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Examining the Association between Abstinence from Smoking and Healthcare Costs Among Patients with Cancer

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Abstract

Continuous tobacco use in cancer patients is linked to substantial healthcare costs due to increased risks and complications, whereas quitting smoking leads to improved treatment outcomes and cost reductions. Addressing the need for empirical evidence on the economic impact of smoking cessation, this study examined the association between smoking cessation and healthcare cost utilization among a sample of 930 cancer patients treated at The University of Texas MD Anderson Cancer Center's Tobacco Research and Treatment Program (TRTP). Applying conditional quantile regression and propensity scores to address confounding, our findings revealed that abstinence achieved through the TRTP significantly reduced the median cost during a 3-month period post-quitting by $1,095 (β=−$1,095, p=0.007, 95%CI=[−$1,886, −$304]). Sensitivity analysis corroborated these conclusions, showing a pronounced cost reduction when outlier data were excluded. The long-term accrued cost savings from smoking cessation could potentially offset the cost of participation in the TRTP program, underscoring its cost-effectiveness. An important implication of this study is that by reducing smoking rates, healthcare systems can more efficiently allocate resources, enhance patient health outcomes, and lessen the overall cancer burden.

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Introduction

Smoking in patients with cancer is associated with substantial healthcare costs because continuous tobacco use among these patients can increase the risk of complications, reduce treatment efficacy, and increase mortality [1]. Research has found that smoking can increase the risk of surgical site infections [2,3], slow wound healing [2,4–6], elevate the risk of bleeding during surgery [7], and exacerbate side effects from chemotherapy, radiation therapy, and other treatments, making them less effective [8–10]. By contrast, cancer patients who quit smoking tend to have improved treatment outcomes, including higher survival rates by 30–40% [11] and reduced risk of cancer recurrence [12–14]. Moreover, quitting smoking significantly lowers the risk of developing secondary cancers [15,16], which reduces costs related to their subsequent treatment and care.

In addition to the direct impact on cancer treatment and recovery, quitting smoking can also alleviate symptoms related to cancer or cancer treatment, such as shortness of breath, fatigue, and coughing [17–19]. These symptoms may require additional supportive care services, like medications, respiratory therapies, or palliative care, adding further to the cost of care [20,21]. By quitting smoking, patients with cancer can improve these symptoms and decrease their need for supportive care, resulting in reduced overall cost of care [22]. When the effectiveness of treatments like chemotherapy, radiation therapy, and surgery is enhanced, patients may require fewer interventions, shorter hospital stays, and less frequent follow-up care, leading to cost savings [23,24]. Quitting smoking can also have a positive effect by reducing the risk of smoking-related comorbidities, such as heart disease, stroke, and lung diseases like chronic obstructive pulmonary disease (COPD) [25–27], that further increase medical expenses and hospitalizations, and decrease quality of life. By quitting smoking, cancer patients can reduce their risk of developing these comorbidities and the costs associated with their treatment [28–30].

The National Cancer Institute (NCI) introduced a grant program to encourage the creation of tobacco treatment programs within multiple comprehensive cancer centers [31], which was part of the White House overall cancer moonshot initiative to reduce the impact of cancer morbidity, mortality, and cost of care. Sustaining these programs in the long-term requires convincing payors and patients of the economic value of smoking cessation on cancer care cost, in addition to the effectiveness of the programs on promoting smoking cessation. While conceptually appealing, there is a lack of critically evaluated empirical evidence using real-world data from established smoking cessation programs in a comprehensive cancer center.

To address this gap, we conducted a study to evaluate the relationship between smoking abstinence (vs. continued smoking) and healthcare costs in patients with cancer who were treated through The University of Texas MD Anderson (MDA) Cancer Center’s Tobacco Research and Treatment Program (TRTP). The treatment protocol of TRTP involves both guideline-concordant smoking cessation individual counseling [13] and pharmacotherapy [32]. Details of the treatment protocol and the program’s treatment efficacy have been published previously [33].

Materials and Methods

Methods for Measuring Impact

The study cohort included patients who had 3 or more treatment-related MDA billing records (Supplementary Table S1) on different dates within each quarter. The requirement of multiple billing records ensured that costs captured from these records during the study period reflected the majority of patients' healthcare utilization. After reviewing the number of patients who met the above inclusion criterion (Supplementary Table S2) by study durations, we determined that the analysis should focus on the first 6 months (i.e., Q1 and Q2) after joining the TRTP program to maximize the sample size available to compare costs between patients in the abstinent and non-abstinent group. Information on abstinence status was based on the first follow-up assessment in month 3 after joining the TRTP. The sample consisted of patients with cancer referred to the MD Anderson Cancer Center TRTP between January 1, 2006, and August 31, 2015. Smoking status was determined based on the self-reported 7-day point prevalence, which was collected prospectively using a timeline follow-back method[34] at all in-person visits and all phone follow-up contact and entered in real-time into the TRTP database. Here, we report abstinence at 3 months, defined as self-report of no smoking (not even a puff) during the previous 7 days. Given the clinical nature of our program, the varying health status of the patients, the time course of their cancer therapy, and the fact that only 5% of the sessions were conducted in person, requiring patients to return or otherwise provide biochemical assessment of abstinence was not feasible. However, we obtained expired carbon monoxide levels at all in-person visits. Congruence between self-reported, 7-day point prevalence abstinence and expired carbon monoxide was 93% for less than 8 ppm and 87% for carbon monoxide level of less than 6 ppm.

Cost Estimates

Cost data was derived from MDA billing records from 3 months prior (Q0) to the TRTP first consultation date and through 24 months after (Q1-Q8). First, we extracted charges from institutional billing records. We then converted these charges to costs using Medicare reimbursement rates. These rates corresponded to each Current Procedural Terminology (CPT)/Healthcare Common Procedure Coding System (HCPCS) code obtained from MDA's records of professional and technical charges. We obtained Medicare Fee-for-Service payment for each code from a number of files on the Centers for Medicare and Medicaid Services (CMS) website [35], including Physician Fee Schedule, Hospital Outpatient Prospective Payment System, Anesthesia Base Units file, Average Sales Price file for Medicare Part B Drugs (with 6% mark-up), Clinical Laboratory Fee Schedule, Durable Medical Equipment, Prosthetics/Orthotics, and Supplies Fee Schedule for lab test, equipment and supplies (Supplementary Table S1) [35], including Physician Fee Schedule, Hospital Outpatient Prospective Payment System, Anesthesia Base Units file, Average Sales Price file for Medicare Part B Drugs (with 6% mark-up), Clinical Laboratory Fee Schedule, Durable Medical Equipment, Prosthetics/Orthotics, and Supplies Fee Schedule for lab test, equipment and supplies (Supplementary Table S1). We obtained Medicare Fee-for-Service payment for each code from a number of files on the Centers for Medicare and Medicaid Services (CMS) website [35], including Physician Fee Schedule, Hospital

Outpatient Prospective Payment System, Anesthesia Base Units file, Average Sales Price file for Medicare Part B Drugs (with 6% mark-up), Clinical Laboratory Fee Schedule, Durable Medical Equipment, Prosthetics/Orthotics, and Supplies Fee Schedule for lab test, equipment and supplies (Supplementary Table S1) [35], including Physician Fee Schedule, Hospital Outpatient Prospective Payment System, Anesthesia Base Units file, Average Sales Price file for Medicare Part B Drugs (with 6% mark-up), Clinical Laboratory Fee Schedule, Durable Medical Equipment, Prosthetics/Orthotics, and Supplies Fee Schedule for lab test, equipment and supplies (Supplementary Table S1). All costs were based on the 2018 Medicare fee schedule. The use of Medicare reimbursement rates allows costs estimated from this study to be generalizable to other institutions. It's important to recognize that our dataset from MDA billing only offers a partial snapshot of the costs within the institution, excluding treatments, medications, or services patients may access outside of MDA. This data might particularly underestimate second-line treatments and oral medications, as these can often be prescribed and dispensed outside the hospital, leading to potential underestimations in our cost analysis.

Statistical Analysis

Our initial approach involved bivariate analyses to examine associations between abstinence (main predictor) and the baseline measures of demographics, smoking behavior, and other cancer related variables. Since all the baseline variables were categorical or categorized (e.g., age) variables, χ^2 tests were performed to evaluate differences associated with abstinence.

Considering that the outcome models (i.e., cost) involved a predictor (i.e., abstinence) that was not a randomly assigned, the estimated effects associated with this model could be biased due to covariate imbalances between the abstinence and non-abstinence groups. To reduce this potential bias, we estimated propensity scores (PS) for the abstinence status using a logistic regression PS model with all baseline characteristics, except the total cost at Q1, included because of their potential associations with the probability of abstinence. Inverse probability of treatment weights (IPTW) based on PS were calculated and applied (1) for checking covariate balance for all the baseline covariates and (2) for fitting the outcome regression model on cost for approximately unbiased estimation of the abstinence effect[36].

Since the outcome variable—the total cost at Q2—is highly skewed, we used nonparametric quantile regression (QR) models[37] to estimate the effects of abstinence status, instead of least-square-based linear models in order to be more robust against observations at heavy tail distributions. Moreover, QR models can identify the potentially differential effects of abstinence at different quantiles of the distribution of cost data for richer interpretation. We used 3 specific percentiles for QR: 25^{th}, 50^{th} (median), and 75^{th}. Beyond applying IPTW, all the covariates used for the PS model as well as the total cost at Q1 were also included as covariates in the outcome models to be doubly-robust by correcting for any residual bias due to the covariates after weighting. All the statistical analyses were performed with STATA 16.0 (StataCorp, College Station, TX) and R 4.1.1[38].

The presence of outliers can significantly modify the estimation of cost differences at different percentile values [39,40]. The identification of outliers was performed using the non-parametric approach by means of Tukey's method [41] applied to the original data. Tukey's method involves the computation of the 25th (1st Quartile) and 75th (3rd Quartile) percentiles and the interquartile range (IQR = 3rd Quartile − 1st Quartile); the exclusion limit corresponds to the sum of the 3rd Quartile and 3 or 1.5 times of IQR, according to the following formula: 3rd Quartile + 3IQR or 3rd Quartile + 1.5IQR.

Data Availability—The data that support the findings of this study are available from the corresponding authors, upon reasonable request.

Results

Compared with the entire study cohort (2,659 patients), the final analytical sample (930 patients, Figure 1) was younger and had more patients with regional and distant cancer (Supplementary Table S3).

Table 1 shows the patients' baseline characteristics by abstinence status - non-abstinent (n=502) and abstinent (n=428). Compared to patients in the non-abstinent group, a significantly higher proportion of patients in the abstinent group were male and had local or regional cancer stage. Gender, stage, and cancer site were significantly associated with abstinence, indicating that the non-abstinent and the abstinent groups were imbalanced in those characteristics. Further, Table 2 presents measures of central tendency and variability for total costs at Q1 (quarter 1) and Q2 (quarter 2) by abstinence status. The distributions of cost by abstinence status for Q1 and Q2 are presented in Figure 2.

The estimated propensity scores (PS) provided acceptable balance between the abstinence groups in PS and all the baseline characteristics used in the PS model. Standardized mean difference (SD) after applying IPTW was lower than the conservative threshold of 0.1 [42] for all the baseline covariates (See Supplementary Table S4 and Figure S1).

Table 3 presents the results of the outcome model for total cost at Q2. Specifically, the 1st doubly-robust quantile regression (QR) model shows that abstinence significantly lowered the 25th percentile total cost at Q2 by $354 (β=−$354, p=0.027, 95% CI=[−$666, −$41], as well as the 50th percentile total cost at Q2 by $1,095 (β=−$1,095, p=0.007, 95%CI=[−$1,886, −$304]), as compared to non-abstinence while controlling for other covariates (see also Figure 2). However, there was no significant effect of abstinence on the 75th percentile total cost at Q2.

Sensitivity analysis

Removing outliers and repeating the quantile regressions (Table 3) yielded larger effects for the 50th percentile (β=−$1,360, $p < 0.001$, 95% CI=[−$1,953 , −$688]), and the 75th (β=−$1422, $p < 0.058$, 95%CI=[−$2,892, −$46]), although the 75th percentile effect remained statistically non-significant (p=.058). Nevertheless, removing the outliers resulted in a substantial improvement in the cost savings associated with abstinence, trending in the expected direction.

Figure 3 illustrates the variability of the impact of abstinence on quantiles for the total analytic sample and for the analysis conducted after excluding outliers. In the overall patient evaluation, the influence of abstinence on cost demonstrates statistical significance within all quantiles ranging approximately from the 35th to the 60th quantile, maintaining a negative trend throughout. Upon the removal of outliers, the abstinence effect is characterized by amplification in higher quantiles, culminating at the 60th cost quantile, after which it plateaus. Additionally, we examined the impact of insurance type (Supplementary Table S5) on both abstinence and cost outcomes. We observed no significant influence of insurance on either abstinence rates or costs (Supplementary Table S6). Moreover, the relationship between abstinence and cost remained significant even after accounting for insurance type (Supplementary Table S6).

Discussion

The study investigated the relationship between smoking abstinence and cost of health care utilization among patients with cancer. We used conditional quantile regression to explore the relationship between abstinence and cost across different quintiles. Our analysis showed that achieving abstinence after participating in the TRTP was associated with significantly lower costs at the first quartile ($2,351 vs. $1,998) and at the median ($6,810 vs. $5,715), after controlling for gender, age, race, cancer site, stage, multiple cancer, and costs incurred prior to completion of the TRTP smoking cessation program. The sensitivity analysis corroborated the preliminary conclusions, indicating a more pronounced cost reduction when excluding outlier data points. The costs savings of $1,095 achieved in one quarter can offset half the cost of participating in a comprehensive smoking cessation program like the TRTP (estimated at $2000 - $3000 per participant [29]). It is important to note that savings in healthcare and improvement in quality of life after quitting smoking is expected to increase progressively as abstinence time increases within 12 months after quitting and continues to accumulate with the number of years after abstinence, compared with continued smoking [43–46]. Our results show a relatively quick reduction in healthcare costs associated with the early stages of smoking cessation. We would expect to see increased benefits and cost savings for those who quit compared to those who do not over time. It is well established that the risk of heart attacks and strokes is reduced by 50% at one year after quitting and it takes 5–10 years to become comparable to non-smokers [47,48], while it takes up to 5 years after quitting to reduce the risk of developing a second primary cancer and up to 15 years for cancer risk to become comparable to non-smokers.

Our study has several strengths and unique features. In addition to the quantile regression analysis, the rich data source allowed for prospective collection of all smoking and related data that was matched with institutional billings in real time.

The cost savings linked to smoking cessation for cancer patients also have broader implications for healthcare systems [49,50]. By reducing the demand for cancer treatments, supportive care, and management of smoking-related comorbidities, healthcare systems can allocate resources more efficiently and effectively. This can result in reduced healthcare costs and better health outcomes for patients across the board. Furthermore, the financial savings from smoking cessation can be reinvested into other areas of cancer care, such

as prevention, early detection, and research[51,52]. By focusing on these areas, healthcare systems can more effectively reduce the overall burden of cancer and improve the quality of life for all patients. Given the significant health and financial costs associated with smoking in cancer patients, it is essential to develop effective strategies for reducing smoking rates and mitigating the impact of smoking on cancer patients. Smoking cessation interventions can help cancer patients quit smoking and reduce their risk of cancer recurrence and other smoking-related health problems [53]. These interventions can include medication, counseling, and support groups.

Limitations

We recognize that MD Anderson is a tertiary and referral cancer center, which resulted in many of our patients following up with outside providers and emergency room visits when they return home. We cannot account for these outside costs, including medications filled at local pharmacies and, in some cases, chemotherapy and radiotherapy conducted at centers outside of MD Anderson. Nevertheless, based on data we observed in the short term, we would expect the savings in healthcare to be higher if such costs could be incorporated into our model. We used Medicare reimbursement rates in order to establish standardized cost levels regardless of payers. However, this approach has the effect of under-estimating the actual overall cost in our analysis, as reimbursement rates from Medicare are in general lower than those set by commercial insurance for similar cases and care. Our reliance on hospital billing data from MDA offers a specific snapshot of costs, but it may not encompass the full cost of cancer treatment. This limitation is accentuated for patients who primarily visited MDA for post-treatment follow-up visits, as their external treatment-related costs would be absent from our dataset. Several references, including those by Warren et al[54]., Iragori et al[55]., and Djalalov et al[56]., provide more comprehensive estimates of the economic implications of cancer care in the context of smoking cessation. These papers highlight the iterative costs associated with second-line treatments and the significant economic benefits of enhanced smoking cessation programs. Additionally, our study’s estimates might differ from other studies evaluating the economic effects of smoking cessation in patients undergoing cancer treatment. This is because our cohort included both patients actively receiving treatment and those monitored post-treatment. For instance, over 25% of patients joined TRTP more than 6 months after their diagnosis. Lastly, while our data offers a tangible and specific cost profile, it’s essential to approach our findings with caution. Understanding the true economic implications of cancer care requires a more encompassing approach to cost, and we acknowledge the potential gaps in our analysis due to the inherent limitations of our data source. In future research, a more comprehensive approach would involve integrating various cost metrics - hospitalizations, pharmaceutical, outpatient, general practice, laboratory- and ensuring their synchronization and validation based on specific timelines of when each cost was incurred relative to diagnosis.

Conclusion

This study provides evidence that smoking cessation among cancer patients is associated with reductions in healthcare costs. Additionally, the reduction in demand for cancer treatments and management of smoking-related comorbidities because of smoking cessation could enhance the efficiency of healthcare resource allocation. Therefore, investing in

smoking cessation interventions could serve as a strategic approach for healthcare systems to lessen the overall cancer burden and improve patient outcomes, all the while optimizing their resources.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Prevention Relevance:

This study emphasizes the dual impact of smoking cessation programs in patients with cancer: quitting smoking and reducing healthcare costs. It highlights the importance of integrating cessation programs into cancer prevention strategies, ensuring both individual health benefits and broader, system-wide economic efficiencies.

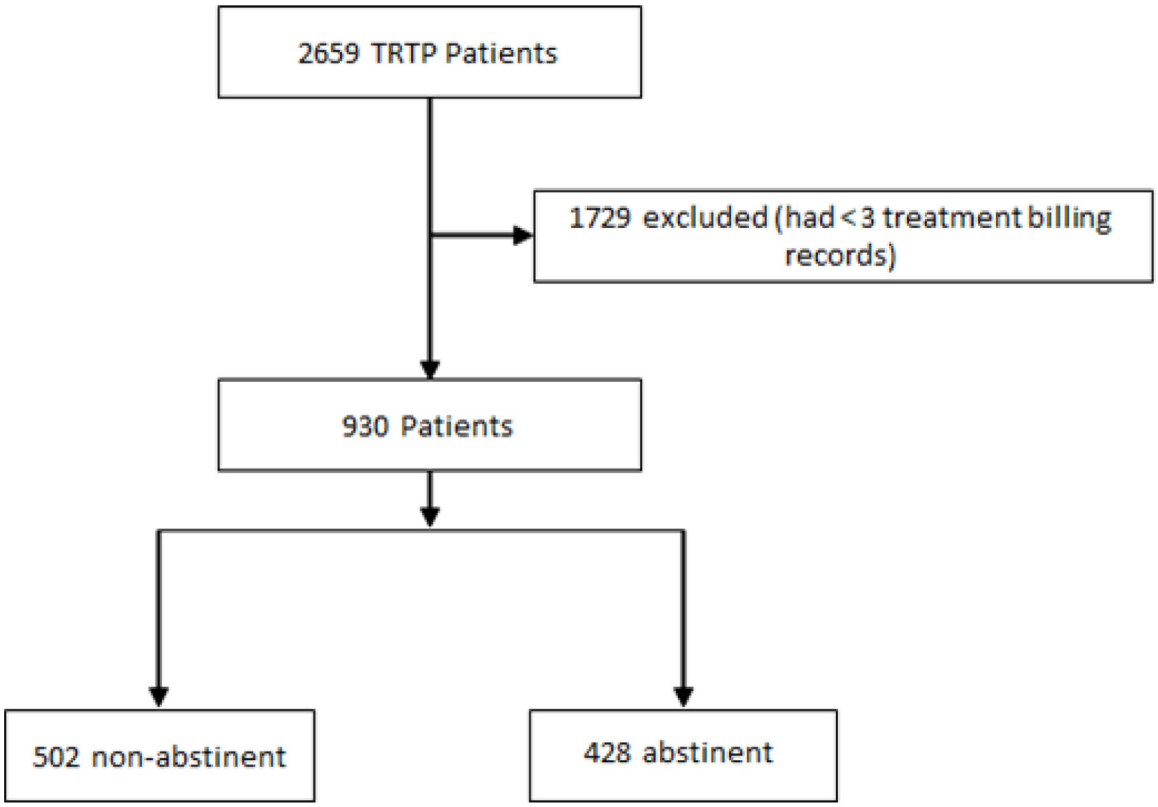

Figure 1.
Breakdown of Initial TRTP Patient Count and Analytic Sample Categorized by Abstinence Status

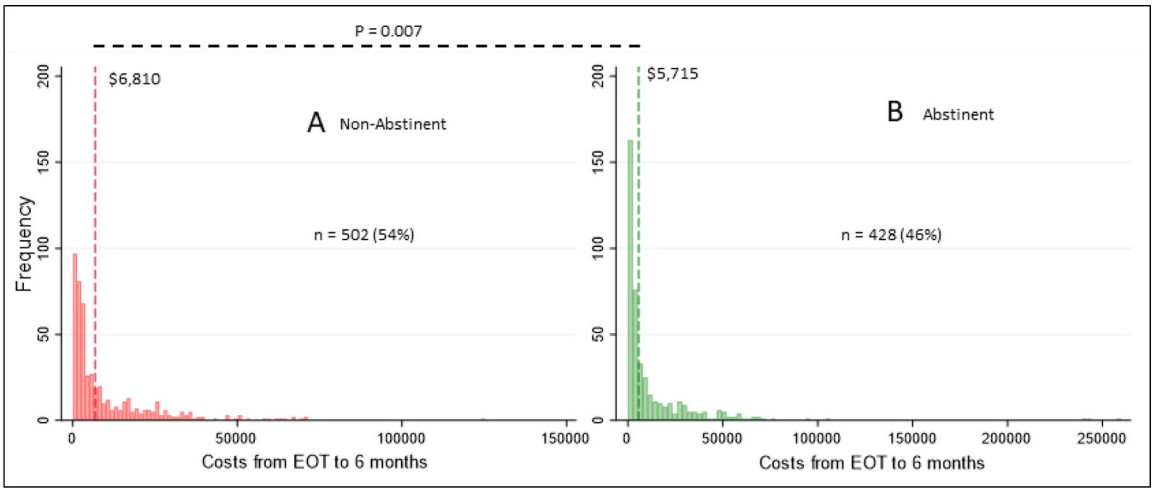

Figure 2.

Cost distributions between non-abstinence (A) and abstinent (B) groups with model adjusted medians. Note: EOT = end-of-treatment.

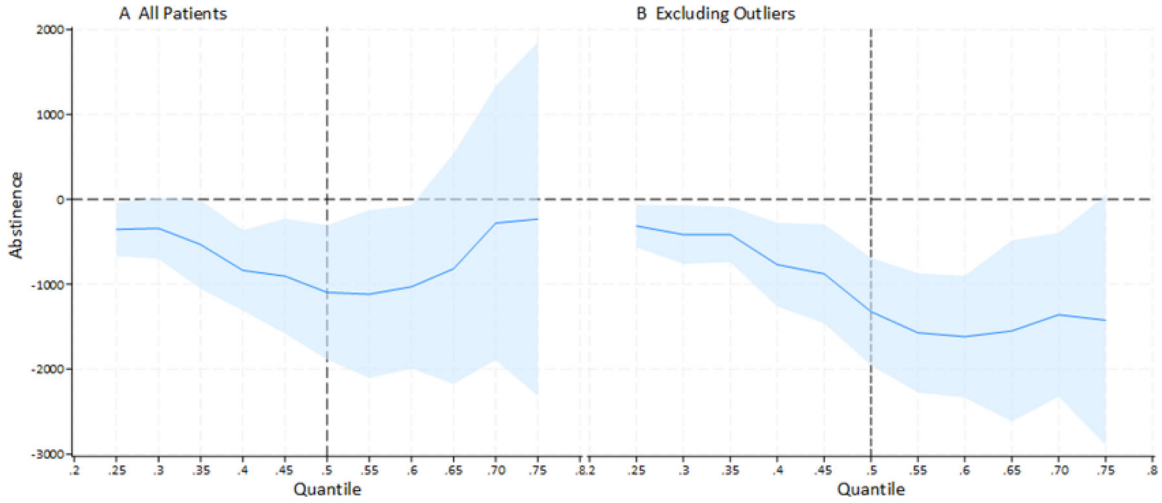

Figure 3.

Variation of the effect of abstinence (in dollars) on the y axis over the conditional quantiles of cost from the analyses of, A) all patients and B) excluding outliers.

Table 1:

Baseline Characteristics by abstinence status at 3 months for patients having 3 or more treatment claims at Q1 and Q2.

Baseline Characteristic	Total	Non-Abstinent		Abstinent		P-value
		N	%	N	%	
Total	930	502	54.0	428	46.0	
Gender						0.009
Female	430(46.2)	252	50.2	178	41.6	
Male	500(53.8)	250	49.8	250	58.4	
Age						0.309
<65	771(82.9)	422	84.1	349	81.5	
>= 65	159(17.1)	80	15.9	79	18.5	
Race						0.188
Non-Hispanic White	747(80.3)	399	79.5	348	81.3	
Hispanic	67(7.2)	31	6.2	36	8.4	
Non-Hispanic Black	88(9.5)	55	11.0	33	7.7	
Other	28(3.0)	17	3.4	11	2.6	
Stage						0.038
Local	153(16.5)	71	14.1	82	19.2	
Regional	315(33.9)	161	32.1	154	36.0	
Distant	246(26.4)	146	29.1	100	23.4	
Other/Unstaged/Unknown	216(23.2)	124	24.7	92	21.5	
Site						0.034
Breast	148(15.9)	86	17.1	62	14.5	
Colorectal & Other GI	126(13.6)	77	15.3	49	11.4	
Head & Neck	161(17.3)	69	13.7	92	21.5	
Lung	165(17.7)	91	18.1	74	17.3	
Lymphoma & Other Hematology	128(13.8)	67	13.3	61	14.3	
Melanoma	55(5.9)	27	5.4	28	6.5	
Other cancer	82(8.8)	43	8.6	39	9.1	
Other GU	39(4.2)	23	4.6	16	3.7	
Prostate	26(2.8)	19	3.8	7	1.6	
Multiple Cancer						0.810
No	636(68.4)	345	68.7	291	68.0	
Yes	294(31.6)	157	31.3	137	32.0	
Total Costs prior to EOT*						<0.001
Quartile 1 ($0 - $3,233.99)	233(25.0)	149	29.7	84	19.6	
Quartile 2 ($3,234 - $8,091.99)	232(25.0)	135	26.9	97	22.7	
Quartile 3 ($8,092 - $24,450.99)	233(25.0)	116	23.1	117	27.3	
Quartile 4 ($24,451 and above)	232(25.0)	102	20.3	130	30.4	

We used gender, age, cancer sites, stage, multiple cancer index, and cost distribution of the first quarters as a proxy of disease severity/ comorbidity.* EOT = end-of-treatment: the time point (approximately 3 - months after entering the TRTP program) that smoking cessation treatment is completed. GI = Gastrointestinal; GU = Genitourinary.

Table 2:

Costs at Q1 and Q2 by Abstinence status

Cost	N	P25	Median	P75
COSTS at Q1				
Total Costs at Q1				
Total	930	$3,134	$8,092	$24,450
No Abstinence	502	$2,618	$6,307	$19,000
Abstinence	428	$3,964	$10,418	$29,553
COSTS at Q2				
Total Costs at Q2				
Total	930	$1,655	$3,968	$14,909
No Abstinence	502	$1,728	$4,098	$14,488
Abstinence	428	$1,649	$3,705	$15,579

Table 3:

Quantile Regression with inverse probability weight for total costs at Q2 (N = 930) and with outliers removed (N = 898)

	Total Costs (Quantile 0.25) 95 % CI				Total Costs (Quantile 0.50) 95 % CI				Total Costs (Quantile 0.75) 95 % CI			
Quantile Regression with inverse probability weight	**Coef.**	**Lower**	**Upper**	**P-value**	**Coef.**	**Lower**	**Upper**	**P-value**	**Coef.**	**Lower**	**Upper**	**P-value**
Abstinence (1 = Yes)												
N = 930 (total sample)	−354	−666	−41	***0.027***	−1095	−1886	−304	***0.007***	−232	−2317	1852	0.827
N = 854 (outliers removed)	−312	−565	−60	***0.015***	−1320	−1953	−688	***<0.001***	−1422	−2892	46	0.058

Note: Models were adjusted for gender, age, race, cancer site, stage, multiple cancer, and costs incurred prior to completion of the TRTP smoking cessation program