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Article

ARTICLE

Cancer-Attributable Medical Costs for Colorectal Cancer Patients by Phases of Care: What Is the Effect of a Prior Cancer History?

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Abstract

Medical care costing studies have excluded patients with a prior cancer history. This study aims to update methods for estimating medical care costs attributable to cancer and to evaluate the effect of a prior history of cancer on costs for colorectal cancer (CRC) patients. We used Surveillance, Epidemiology, and End Results (SEER)-Medicare data and matched cancer patients to controls without cancer to estimate cancer-attributable costs by phases of care using Medicare 2007–2013 claims. CRC annualized average cancer-attributable costs were $56.0 K, $5.3 K, $92.5 K, and $24.3 K in the initial, continuing, and end-of-life cancer and noncancer death phases, respectively, in 2014 dollars. Costs were higher for patients diagnosed with more advanced stage, younger ages, and nonwhite races. Costs for patients with prior cancers were consistently higher than patients without prior cancers, especially in the continuing (4.9 K vs 7.2 K) and end-of-life noncancer death (22.7 K vs 30.0 K). Our CRC costs improve previous estimates by using more recent data and updated methods.

National expenditures for cancer care in the United States were estimated to increase from $124.6 billion in 2010 to $157.8 billion in 2020 (1). This 27% increase in costs over a 10-year period reflects the increase in cancer prevalence due to aging and growth of the population and increases in life expectancy. More recent projections show that increases in the number of cancer survivors will be highest between 2018 and 2030 (2). In addition, innovations in detecting and treating cancer have the potential to markedly affect costs. In particular, costs can be drastically affected by new costly targeted anticancer therapies (3) that often enter the market with list prices exceeding $100 000 per year (4). In 2018, the President's Cancer Panel report (4) concluded that addressing the dramatic increase of cancer drug prices must be made a national priority. Thus, providing accurate and up-to-date estimates of cancer care costs is important to inform cost-effectiveness analyses, health-care delivery policy recommendations, simulation modeling, and projections of national cancer care costs.

The most recent estimates of cancer-attributable costs by phase of care in the United States were based on Medicare claims data from 2001 through 2006 for patients diagnosed with cancer in the Surveillance, Epidemiology, and End Results (SEER) registries between 1975 and 2005 (1) (https://costprojections.cancer.gov/). These estimates do not reflect contemporary patterns of care and costs, did not include oral prescription drugs provided under the Medicare Part D benefit (enacted in 2006), and excluded patients with a prior cancer history. Patients with a prior diagnosis of cancer are usually excluded from costing studies (1,5–8) because of the complexity in attributing treatment and costs to a specific cancer diagnosis. However, among all cancers diagnosed each year in SEER, approximately 18% and 25% occur among individuals who had a history of prior cancer and were of any age or ages 65 years or older, respectively (9). Other more recent estimates are available (10,11); however, they do not evaluate prior cancer history, and they use methods less amenable to national projections than

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the phases-of-care approach. Another recent study included only patients treated in integrated delivery systems (12).

In this article, we advance previous methods (8,13) by including patients with multiple primaries, by using Part D enrollment information, an important predictor of cost, and by matching more efficiently to allow for estimation of cancer-attributable costs for many cancer sites with improved accuracy. We illustrate the method providing updated cancer-attributable costs, including Part D costs, using colorectal cancer (CRC), a common cancer in both men and women (14).

Materials and Methods

Data Sources

We used the SEER registry data linked to Centers for Medicare and Medicaid Services Medicare enrollment and claims data (15). The SEER data contain cancer site, stage, date of diagnosis (month, year), vital status, and cause of death on all incident cancers diagnosed among persons residing in the registry catchment areas, representing approximately 28% of the US population (16). The SEER registries collect information on all cancer diagnoses for a patient, making it possible to identify persons with multiple primaries. We have used a combined stage definition due to changes in the American Joint Committee on Cancer (AJCC) staging system in 2004. For cancer cases diagnosed in 2000–2003 and 2004–2013, we used the modified AJCC stage 3rd ed (1988–2003) and the Derived AJCC Stage Group, 6th ed (2004+), respectively.

Medicare enrollment data contain individual-level demographic characteristics, information about enrollment for Medicare Parts A and B coverage, Medicare Advantage (HMO) and Part D, and whether the beneficiary is eligible for a Part D low-income subsidy (LIS). Medicare Parts A and B claims data include payments and dates of service for beneficiaries with fee-for-service coverage for inpatient hospitalizations, skilled nursing facility care, outpatient hospital services, physician or supplier services, infusion or injectable drugs or their oral equivalent (eg, capecitabine for CRC), durable medical equipment, hospice, and home health care. Part D prescription drug event data include payments and dates of service for oral prescriptions drugs. The SEER-Medicare data also include a random 5% sample of Medicare beneficiaries residing in the SEER areas who did not have a cancer diagnosis per the SEER data. The noncancer sample was used to identify payments and dates of service for controls. The SEER-Medicare data have also been linked to the American Community Survey data at the ZIP code level. In this study, we included quartile groupings for median household income and educational attainment (percent with >4 years college education) based on the US population ZIP code of residency (https://www.census.gov/programs-surveys/acs/).

Study Overview

The method consisted of four steps: 1) identification of cases and controls who had at least 1 month of Medicare eligibility for potential assignment to a phase of care and calculation of costs; 2) classification of postdiagnosis months for cases, hereafter referred to as months of observation, into distinct phases of care at the tumor level, including censoring; 3) matching months of observation for cases and controls within phase of care and calendar year; and 4) estimation of cancer-attributable costs. The matching was done including patients diagnosed with any cancer and controls never diagnosed with any cancer to create a resource for estimation of costs for many cancer sites with improved efficiency and accuracy. In this article, we illustrate the method by selecting CRC cases. We validate the matching method by by using the standard method of first selecting CRC cases and then matching to controls. Details of each step are described below.

Step 1: Identification of Cases and Controls

Cases were persons in the SEER data who were diagnosed with any cancer between 2000 and 2013. Instead of limiting cases to those with CRC, we kept all cancers, including those with prior or multiple tumors, to create a resource to provide cancer-attributable costs for many cancer sites. We excluded cancer cases diagnosed by death certificate and patients whose date of birth differed by more than 1 year between the SEER and Medicare data. Controls were selected from the SEER-Medicare 5% sample and were required to never have been diagnosed with cancer through 2013. Importantly, both cases and controls were required to have at least 1 month between 2007 and 2013 in which they were aged 65 years or older, had Medicare Parts A and B coverage, and were not enrolled in an HMO. For the assessment of Part D costs, we limited analyses to those who also had Part D enrollment.

Step 2: Assigning Months of Observation to Phases of Care

Months of observation were defined as the months for which an individual met the criteria above. For cases, months of observation after each tumor diagnosis were classified into three clinically relevant phases: the initial phase (the first 12 months after diagnosis), the end-of-life (EOL) phase (the 12 months before death), and the continuing phase (the months between the initial and the EOL phase). The phases-of-care approach is used because it allows for a straightforward combination with cancer prevalence to estimate national cancer-related expenditures. We further defined the EOL phase into patients who died from any cancer (EOL cancer death) and those who died from other causes (EOL noncancer death). For persons who survived less than 24 months after their cancer diagnosis, months were first assigned to the applicable EOL phase (up to 12 months) and the remaining months were then assigned to the initial phase. We excluded EOL months of observation for cases with unknown cause of death. Months of observations for cases were censored at the diagnosis of a subsequent tumor, age 99 years, date of death, or end of study (December 31, 2013), whichever occurred first. Months of observation for controls were assigned to two phases: the EOL noncancer death phase (the 12 months prior to death) and the continuing phase (all other months). Months of observations for controls were censored at age 99 years, date of death, or end of study (December 31, 2013), whichever occurred first.

Once the months of observation for cases and controls were allocated to the respective phases, they were then divided into calendar year to allow for analyses of temporal trends in cost estimates. Supplementary Figure 1 (available online) illustrates the matching and classification of months of observation in each phase and calendar year for a case diagnosed with prostate cancer in June 2011 and CRC in September 2013 and alive at December 31, 2013.

Step 3: Matching Observation Months for Cases and Controls

As with previous studies (1,6,8), we used matching of cases to controls to estimate cancer-attributable costs because of the challenges and inefficiencies in identifying all potentially relevant medical services associated with a cancer diagnosis using health claims. Months of observation for cases and controls were 1:1 matched by phase of care, calendar year, registry, sex, age (to the nearest year), race (white, black, and other race/unknown), and Medicare Part D entitlement status (not enrolled, LIS, and not LIS).

Months of observation for controls in the continuing phase were matched to those for cases in the initial, continuing, and EOL cancer death phases. Months of observation for controls in the EOL phase were matched to those for cases in the EOL noncancer death phase. This is the standard approach for estimating cancer-attributable costs. If more than one control was identified for a case, within a phase and calendar year, controls with the greatest number of observation months in that phase and year were given matching priority and then one control was randomly selected. Supplementary Figure 1 (available online) provides an example of potential control matches and priority criteria.

Step 4: Estimating Cancer-Attributable Annualized Average Costs by Phases of Care

Costs were measured as Medicare payments and patient responsibility (patient and other payers' payments through insurance premiums, deductibles, coinsurance, and copayments) and were calculated for each month of observation based on the amounts listed in the Medicare claims data. Each claim's date of service or the date the prescription was filled was used to assign the payment to an observation month. The average monthly cost attributable to cancer is estimated as the difference between average monthly costs for cases and controls. All costs are reported as average annualized cost, calculated as the average monthly cost multiplied by 12 and inflated to the 2014 US dollars using the Medical Consumer Price Index–All Urban (17). The details of the files, variables, and cost calculations are shown in the Supplemental Materials.

Illustrative Example: Cancer-Attributable Costs for CRC and Sensitivity Analysis of Matching Approach

To estimate cancer-attributable costs for CRC patients, we selected individuals diagnosed with CRC between 2000 and 2013 and their respective matched controls. We also conducted a sensitivity analysis of our matching approach by rematching months of observation from controls to the CRC cases specifically rather than to all cancer cases. We used the same method and same matching variables as the main analyses. Thus, the sensitivity analyses evaluate the order of matching and selecting controls on cost estimates. The article's main approach is to match controls to all cancer patients and then select CRC cancer cases and their prematched controls. The old method being tested is to first select CRC cancer cases and then match to controls.

Results

Table 1 shows the number of cases and controls contributing to the calculation of costs by phase of care. The number of controls were identical to the number of cases for the matched characteristics (sex, race, year, prior cancer, Part D enrollment) and were omitted from Table 1. The distribution of cases and controls was very similar by categorized age, Zip code median income, and college education.

How do CRC-attributable medical costs vary by demographic and clinical characteristics and time? Overall, Parts A and B per case average annualized costs were $55 845, $5313, $92 476, and $ 24 235 in the initial, continuing, EOL cancer, and EOL noncancer phases, respectively (Table 2). In all phases of care, average annualized cancer-attributable costs were higher for younger ages, races other than white, and more advanced stages. Stage at diagnosis had the greatest effect on costs. For patients diagnosed with stage I vs stage IV CRC, costs were, respectively, $37 200 and $113 889 in the initial phase and $75 070 and $111 408 in the EOL cancer death phase. Costs were higher in the EOL cancer death phase for people living in areas with higher income and higher education. Costs were slightly higher for patients diagnosed with rectum vs colon cancer, except for EOL cancer death phase.

Patients enrolled in Part D with LIS had overall higher costs compared with patients with no Part D or with Part D but no LIS enrollment in all phases except EOL cancer death; this variation was consistent when stratified by demographic and cancer characteristics (Table 2; Supplemental Materials Table 2). Cancer-attributed average costs were stable over time and declined in 2013 in the initial phase and slightly decreased in the continuing and EOL phases (Table 2).

How do cancer-attributable costs differ for cancer patients with and without a prior cancer? Overall, Parts A and B cancer-attributable costs tended to be slightly higher for CRC patients with a prior cancer regardless of phase of care (Table 3) with greater observed differences for the continuing and EOL noncancer phases. The greatest difference in cancer-attributable costs between cancer patients with and without a prior cancer was observed among younger patients and those diagnosed with Stage I cancers.

How do CRC-attributable prescription drugs costs vary by demographic and clinical characteristics? Average annualized cancer-attributable oral prescription drug (Part D) costs were very low for CRC patients in the initial and continuing phase ($429 and $252, respectively) and slightly higher in the EOL cancer phase ($1164) (Table 4). In all phases, cancer-attributable oral prescription drug costs tended to be higher among the younger age group, males, races other than white, and patients with stage IV tumors, with a prior history of cancer, enrolled in LIS, and living in areas with higher income and education. Patients with a prior history of cancer had much higher oral prescription drug costs in all phases as did those enrolled in LIS in the initial and continuing phases. Oral prescription drug costs did not seem to increase with year, except for the EOL cancer phase where costs increased from an average of $650 in years 2007–2011 to $1600 in 2012 and $3100 in 2013. Cancer-attributable oral prescription drug costs were negative (lower than in controls) in the EOL noncancer phase for patients diagnosed with stage III and IV CRC who died of other causes.

How do CRC-attributable costs vary by matching approach (i.e. sensitivity analysis)? The average annualized cancer-attributable costs were very similar for all phases of care regardless of matching approach. Estimates were similar in the main analyses, where controls were matched to all cancer cases, and in the sensitivity analysis, where controls were matched to CRC cancer cases only (Table 5).

Table 1. Number of CRC cases diagnosed between 2000 and 2013 contributing to each phase of care and their matched controls, SEER-Medicare*

	Initial phase†		Continuing†		EOL cancer†		EOL noncancer†	
Characteristic	Cases	Controls	Cases	Controls	Cases	Controls	Cases	Controls
Total	129 265	—	521 315	—	62 156	—	54 863	—
Colon	97 215	—	383 097	—	44 823	—	42 493	—
Rectum	32 050	—	138 218	—	17 333	—	12 370	—
Age								
65–69	26 643	26 710	94 670	95 356	9343	9384	2790	2783
70–74	27 861	27 989	104 985	105 203	10 609	10 621	4865	4821
75–79	26 660	26 683	104 516	104 105	11 273	11 363	7312	7352
80+	48 101	47 883	217 144	216 651	30 931	30 788	39 896	39 907
Sex								
Male	62 809	—	251 030	—	30 615	—	26 342	—
Female	66 456	—	270 285	—	31 541	—	28 521	—
Race								
White	106 566	—	434 919	—	50 891	—	47 746	—
Black	11 625	—	44 086	—	6437	—	4279	—
Other	11 074	—	42 310	—	4828	—	2838	—
Year								
2007	21 206	—	63 650	—	9431	—	6835	—
2008	20 310	—	68 242	—	9280	—	7328	—
2009	19 119	—	71 992	—	9043	—	7524	—
2010	18 183	—	75 325	—	8921	—	7892	—
2011	17 382	—	78 196	—	8749	—	8233	—
2012	17 053	—	81 061	—	8532	—	8585	—
2013	16 012	—	82 849	—	8200	—	8466	—
Part D								
No	58 458	—	233 314	—	26 368	—	21 308	—
Yes/not LIS	44 167	—	189 986	—	19 778	—	17 010	—
Yes/LIS	26 640	—	98 015	—	16 010	—	16 545	—
Prior cancer								
No	101 896	—	435 585	—	47 373	—	43 569	—
Yes	27 369	—	85 730	—	14 783	—	11 294	—
AJCC stage								
0	10 269	—	58 750	—	1317	—	5398	—
I	34 180	—	165 142	—	5940	—	16 680	—
II	37 001	—	151 439	—	10 600	—	16 971	—
III	29 870	—	109 189	—	16 142	—	10 213	—
IV	10 717	—	14 643	—	21 806	—	2148	—
Unstaged	7228	—	22 152	—	6351	—	3453	—
Zip code median family income‡								
0– $22 512	34 970	35 320	135 094	135 244	17 339	17 287	15 239	14 429
$22 513– $28 571	30 712	30 651	121 082	121 575	14 935	14 604	13 094	12 906
$28 572– $36 332	29 139	29 142	117 064	121 449	13 646	13 903	12 430	12 901
$36 333+	29 728	31 493	121 633	132 544	13 277	15 015	12 053	13 441
Missing	4716	2659	26 442	10 503	2959	1347	2047	1186
Zip code % college graduated‡								
0–16.7%	34 832	34 773	134 413	133 190	17 414	16 963	15 266	14 211
16.8–26.5%	31 754	31 425	125 890	125 179	15 406	15 047	13 872	13 758
26.6–41.3%	30 443	30 565	121 039	126 464	13 941	14 292	12 448	13 100
41.4%+	27 605	29 944	113 810	126 374	12 490	14 562	11 264	12 654
Missing	4631	2558	26 163	10 108	2905	1292	2013	1140

*AJCC = American Joint Committee on Cancer; CRC = colorectal cancer; LIS = Part D low-income subsidy; SEER = Surveillance, Epidemiology, and End Results. The number of controls are displayed only for age (matched to the nearest year) and the nonmatching characteristics: ZIP code percentage with college education and ZIP code median family income.

†Initial phase represents the first 12 months after diagnosis, EOL is defined as the 12 months before death, and the continuing phase is the months between the initial and the EOL phase.

‡ZIP code median family income and ZIP code percentage college graduated cut-points represent the quartiles calculated using the observed values for all US ZIP codes.

Table 2. Average annualized cancer-attributable medical costs (Medicare Parts A and B) in 2014 US dollars and SE for patients diagnosed with CRC 2000–2013, SEER-Medicare*

Patient characteristic	Initial phase† Mean (SE)	Continuing† Mean (SE)	EOL cancer† Mean (SE)	EOL noncancer† Mean (SE)
Site				
CRC	$55 845 (213)	$5313 (60)	$92 476 (426)	$24 235 (543)
Colon	$54 515 (247)	$5021 (69)	$93 844 (513)	$23 861 (621)
Rectum	$59 923 (418)	$6125 (122)	$89 162 (760)	$25 522 (1123)
Age				
65–69	$61 283 (483)	$7282 (121)	$113 023 (1151)	$43 249 (3455)
70–74	$60 102 (466)	$6505 (108)	$108 574 (1026)	$38 369 (2233)
75–79	$56 771 (467)	$5678 (149)	$99 180 (1038)	$32 332 (1813)
80+	$49 878 (338)	$3669 (101)	$77 665 (576)	$20 172 (556)
Sex				
Male	$57 629 (313)	$5992 (74)	$95 389 (624)	$26 437 (838)
Female	$54 169 (288)	$4686 (94)	$89 601 (580)	$22 159 (702)
Race				
White	$55 136 (230)	$5157 (66)	$90 353 (456)	$22 628 (550)
Black	$60 067 (812)	$6109 (218)	$103 044 (1505)	$31 798 (2516)
Other or unk	$58 395 (742)	$6174 (181)	$101 149 (1689)	$35 058 (3129)
Stage				
0	$25 425 (585)	$2849 (286)	$68 299 (2558)	$20 826 (1692)
I	$37 200 (345)	$3818 (80)	$75 070 (1336)	$19 711 (927)
II	$52 756 (392)	$4452 (112)	$84 626 (1111)	$21 211 (972)
III	$76 639 (456)	$6897 (112)	$88 600 (808)	$29 005 (1302)
IV	$113 889 (824)	$32 652 (519)	$111 408 (713)	$69 772 (3363)
Part D				
No	$53 744 (309)	$4982 (66)	$90 645 (650)	$24 694 (833)
Yes, not LIS	$55 315 (342)	$5304 (123)	$95 152 (713)	$22 125 (911)
Yes, LIS	$61 360 (526)	$6243 (142)	$92 057 (900)	$25 751 (1096)
Prior cancer				
No	$55 647 (239)	$4942 (63)	$92 808 (490)	$22 741 (612)
Yes	$56 588 (463)	$7241 (176)	$91 413 (864)	$30 036 (1184)
Zip code median family income‡				
0–$22 512	$55 579 (409)	$5422 (98)	$90 925 (814)	$26 517 (1017)
$22 513–$28 571	$55 089 (419)	$5331 (99)	$89 327 (828)	$22 625 (1088)
$28 572–$36 332	$56 219 (440)	$5538 (101)	$93 698 (893)	$23 468 (1115)
$36 333+	$56 060 (468)	$4931 (191)	$96 812 (981)	$23 840 (1213)
Zip code % college graduated‡				
0–16.7%	$55 250 (411)	$5259 (101)	$90 925 (822)	$24 672 (1036)
16.8–26.5%	$54 207 (426)	$5223 (98)	$88 881 (846)	$23 949 (1099)
26.6–41.3%	$56 243 (440)	$5351 (162)	$91 887 (862)	$21 920 (1107)
41.4%+	$57 310 (456)	$5427 (134)	$98 900 (973)	$26 236 (1179)
Year				
2007	$56 769 (524)	$6197 (142)	$96 918 (1114)	$28 189 (1552)
2008	$58 270 (555)	$6178 (138)	$98 835 (1122)	$28 754 (1635)
2009	$56 457 (569)	$5675 (134)	$95 582 (1152)	$26 540 (1550)
2010	$55 059 (577)	$4630 (273)	$90 903 (1150)	$24 278 (1449)
2011	$56 695 (582)	$5135 (128)	$91 013 (1138)	$22 230 (1391)
2012	$55 344 (573)	$4962 (123)	$88 632 (1105)	$19 591 (1264)
2013	$51 283 (552)	$4780 (118)	$84 229 (1084)	$22 217 (1272)

*CRC = colorectal cancer; EOL = end of life; LIS = Part D low-income subsidy; SE = standard error; SEER = Surveillance, Epidemiology, and End Results; unk = unknown. Cancer-attributable costs are calculated as the average monthly difference in costs between CRC cases minus their matched controls multiplied by 12 and inflated to 2014 US dollars. Medicare costs include Medicare payments and patient's responsibility.

†Initial phase represents the first 12 months after diagnosis, the EOL is defined as the 12 months before death, and the continuing phase is the months between the initial and the EOL phase.

‡ZIP code median family income and ZIP code percentage college graduated cut-points represent the quartiles calculated using the observed values for all US ZIP codes.

Discussion

Using the linked SEER-Medicare data, we advanced earlier cancer costing methods in two important ways: inclusion of people with multiple tumors and the matching method. Inclusion of patients diagnosed with prior cancers is especially important because the incidence of multiple primaries is growing in the United States: nearly one in four of newly diagnosed elderly cancer patients have a history of prior cancer (9). Matching all cancer cases (not the selected cohort) is a more efficient and flexible approach that

Table 3. Average annualized cancer-attributable medical costs (Medicare Parts A and B) in 2014 US dollars for patients diagnosed with CRC 2000–2013, by prior cancer history*

	Initial phase†		Continuing†		EOL cancer†		EOL noncancer†	
Patient characteristic	No	Yes	No	Yes	No	Yes	No	Yes
Site								
CRC	$55 647	$56 588	$4942	$7241	$92 808	$91 413	$22 741	$30 036
Colon	$54 247	$55 489	$4648	$6863	$93 957	$93 488	$22 179	$30 297
Rectum	$59 838	$60 271	$5734	$8486	$90 077	$86 027	$24 646	$29 074
Age								
65–69	$60 704	$64 681	$6978	$9955	$112 365	$116 776	$43 197	$43 342
70–74	$59 675	$61 899	$6019	$9761	$108 377	$109 351	$35 854	$52 254
75–79	$56 319	$58 388	$5274	$7780	$98 590	$101 076	$28 958	$46 714
80+	$49 536	$50 882	$3174	$5627	$77 024	$79 323	$18 742	$25 320
Sex								
Male	$57 700	$57 392	$5597	$7918	$95 885	$93 969	$24 415	$33 341
Female	$53 796	$55 706	$4349	$6549	$89 935	$88 393	$21 218	$26 296
Race								
White	$54 897	$55 986	$4760	$7117	$90 485	$89 951	$20 981	$28 795
Black	$59 809	$61 143	$5709	$8388	$102 654	$104 538	$30 350	$38 557
Other	$58 250	$59 268	$6000	$7700	$102 654	$93 455	$34 541	$38 421
AJCC stage								
0	$24 449	$28 897	$2359	$5287	$60 603	$76 271	$20 795	$20 923
I	$36 208	$40 463	$3418	$5724	$73 400	$78 145	$18 723	$23 313
II	$52 282	$54 527	$4157	$6020	$85 879	$81 026	$19 633	$27 467
III	$76 390	$77 687	$6526	$9136	$88 253	$89 869	$26 296	$40 464
IV	$114 318	$111 991	$31 887	$36 867	$110 944	$113 401	$70 013	$68 907
Part D								
No	$53 445	$54 777	$4582	$6925	$90 923	$89 826	$23 120	$30 153
Yes, not LIS	$55 082	$56 118	$4881	$7397	$95 743	$93 448	$20 121	$29 084
Yes, LIS	$60 981	$63 365	$5995	$8006	$92 203	$91 416	$24 704	$31 218

*Cancer-attributable costs are calculated as the average monthly difference in costs between CRC cases minus their matched controls multiplied by 12 and inflated to 2014 US dollars. Medicare costs include Medicare payments and patient's responsibility. CRC = colorectal cancer; EOL = end of life; LIS = Part D low-income subsidy.
†Initial phase represents the first 12 months after diagnosis, the EOL is defined as the 12 months before death, and the continuing phase is the months between the initial and the EOL phase.

can provide estimates for any cohort of cancer cases, by site, histology, stage, or other tumor characteristic, without having to redo the matching to estimate cancer-attributable costs. We illustrate and validate the matching method using CRC patients. The new estimates are comparable with previous estimates in the initial and EOL cancer phases but slightly higher in the continuing phases and EOL noncancer because of the inclusion of patients with a prior diagnosis of cancer. More updated, accurate, and detailed average estimates of medical costs related to cancer are important in assessments of the national economic burden of cancer. These estimates can be used in simulation modeling to evaluate interventions to reduce disparities, in cost-effectiveness analyses, and as a guide for health resource allocation and planning. In future studies, we plan to estimate cancer-attributable costs for several cancer sites.

CRC-attributable annualized costs for Medicare Parts A and B were $56.0 K, $5.3 K, and $92.5 K in the initial, continuing, and EOL cancer death phases, respectively. Similar to earlier reports, we found the annualized costs of care highest in the initial and EOL cancer death phase. However, unlike earlier reports, costs were substantially higher in EOL cancer death phase than in the initial phase, following a "J-shaped" rather than a "U-shaped" curve. This finding reflects changes in the intensity of cancer care at the EOL.

We found variations in the costs of CRC by sociodemographic and clinical characteristics. Within each phase, costs were higher for patients diagnosed with more advanced stage, younger ages, nonwhite races, and higher median income area of residence. Most of these differences reflect more intensive treatment and higher phase-specific costs for patients diagnosed with advanced stage. Differences in phase-specific costs by age and race warrant further investigation. Part D prescription drugs accounted for a small portion of the overall cancer-attributable costs for CRC care. Notably, capecitabine, a common CRC oral agent, is not covered under Part D but is instead covered by Medicare Part B.

Costs for patients with prior cancers were consistently higher than the costs for cancer patients without a prior cancer in the continuing and EOL noncancer phase. In the initial and EOL cancer phases, the two phases with highest annualized costs, the costs for patients with a prior history of cancer were slightly higher. The largest differences were observed among younger patients or those diagnosed with Stage 0 or Stage I cancers. The difference between the costs for patients diagnosed with and without a prior history cancer may reflect either treatment associated with the prior tumor or more intensive treatment for the current treatment. Incorporating costs associated with prior cancers may affect estimates of national expenditures for CRC and other cancer sites such as breast or prostate, for which prevalence is high in the continuing phase.

We report costs adjusted to the $2014 US dollars using a medical specific price inflation index. This approach removes the effect of general medical price inflation from other factors. Changes in deflated costs reflect growth in nonprice factors,

Table 4. Average annualized cancer-attributable oral prescription drug costs (Medicare Part D) and SE for CRC patients diagnosed 2000–2013, SEER-Medicare*

Patient characteristic	Mean (SE)	Mean (SE)	Mean (SE)	Mean (SE)
Site				
Overall	$429 (30)	$252 (13)	$1164 (55)	$201 (42)
Colon	$494 (35)	$315 (15)	$1197 (66)	$235 (47)
Rectum	$229 (58)	$77 (26)	$1087 (100)	$83 (96)
Age				
65–69	$548 (73)	$310 (34)	$2323 (170)	$14 (269)
70–74	$486 (77)	$283 (30)	$1886 (141)	−$60 (170)
75–79	$540 (63)	$222 (32)	$1393 (158)	$229 (140)
80+	$264 (40)	$222 (17)	$415 (59)	$258 (44)
Sex				
Male	$569 (51)	$349 (20)	$1706 (93)	$289 (71)
Female	$319 (36)	$178 (17)	$716 (64)	$140 (52)
Race				
White	$377 (33)	$207 (14)	$1052 (59)	$180 (46)
Black	$481 (110)	$406 (47)	$1079 (179)	$495 (133)
Other or unk	$758 (96)	$492 (45)	$2117 (207)	$47 (181)
Stage				
0	$561 (80)	$452 (38)	$2284 (432)	$572 (140)
I	$505 (64)	$349 (23)	$1103 (143)	$366 (76)
II	$36 (44)	$95 (22)	$752 (115)	$172 (73)
III	$421 (61)	$82 (27)	$1225 (107)	−$150 (97)
IV	$1023 (148)	$544 (110)	$1437 (107)	−$675 (239)
Part D				
No	— (—)	— (—)	— (—)	— (—)
Yes, not LIS	$341 (28)	$144 (13)	$1190 (64)	$42 (57)
Yes, LIS	$602 (64)	$512 (28)	$1144 (93)	$371 (61)
Prior cancer				
No	$308 (33)	$198 (14)	$1031 (63)	$102 (46)
Yes	$904 (69)	$545 (35)	$1619 (114)	$619 (105)
Zip code median income				
0–$22 512	$303 (53)	$180 (24)	$1049 (101)	$102 (79)
$22 513–$28 571	$303 (53)	$172 (26)	$964 (104)	$90 (83)
$28 572–$36 332	$500 (79)	$360 (31)	$1338 (119)	$282 (90)
$36 333+	$656 (63)	$391 (26)	$1455 (137)	$434 (93)
Zip code college graduated				
0–16.7%	$132 (49)	$114 (23)	$952 (97)	$60 (79)
16.8–26.5%	$397 (56)	$178 (25)	$1077 (108)	$98 (79)
26.6–41.3%	$546 (74)	$429 (31)	$1277 (129)	$396 (89)
41.4%+	$741 (70)	$397 (27)	$1534 (128)	$390 (101)
Diagnosis year				
2007	$377 (57)	$200 (31)	$604 (101)	$206 (99)
2008	$413 (65)	$203 (29)	$737 (117)	$131 (108)
2009	$601 (100)	$240 (32)	$553 (130)	$330 (111)
2010	$444 (81)	$283 (34)	$694 (130)	$156 (106)
2011	$421 (78)	$265 (33)	$637 (111)	$94 (114)
2012	$297 (88)	$230 (34)	$1563 (167)	$253 (110)
2013	$456 (81)	$310 (35)	$3103 (205)	$241 (119)

*CRC = colorectal cancer; EOL = end of life; LIS = Part D low-income subsidy; SE = standard error; SEER = SEER = Surveillance, Epidemiology, and End Results; unk = unknown. Cancer-attributable costs are calculated as the average monthly difference in costs between CRC cases minus their matched controls multiplied by 12 and inflated to 2014 US dollars. Medicare costs include Medicare payments and patient's responsibility.

†Initial phase represents the first 12 months after diagnosis, the EOL is defined as the 12 months before death, and the continuing phase is the months between the initial and the EOL phase.

‡ZIP code median family income and ZIP code percentage college graduated cut-points represent the quartiles observed calculated using the observed values for all US ZIP codes.

including new medical developments, change in the intensity and quantity of health-care services delivered per person, and changes in the composition of the cancer prevalence population. For CRC, costs were stable in the period 2007–2012 and decreased slightly in 2013 and in the EOL cancer phases. This is in alignment with Hartman et al. [18], who report: "During the 2007–2009 economic recession and in the years that followed, the use and intensity of health-care goods and services experienced little to no growth, averaging just 0.3% during the period 2008–2013." Prior annualized cost estimates in the initial, continuing, and EOL cancer and EOL not cancer phases were $51.6 K, $3.9 K, $85.0 K, and $14.9 K in 2010 US dollars and

Table 5. Average annualized cancer-attributable costs (Medicare Parts A and B) for CRC patients diagnosed 2000–2013 using two matching algorithms: matching all cancer cases and matching only CRC cases with controls*

	Matched all cancer sites				Matched CRC only			
Patient characteristic	Initial†	Continuing†	EOL cancer†	EOL noncancer†	Initial†	Continuing†	EOL cancer†	EOL noncancer†
Site								
CRC	$55 845	$5313	$92 476	$24 235	$55 806	$5373	$92 530	$24 384
Colon	$54 515	$5021	$93 844	$23 861	$54 462	$5078	$93 906	$23 995
Rectum	$59 923	$6125	$89 162	$25 522	$59 925	$6193	$89 196	$25 724
Age								
65–69	$61 283	$7282	$113 023	$43 249	$61 011	$7258	$112 733	$43 538
70–74	$60 102	$6505	$108 574	$38 369	$60 005	$6486	$108 517	$38 646
75–79	$56 771	$5678	$99 180	$32 332	$56 817	$5676	$99 556	$32 687
80+	$49 878	$3669	$77 665	$20 172	$49 953	$3833	$77 744	$20 257
Sex								
Male	$57 629	$5992	$95 389	$26 437	$57 475	$6101	$95 255	$26 493
Female	$54 169	$4686	$89 601	$22 159	$54 238	$4701	$89 837	$22 391
Race								
White	$55 136	$5157	$90 353	$22 628	$55 170	$5205	$90 522	$22 752
Black	$60 067	$6109	$103 044	$31 798	$59 830	$6199	$102 923	$31 738
Other or unk	$58 395	$6174	$101 149	$35 058	$57 860	$6318	$100 221	$35 973
Stage								
0	$25 425	$2849	$68 299	$20 826	$25 149	$3164	$68 591	$21 423
I	$37 200	$3818	$75 070	$19 711	$37 148	$3901	$75 251	$19 710
II	$52 756	$4452	$84 626	$21 211	$52 573	$4443	$84 591	$21 501
III	$76 639	$6897	$88 600	$29 005	$76 688	$6842	$88 812	$29 269
IV	$113 889	$32 652	$111 408	$69 772	$114 064	$32 798	$111 420	$68 210
Unstaged	$41 576	$6079	$78 425	$32 943	$41 982	$6273	$78 200	$33 157
Part D								
No	$53 744	$4982	$90 645	$24 694	$53 696	$4946	$90 614	$24 842
Yes, not LIS	$55 315	$5304	$95 152	$22 125	$55 292	$5526	$95 126	$22 100
Yes, LIS	$61 360	$6243	$92 057	$25 751	$61 310	$6218	$92 351	$26 077
Prior cancer								
No	$55 647	$4942	$92 808	$22 741	$55 547	$4966	$92 798	$23 161
Yes	$56 588	$7241	$91 413	$30 036	$56 774	$7486	$91 672	$29 144

*CRC = colorectal cancer; EOL = end of life; LIS = Part D low-income subsidy; unk = unknown. Cancer-attributable costs are calculated as the average monthly difference in costs between CRC cases minus their matched controls multiplied by 12 and inflated to 2014 US dollars. Medicare costs include Medicare payments and patient's responsibility.

†Initial phase represents the first 12 months after diagnosis, EOL is defined as the 12 months before death, and the continuing phase is the months between the initial and the EOL phase.

$57.8 K, $4.3 K, $95.4 K, and $16.6 K in 2014 US dollars, thus comparable with the current cost estimates. However, we observed a more than doubled increase in the costs of oral prescription drugs in 2012 and 2103, which likely reflects greater use of combinations of therapies and dissemination and introduction of new expensive oral therapies (19).

We used a prevalence cost approach, which considers trajectories of cancer patients within a calendar period and assigns them to different phases of care. This approach has the advantage of being straightforward when combined with US prevalence estimates by phase of care to obtain national expenditures in a specific year. In contrast, the incidence cost approach quantifies cost along the trajectory from diagnosis and is more appropriate for estimating lifetime costs and cost-effectiveness modeling (20). The incidence cost approach cannot be easily used to estimate national expenditures. We used a 12-month definition of costs in the initial and EOL phases because they are the most straightforward to combine with annual prevalence estimates for the calculation of national costs. Consistent with previous studies, the EOL phase (1,20,21) had priority over the initial phase for individuals who survive less than 24 months, because costs in the EOL phase are higher compared with costs in the initial phase. As a result, costs in the initial phase are censored among those patients who survived less than 2 years; therefore, comparisons of initial costs and their interpretation are challenging because different groups may have a different distribution of short- vs long-term survivors.

We estimated cancer-attributable costs by comparing costs among cancer cases with their matched controls. More specifically, we matched case (any cancer type) months of costs to control months of costs by phase of care and calendar year, registry, sex, age (to the nearest year), race, and Medicare Part D entitlement status. Race, calendar year, and Part D entitlement covariates have not been included in previous matching and allow for a more accurate estimate of the costs by these covariates. Sensitivity analyses showed that matching all cancer cases to controls produced very similar estimates of cancer-attributable costs to when the controls were specifically matched to CRC cases. In our study, it was not feasible to match for comorbidities because comorbidity can change with time and, thus, with each phase of care. However, the impact of comorbidities on cost may not be large, at least for CRC; a recent study showed that for CRC patients, matching to controls on comorbidity did not change cancer-attributable cost estimates in an important way (10). We used the date the prescription was filled to assign oral

prescription drug payment to an observation month. This may understate costs in subsequent months for prescriptions with longer duration (eg, 90 days). Other important limitations are that our estimates do not include younger patients younger than 65 years, patients enrolled in Medicare Advantage (HMO), and patients residing outside the SEER geographic areas.

In summary, cancer attributable costs are becoming increasingly important to monitor the economic burden of cancer. The method and estimates provided in this article advance previous estimates by including people with a prior history of cancer and Part D costs and by providing cost estimates not only by phases of care but by different tumor and demographic characteristics. CRC patients with prior cancers have a cost burden that is only slightly higher than for individuals with only one cancer in the initial and EOL cancer death phases. However, in the continuing and EOL noncancer death phases, CRC patients with prior cancers had higher costs. With increasing prevalence of multiple cancer diagnoses, including costs for individuals with multiple cancer is becoming increasingly important and may affect estimates of total expenditures.

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