Medical Care Costs Associated with Cancer Survivorship in the United States

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ABSTRACT

Background: The prevalence of cancer survivorship is increasing. In this study, we provide contemporary population–based estimates and projections of the overall and site-specific cancer-attributable medical care costs in the United States.

Methods: We identified survivors aged ≥65 years diagnosed with cancer between 2000 and 2012 from the Surveillance, Epidemiology, and End Results (SEER)-Medicare database and used 2007 to 2013 claims to estimate costs by cancer site, phases of care, and stage at diagnosis. Annualized average cancer-attributable costs for medical care (Medicare Parts A and B) and oral prescription drugs (Medicare Part D) were estimated by subtracting costs between patients with cancer and matched controls. Costs are reported in 2019 U.S. dollars. We combined phase-specific attributable costs with prevalence projections to estimate national costs from 2015 through 2030.

Results: Overall annualized average costs were highest in the end-of-life–cancer death phase, followed by the initial and continuing phases (medical care: $105,500, $41,800, and $5,300 and oral prescription drugs: $4,200, $1,800, $1,100, respectively). There was considerable variation in costs by cancer site and stage. Overall national costs in 2015 were $183 billion and projected to increase 34% to $246 billion by 2030, based only on population growth.

Conclusions: Phase of care cancer-attributable cost estimates by cancer site and stage are key inputs for simulation models and cost-effectiveness analyses.

Impact: The national cancer-attributed medical care costs in the United States are substantial and projected to increase dramatically by 2030, due to population changes alone, reflecting the rising burden of cancer care among cancer survivors.

See the interview with Angela B. Mariotto, PhD, recipient of the 2024 CEBP Frederick P. Li Impact Award: https://vimeo.com/992980417

Introduction

Almost 17 million individuals are currently alive with a history of cancer in the United States (1). The prevalence of cancer survivorship is expected to increase because of the aging and growing U.S. population, and advances in effective screening, early detection, and treatment (1). Thus, an increasing number of cancer survivors will receive cancer-related medical care at diagnosis, and some will receive cancer care throughout the rest of their lives.

Based only on population aging and growth, the medical national costs associated with cancer were previously projected to increase 27% between 2010 and 2020, from $124.6 billion to $157.8 billion (in 2010 dollars; ref. 2). Recent trends that show greater treatment intensity, with more patients with cancer being treated and for longer periods of time (3, 4), increasing use of supportive agents and advanced imaging and increasing cost of cancer treatment (5, 6) have accelerated the growth in costs. Thus, medical care costs associated with cancer survivorship will likely exceed earlier projections.

Most medical care cost studies are limited as they evaluated a small number of cancer sites (7) or did not estimate costs by cancer site or stage of disease at diagnosis (8, 9), limiting their utility for evaluating the economic impact of recent trends in cancer incidence, patterns of care, and survival (10). Another study used data for multiple cancer sites, but reported all costs following a cancer diagnosis, rather than only those attributable to cancer (11). With improving cancer survival (12) and increasing prevalence of multiple comorbidities (13), it is critical to assess cancer-attributable costs; otherwise medical cost estimates will be influenced by conditions other than cancer, especially in an elderly population. Thus, the purpose of this study is to address limitations in prior research and provide contemporary estimates of the cancer-attributable costs for 21 most common cancer sites, by phase of care, stage of disease at diagnosis, and type of cost (medical services and oral prescription drugs), key inputs for simulation models and cost-effectiveness analyses of cancer control interventions. We also project total national cancer-attributable costs, overall and separately for many cancers. Our estimates by single cancer site use the assumption of constant incidence, survival and cost and represent the impact of ageing and growth of the U.S. population under current cancer control interventions. For all cancer sites combined, we also report projections extrapolating incidence and survival trends.

Materials and Methods

Data sources

We used the National Cancer Institute's (NCI) Surveillance, Epidemiology, and End Results (SEER) registry data (14) linked with the Centers for Medicare and Medicaid's (CMS) Medicare data to estimate health care cancer-attributable costs for cancer survivors aged 65 years and older (15). The SEER data include age at diagnosis, cancer site, stage, date of diagnosis, vital status, and cause of death for all patients diagnosed with incident cancers. We used the SEER historical stage that classifies solid tumors into localized, regional, and distant disease at diagnosis (ref. 16; https://seer.cancer.gov/seerstat/variables/seer/yr1973_2009/lrd_stage/index.html). For prostate cancer historical stage classifies tumors into local/regional versus distant, because

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Note: Supplementary data for this article are available at Cancer Epidemiology, Biomarkers & Prevention Online (http://cebp.aacrjournals.org/).

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regional and local disease can only be well evaluated for patients receiving prostatectomy and not all patients received prostatectomy.

The SEER data have been linked to Medicare enrollment and claims, to create the SEER-Medicare database (17). Medicare enrollment data contain individual-level demographic characteristics, and monthly indicators for enrollment in: Part C (Medicare Advantage-claims not available) or fee-for-service (FFS) plans, Parts A (inpatient), B (outpatient), and D (oral prescription drugs), and Part D low-income subsidy (LIS). Medicare Parts A and B claims data include payments and dates of service for beneficiaries with FFS coverage for inpatient hospitalizations, skilled nursing facility care, outpatient hospital services, physician/supplier services, infusion/injectable drugs or their oral equivalent, durable medical equipment, hospice, and home health care. Medicare Part D claims data include payments and dates of service for oral prescription drugs. The SEER-Medicare database also includes Medicare data for a 5% random sample of all Medicare beneficiaries residing in the SEER areas. Payments and dates of services for beneficiaries included in the 5% random sample without a cancer diagnosis in the SEER data serve as controls for calculation of costs attributable to a cancer diagnosis. We combined Medicare payments and patient responsibility (copayments, coinsurance, deductibles, and payments from other insurers) to represent the costs of care.

Methods to estimate cancer-attributable annualized average costs by phases of care

Methods for identifying eligible cases and controls, defining and assigning observation time to phases of care, matching cases and controls, and estimating phase-specific cancer attributable costs consists of four steps, briefly described below. A more detailed description of the methods for each step has previously been published (18).

Step 1: Identification of eligible cancer survivors and controls

We estimate costs from claims between 2007 and 2013 for persons diagnosed with any cancer, thereafter referred as survivors, between 2000 and 2012 in the SEER-18 areas (19). We include individuals diagnosed prior to 2007 to estimate current costs for long-term survivors. Unlike prior studies (2, 20), we included survivors with multiple primary cancers, as over 20% of cancer diagnosed among the 65 years and older population had a prior cancer (21). We excluded cancer cases identified by death certificate or autopsy and those whose date of birth differed by more than 1 year between the SEER registry data and Medicare enrollment data. To estimate costs, survivors were required to have at least 1 month of observation between 2007 and 2013 in which they were ≥65 years and enrolled in a FFS plan with both Parts A and B coverage.

Step 2: Assigning months of observation to phases of care

Months of observation were defined as the months for which an individual met the initial inclusion criteria between 2007 and 2013, as described above. Phase definitions are consistent with previous studies (2, 20). For survivors, months of observation after each tumor diagnosis were classified into three clinically relevant phases: the initial phase, defined as the first 12 months after each diagnosis; the end-of-life (EOL) phase, defined as the 12 months before death among survivors who died, and the continuing phase, the months in-between the initial and the EOL phases. We further divided the EOL phase into months of observation contributed by survivors who died from cancer (EOL-cancer death) or from other causes (EOL-noncancer death). For survivors who survived less than 24 months after their cancer diagnosis, months were first assigned to the EOL phase (up to 12 months) and the remaining months were then assigned to the initial phase. Months of observations for survivors were censored at the diagnosis of a subsequent tumor, date of death or age 99 because of small numbers. For cases with unknown cause of death, we censored months of observations at 12 months prior to death because of an inability to classify patients into EOL-cancer versus EOL-noncancer. We included cases diagnosed in the earlier years (2000–2006) to calculate continuing and EOL phase costs for long-term survivors and to be more aligned with prevalence estimates that include all survivors.

Months of observation for controls were assigned to two phases: the EOL phase, the 12 months prior to death among controls who died and the continuing phase, which included all other months. Months of observations for controls were also censored at the date of first cancer diagnosis, age 99, or date of death. Once the months of observation for cases and controls were allocated to the respective phases, they were then stratified by calendar year (18).

Step 3: Matching controls to cases

Months of observation for survivors and controls were matched in a 1:1 ratio by phase of care, calendar year, registry, sex, age (to the nearest year), race and Medicare Part D enrollment and entitlement status (not enrolled in Part D, Part D LIS, and Part D non-LIS) because not all Medicare beneficiaries have Part D prescription drug coverage. Similar to previous studies (20, 22), 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 (18).

Step 4: Estimating cancer-attributable annualized average costs by phases of care

Costs were calculated from Medicare payments and patient responsibility (copayments, coinsurance, deductibles, and payments from other insurers) for each month of observation based on the amounts listed in Medicare Parts A and B claims (medical services costs) and Part D claims (oral prescription drug costs). Each claim's date of service was used to assign the cost to an observation month. The average monthly cost attributable to cancer was estimated as the difference between the average monthly cost between cases and controls. All costs are reported as annualized average cost, calculated as the average monthly cost multiplied by 12, and inflated to the 2019 U.S. dollars using the Medical Consumer Price Index (CPI) – All Urban (23).

Method to estimate U.S. cancer prevalence

We used cancer prevalence estimates and projections recently developed for the 15 most prevalent cancer sites (24) that used the Prevalence Incidence Approach Model (PIAMOD) approach (25, 26). This method fits an age, period and cohort (APC) Poisson model to cancer incidence data, where each APC component is modeled either as a polynomial or spline function (25). Log-likelihood ratio tests are used to select the best fitted model (e.g., degrees of polynomials or number and location of spline knots). Once the best fitted model is chosen, prevalence is estimated from an equation that calculates prevalence as the sum of past incidence times survival to the prevalence date.

The inputs for the model are survival and incidence data for the period 1975–2015 from the 9 oldest SEER registries (19), U.S. populations by single year of age and year and projections through 2030 as estimated from the U.S. Census Bureau (27). U.S. incidence counts are estimated by applying SEER incidence rates by age and year at

diagnosis, and race, to the respective U.S. populations. Survival is modeled by fitting cancer-specific relative survival to cure survival models by age and period of diagnosis using the CANSURV software (ref. 28; https://surveillance.cancer.gov/cansurv/) described in detail elsewhere (2, 29).

Prevalence projections

We used an assumption of dynamic population changes and constant incidence, survival, and cost trends for cancer site–specific projections. This assumption represents the most basic projection scenario of the impact of the aging and growth of the U.S. population under current cancer interventions and is a starting point for other trend scenarios. For all cancer sites combined, we also considered two trend scenarios: (i) projection of recent incidence trends and (ii) both incidence and survival trends. For the constant incidence scenario, we assume incidence rates by age and race from 2016 to 2030 to be the same as the 3-year average SEER age–specific rate in 2013 to 2015. For the incidence trend scenario, we assume that the age and cohort components of the APC incidence model hold in the future. For projections of period effect, PIAMOD uses a more cautious approach, by extrapolating a linear trend estimated in the most recent period (2011–2015; ref. 25). Details of the method is provided in the Supplementary Materials. The constant survival trend scenario assumes future survival as equal to the most recent year of data 2015, whereas the linear trend scenario extrapolates survival using a period trend parameter as described in Mariotto and colleagues (2011; ref. 2).

Prevalence was then decomposed into four different phases of care: initial, continuing, and EOL-cancer death and EOL-noncancer death phases using previously developed methods (2, 29).

National costs attributable to cancer survivorship

To estimate and project national cancer-attributed costs, we combined prevalence projections with the annualized average cost estimates using previously described methods (2). We used ratios of 1.2 and 1.5 to adjust the annual attributable cost for patients with cancer younger than 65 years treated in the initial and EOL-cancer phases, respectively, for both medical services and prescription drugs costs. Attributable costs in the continuing and EOL-noncancer phases were assumed to be the same in both age groups. If annualized cancer-attributable costs were negative, we assumed them to be zero. We assumed that costs remained constant at the levels of the most recent data, 2007 to 2013. We multiplied the annualized net costs of cancer care with U.S. prevalence estimates by age (<65, 65+), sex, cancer site, and phase of care and did summations to obtain national estimates of costs of care. National projected costs are reported in 2019 U.S. dollars.

Table 1. Number[a] of patients with cancer (rounded to 100s) diagnosed between 2000 and 2012, overall and by cancer site, with Medicare Parts A and B claims data between 2007 and 2013 to contribute to each phase of care cost calculations, SEER-Medicare.

	Medicare Parts A and B			
			Last year of life	
Site	Initial	Continuing	Cancer	Noncancer
All sites	808,100	1,316,900	436,900	270,800
Bladder	52,400	74,900	15,100	19,600
Brain	2,800	2,400	7,800	1,700
Breast	126,000	250,100	22,500	35,900
Cervix uteri	2,200	4,200	1,600	700
Colorectal	81,200	137,600	42,000	34,500
Esophagus	5,200	5,100	8,400	1,600
Hodgkin	1,400	2,500	800	500
Kidney	26,700	40,000	10,800	8,100
Leukemia	18,300	24,800	15,100	7,300
AML	2,200	1,800	7,400	1,000
CLL	11,700	17,500	3,800	4,300
CML	2,500	3,100	1,500	1,200
Liver	5,600	4,900	9,200	2,200
Lung	73,800	70,000	124,200	24,700
Lung—NSC	68,100	66,400	106,700	23,000
Lung—SC	5,700	3,600	17,500	1,700
Melanoma	64,400	97,500	7,200	15,600
Myeloma	11,700	13,900	9,600	3,700
Non-Hodgkin	34,400	52,900	18,000	11,300
Oral cavity	15,800	23,400	8,200	5,200
Ovary	8,000	11,800	10,200	1,400
Pancreas	8,800	5,300	29,500	2,400
Prostate	158,800	335,500	23,400	48,500
Stomach	9,400	10,600	11,800	3,300
Thyroid	10,600	19,200	1,600	1,700
Uterus	22,000	42,100	7,500	5,800

Abbreviations: AML, acute myeloid leukemia; CLL, chronic lymphocytic leukemia; CML, chronic myeloid leukemia; NSC, non–small cell; SC, small cell.
[a]Due to 1:1 matching, an equivalent number of controls contributed to each phase. Phases of care are as follows: initial, the first 12 months after each diagnosis; end-of-life (EOL), the 12 months before death; and continuing, the months in between the initial and the EOL phases.

Results

Table 1 shows the number of patients with cancer contributing to the calculation of costs in each phase of care overall and by cancer site. Because of 1:1 matching, there was an equivalent number of controls who contributed to each phase. For all cancer sites combined, cancer-attributable annualized average medical costs (Parts A and B) were highest in the EOL-cancer phase followed by the initial phase and continuing phase of care, respectively, $105K, $42K, and $5K (**Table 2**). Annualized costs for EOL-noncancer death were substantially lower than EOL-cancer death phase. Annualized cancer-attributable costs in the EOL-cancer phase ranged from $71K (prostate) to $239K (acute myeloid leukemia: AML). Average annualized attributable medical costs in the initial phase were highest among patients diagnosed with AML ($183K), brain ($134K), pancreas ($104K), esophageal ($86K), and small-cell lung cancer ($82K) and lowest among patients diagnosed with melanoma ($8K), thyroid ($24K), chronic lymphocytic leukemia (CLL; $25K), and bladder ($25K; **Table 2**).

Annualized attributable oral prescription drug (Part D) costs in the initial phase were highest among patients diagnosed with chronic myeloid leukemia (CML; 31K) and myeloma ($29K) followed by AML ($9K), liver ($9K), and pancreas (5K; **Table 2**). For these cancer sites, oral prescription drug costs remained high in all phases of care. Oral prescription drug costs were also high in the EOL-cancer phases for kidney ($11K) and prostate cancers ($6K). Women diagnosed with cervical cancer had small negative cancer-attributable oral prescription drug costs in all phases except in the EOL-cancer phase. We also observed small negative prescription annualized costs for uterus and ovary in the EOL-noncancer phase. Patients enrolled in Part D with LIS had overall higher cancer-attributable oral prescription drug costs compared with patients with no LIS enrollment (Supplementary Table S1).

Annualized cancer-attributable costs also varied by stage at diagnosis. In general, within a phase of care, costs were highest for patients diagnosed with distant stage disease (**Table 3**). The exceptions were

Table 2. Cancer-attributable annualized average costs[a] in 2019 U.S. thousand dollars for medical services (Medicare Parts A and B) and oral prescription drugs (Medicare Part D) by cancer site and phases of care, SEER-Medicare.

	Costs in 2019 U.S. thousand dollars							
	Medical services costs				Oral prescription drugs costs			
			End of life				End of life	
Site	Initial	Cont.	Cancer	Noncancer	Initial	Cont.	Cancer	Noncancer
All sites	$41.8	$5.3	$105.5	$23.5	$1.8	$1.1	$4.2	$1.2
Bladder	$25.4	$6.1	$92.2	$21.8	$0.7	$0.5	$1.3	$0.3
Brain	$134.4	$16.7	$169.5	$98.5	$2.3	$1.4	$1.8	−$0.8
Breast	$33.7	$3.5	$73.2	$10.1	$1.1	$0.8	$2.7	$0.6
Cervix uteri	$56.5	$3.9	$93.3	$28.2	−$0.3	−$0.6	$0.6	−$0.7
Colorectal	$63.9	$6.1	$105.9	$27.7	$0.5	$0.3	$1.3	$0.2
Esophagus	$86.5	$9.5	$115.3	$53.2	$1.5	$0.8	$1.0	$0.2
Hodgkin	$72.5	$9.5	$123.9	$38.1	$2.8	$0.6	$2.6	$0.2
Kidney	$39.5	$8.3	$92.3	$31.2	$2.3	$1.9	$11.4	$1.6
Leukemia	$45.5	$12.3	$162.9	$45.3	$6.7	$6.7	$5.8	$4.7
AML	$182.9	$21.0	$239.4	$144.4	$8.8	$4.0	$4.8	$5.4
CLL	$24.6	$11.6	$90.4	$27.4	$0.7	$0.8	$2.9	$1.0
CML	$33.6	$13.5	$117.6	$55.7	$31.3	$44.9	$14.8	$20.0
Liver	$60.4	$17.6	$88.5	$47.2	$8.5	$7.4	$11.8	$6.3
Lung	$65.7	$11.9	$106.0	$38.3	$3.5	$2.7	$4.5	$1.3
Lung—NSC	$64.6	$11.8	$104.8	$37.7	$3.6	$2.8	$4.9	$1.4
Lung—SC	$82.0	$14.2	$113.5	$46.9	$2.2	$1.2	$1.8	$0.0
Melanoma	$8.3	$2.7	$75.8	$4.8	$0.6	$0.4	$3.8	$0.8
Myeloma	$74.0	$27.4	$118.6	$58.8	$28.8	$25.4	$24.0	$14.2
Non-Hodgkin	$72.3	$12.3	$139.0	$33.7	$1.6	$0.7	$2.6	$0.8
Oral cavity	$56.4	$5.7	$105.7	$22.3	$0.5	$0.1	$0.9	$0.0
Ovary	$76.0	$13.6	$107.6	$37.9	$1.1	$0.1	$1.0	−$0.6
Pancreas	$103.9	$17.8	$120.1	$75.8	$5.3	$3.8	$5.6	$2.3
Prostate	$27.1	$2.5	$71.3	$7.3	$0.4	$0.4	$5.7	$0.8
Stomach	$76.0	$6.9	$117.2	$48.5	$3.3	$2.5	$1.8	$1.5
Thyroid	$23.9	$4.0	$103.2	$19.4	$1.0	$0.9	$5.3	$0.9
Uterus	$37.5	$3.0	$89.9	$12.9	$0.2	$0.0	$1.1	−$0.1

Abbreviations: AML, acute myeloid leukemia; CLL, chronic lymphocytic leukemia; CML, chronic myeloid leukemia; NSC, non–small cell; SC, small cell.
[a]Costs calculated from 2007 to 2013 Medicare claims for patients diagnosed with cancer between 2000 and 2012 and 65 years or older. Phases of care are as follows: initial, the first 12 months after each diagnosis; end-of-life (EOL), the 12 months before death; and continuing, the months in between the initial and the EOL phases.

pancreas, esophageal, or stomach cancers where initial costs were higher among patients diagnosed with regional stage disease. Oral prescription drug costs were also, in general, higher for patients diagnosed with distant stage disease (**Table 3**); the highest observed oral prescription drug costs were for patients diagnosed with distant kidney and liver cancers in the initial phase of care ($20K and $19K, respectively). Oral prescription drug costs for patients diagnosed with liver cancer consistently made it one of the most expensive cancer sites, regardless of phase of care and stage at diagnosis.

In 2015, the national cost for medical services for cancer survivors of all ages was estimated to be $165 billion and for prescription drugs was $18 billion, totaling $183 billion (**Table 4**). The national cost of medical services in 2015 was highest in the continuing phase ($68 billion) followed by the initial ($48 billion) and EOL-cancer death ($40 billion) phases. Because most high prevalence cancers have a large number of survivors in the continuing phase, national continuing phase costs are higher than initial costs. Exceptions are lung, oral cavity, colorectal, and prostate cancer for which costs in the initial phases are higher or similar. Total national costs for medical services and oral prescription drug costs were highest for the most common cancer sites: female breast cancer ($26 billion), colorectal ($21 billion), lung ($20 billion), and prostate ($19 billion). National prescription oral drugs costs overall are highest for female breast ($2.7 billion), leukemia ($2.4 billion), lung ($1.4 billion), and prostate ($1.3 billion) cancers.

Based solely on population changes due to aging and growth, total national costs are projected to increase by 34% to $246 billion in 2030 (**Table 5**). In the same period, national costs for medical services are projected to increase by 34% and prescription drugs by 40%. Cancer sites for which population changes will increase costs more than the average (34%) from 2015 through 2030 are bladder (45%), kidney (54%), leukemia (51%), melanoma (51%), non-Hodgkin (45%), prostate (46%), and thyroid (55%) cancers (**Table 5**). If both incidence and survival recent trends continue in the future, cost projections will still increase for both males and females (**Table 6**). However, compared with the base scenario, the estimates in 2030 are higher for females (trend: $133 billion vs. base: $129 billion) and lower for males (trend: $106 billion vs. base: $117 billion).

Discussion

In this study, we used the linked SEER-Medicare data to provide contemporary estimates of cancer-attributable medical costs for older cancer survivors in the United States, including survivors with multiple cancers. We applied these medical cost estimates to projections of the national prevalence of cancer survivorship and found that the national cancer-attributable medical costs of care including inpatient and outpatient services and prescription drugs were $183 billion in year 2015. When medical cost estimates were combined with projected

Table 3. Cancer-attributable annualized average costs[a] in 2019 U.S. dollars for medical services (Medicare Parts A and B) and oral prescription drugs (Medicare Part D) by cancer site, phase of care, and stage of disease at diagnosis.

	Medical services costs in 2019 U.S. thousand dollars								
	Initial			Continuing			EOL-cancer		
Site	Local[b]	Regional	Distant	Local	Regional	Distant	Local	Regional	Distant
Bladder	$19.4	$64.8	$86.1	$5.7	$9.1	$14.4	$73.3	$104.9	$139.4
Breast	$30.4	$50.7	$67.4	$2.9	$5.2	$22.3	$65.7	$72.0	$91.9
Cervix uteri	$41.1	$66.3	$78.2	$2.7	$4.4	$15.4	$77.9	$92.2	$111.0
Colorectal	$46.4	$78.9	$125.8	$4.6	$6.8	$31.4	$89.1	$100.9	$126.7
Esophagus	$74.7	$103.4	$94.7	$9.0	$8.2	$19.2	$101.5	$122.0	$120.5
Kidney	$35.2	$47.5	$70.5	$7.7	$9.1	$20.0	$81.3	$87.8	$112.5
Liver	$60.7	$63.2	$72.3	$17.6	$19.3	$11.9	$81.9	$89.9	$116.4
Lung	$51.4	$70.6	$88.1	$8.9	$12.1	$26.2	$80.5	$95.6	$123.1
Lung—NSC	$51.0	$69.7	$87.8	$8.9	$12.0	$27.3	$80.3	$94.7	$123.4
Lung—SC	$67.0	$80.8	$89.6	$11.6	$13.7	$17.5	$84.6	$102.1	$121.4
Melanoma	$8.8	$28.9	$60.9	$2.8	$6.5	$15.5	$65.6	$75.3	$119.2
Oral cavity	$30.2	$77.0	$88.4	$4.8	$6.3	$8.1	$86.1	$108.4	$123.3
Ovary	$44.2	$67.4	$86.6	$2.7	$9.0	$21.9	$79.8	$92.5	$111.3
Pancreas	$79.8	$121.7	$101.1	$11.4	$18.5	$33.6	$104.5	$119.9	$130.4
Prostate#	—	$26.8	$33.0	—	$2.3	$14.4	—	$69.0	$78.7
Stomach	$62.5	$103.7	$96.8	$5.6	$7.0	$17.1	$100.9	$120.4	$132.8
Thyroid	$18.3	$30.9	$61.8	$3.6	$4.2	$9.2	$83.7	$104.6	$122.1
Uterus	$29.5	$53.4	$75.5	$2.4	$5.1	$9.7	$80.6	$86.5	$110.9

	Oral prescription drug costs in 2019 U.S. thousand dollars								
	Initial			Continuing			EOL-cancer		
Site	Local[b]	Regional	Distant	Local[b]	Regional	Distant	Local[b]	Regional	Distant
Bladder	$0.6	$0.7	$0.9	$0.6	−$0.1	−$0.2	$2.0	$0.7	$1.3
Breast	$1.1	$1.6	$1.7	$0.8	$1.2	$2.3	$2.8	$2.8	$2.7
Cervix uteri	−$0.2	−$0.5	−$0.7	−$0.4	−$1.0	−$0.8	$2.9	$0.3	−$0.4
Colorectal	$0.4	$0.4	$1.1	$0.3	$0.1	$0.5	$1.3	$1.3	$1.6
Esophagus	$1.4	$1.0	$2.9	$1.0	$0.0	$1.2	$1.0	$0.7	$1.4
Kidney	$1.2	$1.7	$20.0	$1.5	$2.7	$13.0	$7.9	$11.2	$16.8
Liver	$7.1	$12.6	$18.6	$7.1	$8.8	$10.1	$10.9	$14.5	$13.4
Lung	$2.0	$2.5	$7.7	$1.8	$2.6	$6.9	$3.9	$4.2	$5.0
Lung—NSC	$2.0	$2.5	$8.4	$1.9	$2.7	$7.7	$4.0	$4.5	$5.7
Lung—SC	$2.1	$2.2	$2.5	$1.0	$1.2	$1.1	$1.7	$2.0	$1.8
Melanoma	$0.6	$1.8	$2.1	$0.4	$0.7	$0.6	$3.5	$3.5	$3.9
Oral cavity	$0.6	$0.4	$0.5	$0.3	−$0.2	$0.0	$1.4	$0.6	$1.3
Ovary	$0.4	$0.8	$1.4	$0.1	−$0.2	$0.3	$1.9	$0.7	$1.0
Pancreas	$3.0	$4.8	$9.0	$2.7	$3.6	$7.0	$3.9	$5.4	$7.0
Prostate#	—	$0.3	$1.5	—	$0.3	$4.5	—	$5.5	$6.8
Stomach	$3.8	$1.7	$5.5	$2.1	$1.5	$10.5	$2.1	$1.5	$2.0
Thyroid	$0.9	$0.7	$3.4	$0.8	$1.0	$3.4	$7.9	$5.7	$3.2
Uterus	$0.1	$0.2	$0.9	$0.0	$0.0	−$0.1	$1.5	$0.9	$1.3

Abbreviations: AML, acute myeloid leukemia; CLL, chronic lymphocytic leukemia; CML, chronic myeloid leukemia; NSC, non–small cell; SC, small cell.
[a]Costs calculated from 2007 to 2013 Medicare claims for patients diagnosed with cancer between 2000 and 2012 and 65 years or older. Phases of care are as follows: initial, the first 12 months after each diagnosis; end-of-life (EOL), the 12 months before death; and continuing, the months in between the initial and the EOL phases.
[b]We used the SEER historical stage that classifies solid tumors into localized, regional, and distant. #, For prostate cancer, historical stage classifies tumors into local/regional versus distant.

cancer survivorship prevalence in 2030, national cancer-attributable costs of care increased by 34% to $246 billion, based solely on the aging and growth of the U.S. population.

We refined and expanded prior research estimating and projecting the costs of cancer care in two important ways. First, in this study, costs and prevalence estimates included people diagnosed with multiple tumors, better reflecting the population of cancer survivors and their costs of care in the United States. Previous research found that costs for those with prior cancers compared to those without prior cancers were higher in the continuing and EOL-noncancer death phases (18). More importantly, we included cancer-attributable costs for oral prescription drugs from Medicare Part D. These costs varied widely by cancer sites and were highest for some hematologic cancers, including CML, ALL, and myeloma. Inclusion of oral prescription drugs costs increased the national costs estimates by 10% in 2015. The highest increase from including oral prescription drugs was 27% for leukemias, representing $2.35 billion. From 2000 to 2014, the average annual list price of new cancer drugs increased dramatically from $5,000 to $10,000 to $120,000 to

Table 4. National cost estimates by phases of care and cancer site for medical services and oral prescription drugs in 2015.

	2015 national costs in 2019 billion dollars														
	Medical services					Oral prescription drugs					Medical services and oral prescription drugs				
			End-of-life					End-of-life					End-of-life		
Site	Initial	Cont.	Cancer	Non-cancer	Total	Initial	Cont.	Cancer	Non-cancer	Total	Initial	Cont.	Cancer	Non-cancer	Total
All sites	$47.80	$68.19	$40.04	$8.77	$164.81	$2.07	$13.69	$1.62	$0.46	$17.84	$49.87	$81.88	$41.67	$9.23	$182.65
Bladder	$1.77	$3.80	$1.40	$0.57	$7.54	$0.05	$0.34	$0.02	$0.01	$0.39	$1.82	$4.14	$1.42	$0.58	$7.93
Breast	$8.24	$10.59	$3.35	$0.61	$22.79	$0.28	$2.54	$0.12	$0.04	$2.74	$8.51	$13.13	$3.47	$0.65	$25.53
Cervix uteri	$0.63	$1.00	$0.37	$0.15	$2.15	$0.00	−$0.15	$0.00	$0.00	—	$0.58	$0.92	$0.34	$0.14	$1.98
Colorectal	$7.83	$7.29	$4.68	$1.09	$20.89	$0.06	$0.36	$0.06	$0.01	$0.46	$7.89	$7.65	$4.75	$1.10	$21.35
Hodgkin	$0.72	$1.86	$0.20	$0.09	$2.88	$0.03	$0.12	$0.01	$0.00	$0.14	$0.75	$1.98	$0.20	$0.09	$3.02
Kidney	$1.79	$3.41	$1.26	$0.37	$6.83	$0.10	$0.80	$0.16	$0.02	$1.00	$1.90	$4.21	$1.42	$0.39	$7.83
Leukemia	$1.67	$4.02	$2.59	$0.42	$8.69	$0.24	$2.18	$0.09	$0.04	$2.35	$1.91	$6.19	$2.68	$0.46	$11.05
Lung	$5.08	$3.96	$8.87	$0.76	$18.67	$0.27	$0.88	$0.37	$0.03	$1.43	$5.35	$4.84	$9.24	$0.79	$20.10
Melanoma	$0.66	$2.74	$0.74	$0.09	$4.23	$0.05	$0.38	$0.04	$0.01	$0.44	$0.71	$3.12	$0.78	$0.10	$4.67
Non-Hodgkin	$4.51	$6.85	$3.02	$0.59	$14.98	$0.10	$0.38	$0.06	$0.01	$0.51	$4.61	$7.23	$3.08	$0.61	$15.48
Oral cavity	$1.80	$1.62	$1.46	$0.24	$5.12	$0.02	$0.02	$0.01	$0.00	$0.05	$1.82	$1.64	$1.47	$0.14	$5.17
Ovary	$1.39	$2.64	$1.45	$0.12	$5.59	$0.02	$0.02	$0.01	$0.00	$0.05	$1.41	$2.66	$1.46	$0.14	$5.65
Prostate	$7.38	$6.88	$2.29	$0.67	$17.23	$0.10	$1.05	$0.18	$0.07	$1.29	$7.48	$7.93	$2.47	$0.75	$18.52
Thyroid	$1.13	$2.76	$0.25	$0.15	$4.29	$0.05	$0.64	$0.01	$0.01	$0.65	$1.18	$3.40	$0.26	$0.15	$4.94
Uterus	$1.91	$1.95	$0.97	$0.21	$5.04	$0.01	$0.00	$0.01	$0.00	$0.02	$1.92	$0.14	$0.98	$0.14	$5.05

Note: Phases of care are as follows: initial, the first 12 months after each diagnosis; end-of-life (EOL), the 12 months before death; and continuing, the months in between the initial and the EOL phases. Costs in 2019 billion dollars.

$170,000 (30). List price increases for existing drugs occurred during this time as well. For example, the cost for tyrosine kinase inhibitors (TKI), one of the most commonly used targeted therapies for hematologic cancers, was $30,000 per year in 2001 and by 2012, that price tag had tripled to $92,000 per year (31). With increasing oral cancer drug prices, ongoing monitoring will be important.

The average overall annualized costs for medical services were $41.8K, $5.3K and $105.5K for all cancer survivors in the initial, continuing, and

Table 5. National cost projections and percent increase (in bold) from 2015 to 2030 by cancer site using constant trends of incidence, survival, and costs.

	National costs in 2019 billion dollars-constant trends of incidence, survival, and costs														
	Medical services					Oral prescription drugs					Medical services and oral prescription drugs				
Site	2015	2020	2025	2030	Increase 2015–2030	2015	2020	2025	2030	Increase 2015–2030	2015	2020	2025	030	Increase 2015–2030
All sites	$164.8	$180.6	$199.8	$220.7	**34%**	$17.8	$20.0	$22.4	$24.9	**40%**	$182.6	$200.7	$222.2	$245.6	**34%**
Bladder	$7.5	$8.5	$9.7	$10.9	**45%**	$0.4	$0.5	$0.6	$0.6	**48%**	$8.0	$9.0	$10.2	$11.6	**45%**
Breast	$22.8	$25.2	$27.7	$30.1	**32%**	$3.0	$3.4	$3.8	$4.2	**41%**	$25.8	$28.6	$31.5	$34.3	**33%**
Cervix uteri	$2.2	$2.2	$2.2	$2.2	**3%**	—	—	—	—	—	$2.2	$2.2	$2.2	$2.2	**3%**
Colorectal	$20.9	$22.8	$25.0	$27.7	**33%**	$0.5	$0.6	$0.6	$0.7	**36%**	$21.4	$23.3	$25.7	$28.4	**33%**
Hodgkin	$2.9	$3.2	$3.4	$3.7	**29%**	$0.2	$0.2	$0.2	$0.2	**33%**	$3.0	$3.3	$3.6	$3.9	**29%**
Kidney	$6.8	$8.0	$9.3	$10.5	**53%**	$1.1	$1.3	$1.5	$1.7	**59%**	$7.9	$9.3	$10.8	$12.2	**54%**
Leukemia	$8.7	$10.1	$11.5	$13.0	**49%**	$2.6	$3.0	$3.5	$4.0	**56%**	$11.3	$13.1	$15.0	$17.0	**51%**
Lung	$18.7	$21.1	$23.3	$25.3	**36%**	$1.6	$1.8	$2.0	$2.2	**39%**	$20.2	$22.8	$25.3	$27.5	**36%**
Melanoma	$4.2	$4.9	$5.7	$6.4	**50%**	$0.5	$0.6	$0.7	$0.7	**54%**	$4.7	$5.5	$6.3	$7.1	**51%**
Non-Hodgkin	$15.0	$17.2	$19.5	$21.7	**45%**	$0.6	$0.6	$0.7	$0.8	**49%**	$15.5	$17.8	$20.2	$22.5	**45%**
Oral cavity	$5.1	$5.7	$6.2	$6.7	**30%**	$0.1	$0.1	$0.1	$0.1	**40%**	$5.2	$5.7	$6.3	$6.7	**30%**
Ovary	$5.6	$6.1	$6.6	$7.0	**25%**	$0.1	$0.1	$0.1	$0.1	**17%**	$5.7	$6.2	$6.6	$7.0	**25%**
Prostate	$17.2	$19.8	$22.4	$25.0	**45%**	$1.4	$1.6	$1.9	$2.2	**54%**	$18.6	$21.4	$24.4	$27.2	**46%**
Thyroid	$4.3	$5.0	$5.8	$6.6	**54%**	$0.7	$0.9	$1.0	$1.2	**62%**	$5.0	$5.9	$6.8	$7.8	**55%**
Uterus	$5.0	$5.6	$6.1	$6.6	**32%**	$0.0	$0.0	$0.0	$0.0	**0%**	$5.1	$5.6	$6.1	$6.7	**31%**

Note: National costs for medical services, oral prescription drugs, and total costs by cancer site. Percent increase from 2015 for all sites combined. All estimates in 2019 billion dollars.

Table 6. National cost projections and percent increase (in bold) from 2015 to 2030, for all cancer sites combined and by sex, using different scenarios for projections of incidence and survival.

		National costs in 2019 billion dollars														
		Medical services					Oral prescription drugs					Medical services and oral prescription drugs				
Sex	Trend scenario[a]	2015	2020	2025	2030	Increase 2015–2030	2015	2020	2025	2030	Increase 2015–2030	2015	2020	2025	2030	Increase 2015–2030
Males	Base	$78	$86	$96	$105	**35%**	$8	$9	$10	$12	**40%**	$86	$95	$106	$117	**35%**
	Inc.	$78	$85	$89	$92	**18%**	$8	$9	$10	$10	**25%**	$86	$94	$99	$102	**18%**
	Inc.+Surv.	$78	$86	$91	$95	**22%**	$8	$9	$10	$11	**33%**	$87	$95	$101	$106	**23%**
Females	Base	$87	$95	$104	$116	**33%**	$10	$11	$12	$13	**39%**	$96	$105	$116	$129	**34%**
	Inc.	$88	$98	$108	$118	**34%**	$10	$11	$12	$13	**39%**	$98	$109	$120	$131	**34%**
	Inc.+Surv.	$88	$98	$108	$119	**35%**	$10	$11	$12	$14	**43%**	$98	$109	$120	$133	**36%**
Both	Base	$165	$181	$200	$221	**34%**	$18	$20	$22	$25	**40%**	$183	$201	$222	$246	**34%**
	Inc.	$166	$183	$197	$210	**26%**	$18	$20	$22	$24	**32%**	$184	$203	$219	$234	**27%**
	Inc.+Surv.	$166	$183	$199	$214	**29%**	$18	$20	$23	$25	**38%**	$184	$204	$222	$239	**30%**

Note: National costs for medical services, oral prescription drugs, and total costs by sex. Percent increase from 2015. Costs are in 2019 billion dollars.

[a]All scenarios include the aging and growth of the U.S. population: Base = incidence and survival constant as observed in last years of data; Inc. = future trends of incidence and constant survival; and Inc.+Surv. = future trends of incidence and survival.

EOL-cancer phases, respectively. Annualized costs by cancer site followed a similar pattern. High costs at the initial and EOL phases of care and lower costs in the continuing phase have previously been referred to as a "U-shaped" curve (2, 22). However, we found that costs in the EOL cancer death phase were substantially higher than in the initial phase, suggesting a "J-shaped", rather than a "U-shaped" curve. This J-shaped curve reflects greater treatment intensity at the EOL, especially for patients originally diagnosed with distant disease and those with poor prognosis cancers. Increasingly, professional societies have focused efforts on identifying the value of specific cancer treatments in relation to expected survival and quality of life benefits weighed against side effects, adverse event, and costs of care (32, 33). Ensuring that treatment intensity reflects patient goals of care, especially for cancers with poor prognosis, is a critical component of patient-provider discussions.

Within each phase of care, annualized cancer-attributable costs of care varied by cancer site, reflecting differences in stage distribution, prognosis, and treatment. Costs were generally higher for patients diagnosed with distant rather than localized disease, and shorter survival, reflecting treatment intensity.

Historically, health care in the United States has used a FFS model, which reimburses providers for each service delivered to patients. FFS provides incentives for greater volume of services, without consideration of quality of care, patient outcomes, or cost of care. Other models of care have been developed within Medicare FFS and include Accountable Care Organizations (ACO), networks of primary care and specialty clinicians, usually in partnership with a hospital system, that are accountable for services provided to a defined population. An early evaluation found that utilization and costs are similar for Medicare beneficiaries treated for cancer in ACOs and non-ACO practices (34). More recently, the Oncology Care Model (OCM), an episode-of-care based payment model within Medicare FFS was introduced in more than 150 oncology practices and multiple payers nationwide in 2016 (35). Evaluating quality of care, costs, and patient outcomes in similar cancer patients defined by cancer site, stage at diagnosis, comorbidity burden, and other factors, and treated under these different models of care delivery will be important for future research.

Another model of care within the Medicare program is Medicare Advantage, private plans which are paid a capitated rate or fixed fee for each patient in their defined population. Enrollment in Medicare Advantage has grown in the past decade, and in 2017, comprised 33% (19.0 million) of Medicare beneficiaries. We could not include beneficiaries in Medicare Advantage in this study, because utilization and spending data were not available. However, starting in August 2018, the CMS began releasing these data for research. Evaluating differences in spending and spending increases for patients with cancer in FFS and Medicare Advantage will be important for future research.

Our estimates of cancer-attributable costs in elderly cancer survivors aged 65+ years cannot be directly applied to the population of cancer survivors younger than 65 years. Cancer treatment patterns tend to be more intensive for younger patients (7, 36) and comorbidity prevalence increases with age, in patients with cancer as well as controls without cancer. Therefore, cancer-attributable costs are generally higher in younger than in older cancer survivors (7, 36). Survivors younger than 65 years represented 38% of all cancer survivors in 2015. Future research evaluating costs of medical care for both age groups in the same setting will be important to fill this research gap.

Despite the strengths of evaluating medical services and oral prescription drugs costs separately with a large population-based sample with recently available data, our study had limitations. We used an assumption of dynamic population changes and constant incidence, survival, and costs as estimated in the most recent years of data, for cancer site–specific projections. This assumption represents the impact of the aging and growth of the U.S. population under current cancer interventions on national costs. Projections for all cancer sites using other trend scenarios showed that estimates in 2030 varied depending on the assumption used. Using trends for incidence and survival, the 2030 cost projections decreased by 9% for males, while it increased by 3% for females, compared to the base assumption, reflecting a cancer incidence that was declining for males and stable for females. Very recent data has shown that overall cancer incidence rates are leveling off among males and increasing slightly among females (37). Cancer

site–specific projections under multiple assumptions will be important for future research. Cost estimates are for Medicare FFS beneficiaries only as data for Medicare Advantage enrollees were not available. We assumed cancer-attributable costs were the same for beneficiaries in both settings in our projections of national spending. Estimates of the costs for younger patients were based on prior assumptions. Treatment patterns have been changing rapidly for many cancers and estimates may not fully reflect patterns and costs in 2020.

In summary, the national medical care costs associated with cancer survivorship in the United States in 2015 are substantial and projected to increase dramatically by 2030, due to population changes alone. National projections can inform resource prioritization and planning at local, state, and national levels. Phase-specific cancer-attributable cost estimates by cancer site and stage at diagnosis are critical inputs for simulations and cost-effectiveness studies that can be used to evaluate cancer control interventions, including those addressing prevention, screening and early detection, treatment, and survivorship care.

Disclosure of Potential Conflicts of Interest

No potential conflicts of interest were disclosed.

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Conception and design: A.B. Mariotto, K.R. Yabroff
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