but statistically less significant: Higher rectal spacer use 4 and 5 years prior had lower procedure prevalence related to bowel (IRR at 4 year: 0.552, 95% CI [0.359, 0.848]; IRR at 5 years: 0.371, 95% CI [0.189, 0.731]) and urinary dysfunction (IRR at 4 year: 0.704, 95% CI [0.541, 0.916]; IRR at 5 years: 0.577, 95% CI [0.372, 0.897]). The association between rectal spacer use and procedures related to sexual dysfunction was insignificant, regardless of the year lag.

Discussion

This is the first study to use real-world, county-level data to evaluate the association between historical rates of rectal spacer use (up to 5 years prior) and current county-level prevalence of bowel, urinary, and sexual dysfunction among PCa patients undergoing RT. It complements findings from clinical trials and secondary studies that reported reduced bowel and urinary toxicities and maintained bowel, urinary, and sexual QOL measures among patients with rectal spacers

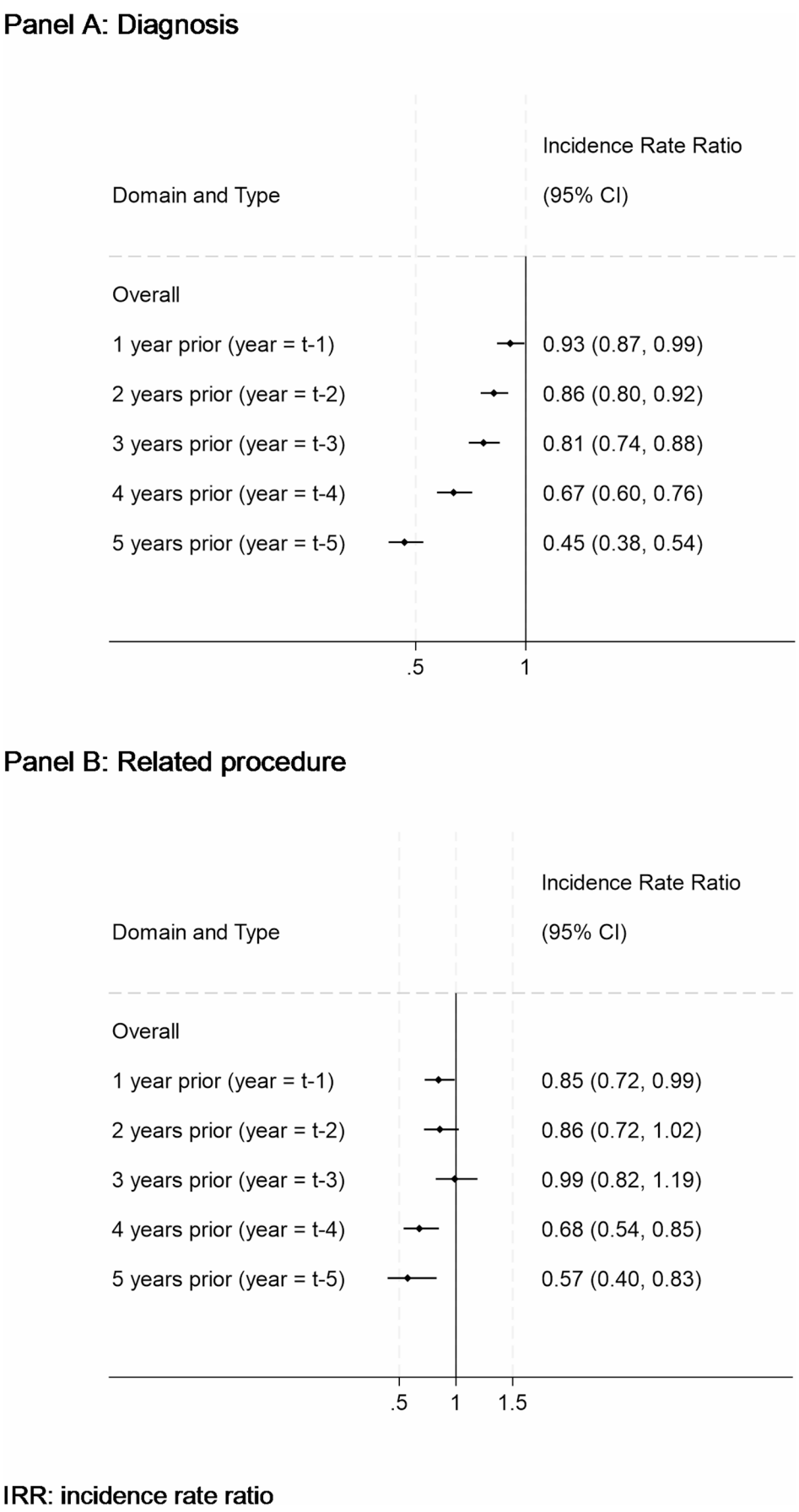

Fig. 1 Effect size (IRR) on % any diagnoses and related procedures (bowel, urinary, or sexual dysfunction) per 100% points increase in % rectal spacer

post-treatment. This county-level result shows increasing effect sizes over time, supporting a previously established timeline of improvements in bowel and urinary function. Overall, this study contributes to emerging evidence indicating that higher rectal spacer use at the population level may be associated with lower rates of treatment-related dysfunction.

Hamstra et al. [19] conducted a trial following 222 men randomized in a 2:1 ratio, observing significantly lower rates of rectal toxicity in the spacer group, along with detectable improvements in bowel EPIC QOL measures from 6 to 37 months follow-up. Seymour et al. [22] evaluated 380 men (64% with a spacer, 36% without) and found that the spacer group experienced less decline in average long-term bowel QOL compared to the control group, with significant differences in bowel scores at final follow-up of ≥24 months. Hamstra et al. [19] also observed a significant reduction in Grade≥1 urinary incontinence at 37 months in men with spacer and reported urinary QOL scores favoring the spacer cohort. Finally, Seymour et al. [21] examined 128 potent men with good baseline sexual function and found that the control group was significantly more likely to experience declines in sexual function.

To further expand upon these clinical studies, the present study found that counties with higher rectal spacer use 1–5 years prior were associated with significantly lower county-level prevalence of bowel, urinary, and sexual dysfunction, such that a 100-percentage point increase in rectal spacer use at the county level was associated with 7.1–55.1% lower prevalence of any of three dysfunctions after 1–5 years (all $p<0.05$). Furthermore, the analysis revealed that the timeline of observed associations between rectal spacer use and dysfunction prevalence varied by dysfunction type. Statistically significant associations ($p<0.05$) were observed at 1–5 years for bowel dysfunction, 2–5 years for urinary dysfunction, and 3–5 years for sexual dysfunction. These results highlight a population-level long-term association between rectal spacer use and lower prevalence of long-term bowel, urinary, and sexual dysfunction in real-world radiotherapy settings.

Furthermore, the association between the spacer use and the lower prevalence of diagnosis of bowel, urinary, and sexual dysfunction diagnoses found in the study is likely a conservative estimate. If the frequency of spacer placement in counties reflects well-served medical areas, one might expect these places to have higher medical utilization and, consequently, increased reports of side effects. Thus, the true association between higher spacer use and lower prevalence of diagnoses of bowel, urinary, and sexual dysfunction could be even stronger, as the correlation runs counter to expected bias.

Regarding the treatment landscape, rectal spacer uptake increased significantly among PCa patients over the study period: the percentage uptake of spacers increased from 4.4% 5 years prior to 19.8% at the present time. These shifts underscore the growing adoption of rectal spacers as a standard component of prostate cancer treatment [27].

The strengths of this analysis include the use of large national datasets comprising over 300,000 PCa patients who underwent RT. Unlike previous studies, which primarily relied on controlled clinical trial data, this study leverages real-world data. This approach enables a more comprehensive understanding of patient outcomes following RT in a broader population. In addition, the use of county-level claims data rather than individual level claims data reduces sensitivity to individual health variations and facilitates the quantification of long-term changes of rare events such as ones investigated in this study, strengthening overall findings. Furthermore, this study identified a gradual strengthening of the inverse relationship between spacer use and diagnosis prevalence as the time lag increased. This finding was made possible by the county-level approach of the analysis, which allowed for a broader and more nuanced evaluation over time.

Nevertheless, this study is subject to several limitations. The use of Medicare 100% data has contributed to the low observed prevalence of dysfunction, as patients could not be followed if they received diagnosis or procedures related to dysfunction at setting outside of hospital. Furthermore, the notably low prevalence of sexual dysfunction may be further attributable to the lack of data on pharmaceutical interventions in the Medicare dataset. Given the widespread availability of erectile dysfunction medications, it is plausible that many cases remain undiagnosed or unreported. As a population-based study, it does not provide information about individual-level relations between variables. The observational nature of claims data establishes associations but does not allow for causal interpretations. The reliance on Medicare claims data excludes patients under the age of 65, which may affect generalizability of the study findings [28]. While potential explanations for the observed lag between rectal spacer use and reduced dysfunction prevalence may relate to the differing biological and clinical trajectories of bowel, urinary, and sexual toxicities following radiotherapy, the study does not address why a lag period exists, especially between spacer use and a decline in prevalence of sexual dysfunction, warranting further research to clarify these temporal patterns. Finally, the current data dominantly permitted evaluation of only a single spacer type (SpaceOAR); however, future studies using more recent data would be valuable in distinguishing the effects of different spacer types.

Despite these limitations, this study demonstrates a statistically significant, population-level association between higher rectal spacer use and lower county-level prevalence of bowel, urinary, and sexual dysfunction-related diagnoses and procedures, with associations observed with 1–5 year time lag and appearing to strengthen over time. These population-level results align with prior clinical studies that have reported associations between rectal spacer use and lower incidence of bowel and urinary toxicities, as well as better maintenance of sexual function in PCa patients following RT.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s00345-025-05802-2.

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Author contributions R.S. conceived, designed and conducted the analysis. J.Y., M.F., S.C., R.H., P.M., D.H. supervised and validated the analysis. R.S., S.B., and E.E. contributed to the project management. R.S. drafted the manuscript and all authors reviewed and approved the manuscript.

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Data availability The data used in this analysis are not available for sharing as they were collected under a strict data sharing agreement with a third party.

Declarations

Conflict of interest Ryoko Sato, Samir Bhattacharyya, and Emmanuel Ezekekwu are employees of Boston Scientific. James Yu reports consulting fees from Boston Scientific, Teleflex, and AlphaSights, research support from Pfizer/Myovant/Sumitomo Pharma, and is a stockholder of Modifi Bio. Michael Folkert has received travel reimbursement from Varian and Boston Scientific, and his affiliated institutions have received funding for clinical trials from Boston Scientific. Ryan Hankins is a clinical consultant for Boston Scientific. Sean Collins is a consultant for Boston Scientific. Daniel Hamstra is a paid consultant for Boston Scientific.

Ethics approval and consent to participate The study was exempt from Institutional Review Board (IRB) approval as this research project used data from an anonymous, de-identified, medical clearinghouse administrative claims database compliant with the Health Insurance Portability and Accountability Act of 1996.

References

1. Harvey M, Ong WL, Chao M, Udovicich C, McBride S, Bolton D et al (2023) Comprehensive review of the use of hydrogel spacers prior to radiation therapy for prostate cancer. BJU Int 131(3):280–287
2. Donovan JL, Hamdy FC, Lane JA, Young GJ, Metcalfe C, Walsh EI et al (2023) Patient-reported outcomes 12 years after localized prostate cancer treatment. NEJM Evid 2(4):EVIDoa2300018. https://doi.org/10.1056/EVIDoa2300018
3. Nguyen D-D, Berlin A, Matthew AG, Perlis N, Elterman DS (2021) Sexual function and rehabilitation after radiation therapy for prostate cancer: a review. Int J Impot Res 33(4):410–417. https://doi.org/10.1038/s41443-020-00389-1
4. Sanda MG, Dunn RL, Michalski J, Sandler HM, Northouse L, Hembroff L et al (2008) Quality of life and satisfaction with outcome among prostate-cancer survivors. N Engl J Med 358(12):1250–1261. https://doi.org/10.1056/NEJMoa074311
5. Gami B, Harrington K, Blake P (2003) How patients manage gastrointestinal symptoms after pelvic radiotherapy: gastronomical symptoms after pelvic radiotherapy. Aliment Pharmacol Ther 18(10):987–994. https://doi.org/10.1046/j.1365-2036.2003.01760.x
6. Krol R, Smeenk RJ, van Lin ENJT, Hopman WPM (2013) Impact of late anorectal dysfunction on quality of life after pelvic radiotherapy. Int J Colorectal Dis 28(4):519–526. https://doi.org/10.1007/s00384-012-1593-5
7. Biran A, Bolnykh I, Rimmer B, Cunliffe A, Durrant L, Hancock J et al (2023) A systematic review of population-based studies of chronic bowel symptoms in cancer survivors following pelvic radiotherapy. Cancers (Basel) 15(16). https://doi.org/10.3390/cancers15164037
8. Liberman D, Mehus B, Elliott SP (2014) Urinary adverse effects of pelvic radiotherapy. Transl Androl Urol 3(2):186–195. https://doi.org/10.3978/j.issn.2223-4683.2014.04.01
9. Zietman AL, Desilvio ML, Slater JD (2005) Comparison of conventional-dose vs high-dose conformal radiation therapy in clinically localized adenocarcinoma of the prostate: a randomized controlled trial. JAMA 294(10):1233–1239. https://doi.org/10.1001/jama.294.10.1233
10. Zelefsky MJ, Wallner KE, Ling CC, Raben A, Hollister T, Wolfe T et al (1999) Comparison of the 5-year outcome and morbidity of three-dimensional conformal radiotherapy versus transperineal permanent iodine-125 implantation for early-stage prostatic cancer. J Clin Oncol 17(2):517–522. https://doi.org/10.1200/JCO.1999.17.2.517
11. Zelefsky MJ, Cowen D, Fuks Z, Shike M, Burman C, Jackson A et al (1999) Long term tolerance of high dose three-dimensional conformal radiotherapy in patients with localized prostate carcinoma. Cancer 85(11):2460–2468. 10.1002/(sici)1097-0142(19990601)85:11<2460::aid-cncr23>3.0.co;2-n
12. Lawton CA, Won M, Pilepich MV, Asbell SO, Shipley WU, Hanks GE et al (1991) Long-term treatment sequelae following external beam irradiation for adenocarcinoma of the prostate: analysis of RTOG studies 7506 and 7706. Int J Radiat Oncol Biol

Phys 21(4):935–939. https://doi.org/10.1016/0360-3016(91)90732-j
13. Vaggers S, Rai BP, Chedgy ECP, de la Taille A, Somani BK (2021) Polyethylene glycol-based hydrogel rectal spacers for prostate brachytherapy: a systematic review with a focus on technique. World J Urol 39(6):1769–1780. https://doi.org/10.1007/s00345-020-03414-6
14. Mariados NF, Orio PF, Schiffman Z, Van TJ, Engelman A, Nurani R et al (2023) Hyaluronic acid spacer for hypofractionated prostate radiation therapy: a randomized clinical trial. JAMA Oncol 9(4):511–518. https://doi.org/10.1001/jamaoncol.2022.7592
15. Song D, Dabkowski M, Costa P, Nurani R, Kos M, Vanneste B et al (2024) Prospective, randomized controlled pivotal trial of biodegradable balloon rectal spacer for prostate radiation therapy. Int J Radiat Oncol Biol Phys 120(5):1410–1420. https://doi.org/10.1016/j.ijrobp.2024.07.2145
16. Karsh LI, Gross ET, Pieczonka CM, Aliotta PJ, Skomra CJ, Ponsky LE et al (2018) Absorbable hydrogel spacer use in prostate radiotherapy: a comprehensive review of phase 3 clinical trial published data. Urology 115:39–44. https://doi.org/10.1016/j.urology.2017.11.016
17. Miller LE, Efstathiou JA, Bhattacharyya SK, Payne HA, Woodward E, Pinkawa M (2020) Association of the placement of a perirectal hydrogel spacer with the clinical outcomes of men receiving radiotherapy for prostate cancer: a systematic review and meta-analysis. JAMA Netw Open 3(6). https://doi.org/10.1001/jamanetworkopen.2020.8221
18. Pinkawa M, Berneking V, Schlenter M, Krenkel B, Eble MJ (2017) Quality of life after radiation therapy for prostate cancer with a hydrogel spacer: 5-year results. Int J Radiat Oncol Biol Phys 99(2):374–377. https://doi.org/10.1016/j.ijrobp.2017.05.035
19. Hamstra DA, Mariados N, Sylvester J, Shah D, Karsh L, Hudes R et al (2017) Continued benefit to rectal separation for prostate radiation therapy: final results of a phase III trial. Int J Radiat Oncol Biol Phys 97(5):976–985. https://doi.org/10.1016/j.ijrobp.2016.12.024
20. Hamstra DA, Mariados N, Sylvester J, Shah D, Gross E, Hudes R et al (2018) Sexual quality of life following prostate intensity modulated radiation therapy (IMRT) with a rectal/prostate spacer: secondary analysis of a phase 3 trial. Pract Radiat Oncol 8(1):e7–15. https://doi.org/10.1016/j.prro.2017.07.008
21. Seymour ZA, Pinkawa M, Daignault-Newton S, Bosch W, Michalski JM, Gay H et al (2023) A pooled long-term follow-up after radiotherapy for prostate cancer with and without a rectal hydrogel spacer: impact of hydrogel on decline in sexual quality of life. Front Oncol 13:1239104. https://doi.org/10.3389/fonc.2023.1239104
22. Seymour ZA, Hamstra DA, Daignault-Newton S, Bosch W, Michalski J, Gay HA et al (2020) Long-term follow-up after radiotherapy for prostate cancer with and without rectal hydrogel spacer: a pooled prospective evaluation of bowel-associated quality of life: rectal spacer and bowel-associated QOL after RT. BJU Int 126(3):367–372. https://doi.org/10.1111/bju.15097
23. Porzsolt F, Rocha NG, Toledo-Arruda AC, Thomaz TG, Moraes C, Bessa-Guerra TR et al (2015) Efficacy and effectiveness trials have different goals, use different tools, and generate different messages. Pragmat Obs Res 6:47–54. https://doi.org/10.2147/POR.S89946
24. Standard Analytical Files (Medicare Claims) - LDS| CMS. www.cms.gov. (Updated 2024). https://www.cms.gov/data-research/files-for-order/limited-data-set-lds-files/standard-analytical-files-medicare-claims-lds. Accessed 31 Oct 2024
25. Social Determinants of Health (SDOH)| Agency for Healthcare Research and Quality. www.ahrq.gov.2023. (Updated 2024). https://www.ahrq.gov/sdoh/index.html. Accessed Oct 2024
26. Pan HY, Jiang J, Hoffman KE, Tang C, Choi SL, Nguyen QN et al (2018) Comparative toxicities and cost of intensity-modulated radiotherapy, proton radiation, and stereotactic body radiotherapy among younger men with prostate cancer. J Clin Oncol 36(18):1823–1830. https://doi.org/10.1200/jco.2017.75.5371
27. Hamstra DA (2023) Available Rectal Spacer Options for Patients with Prostate Cancer Undergoing Radiation Therapy. Urology Times. http://www.urologytimes.com/view/available-rectal-spacer-options-for-patients-with-prostate-cancer-undergoing-radiation-therapy. Accessed 24 Oct
28. American Cancer Society (2024) Key statistics for prostate Cancer| prostate Cancer facts. Www.cancer.org. Am Cancer Soc. https://www.cancer.org/cancer/types/prostate-cancer/about/key-statistics.html