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Lung cancer treatment costs, including patient responsibility, by disease stage and treatment modality, 1992 to 2003

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A B S T R A C T

Objectives: The objective of this analysis was to estimate costs for lung cancer care and evaluate trends in the share of treatment costs that are the responsibility of Medicare beneficiaries.

Methods: The Surveillance, Epidemiology, and End Results (SEER)-Medicare data from 1991–2003 for 60,231 patients with lung cancer were used to estimate monthly and patient-liability costs for clinical phases of lung cancer (prediagnosis, staging, initial, continuing, and terminal), stratified by treatment, stage, and non-small- versus small-cell lung cancer. Lung cancer-attributable costs were estimated by subtracting each patient's own prediagnosis costs. Costs were estimated as the sum of Medicare reimbursements (payments from Medicare to the service provider), co-insurance reimbursements, and patient-liability costs (deductibles and "co-payments" that are the patient's responsibility). Costs and patient-liability costs were fit with regression models to compare trends by calendar year, adjusting for age at diagnosis.

Results: The monthly treatment costs for a 72-year-old patient, diagnosed with lung cancer in 2000, in the first 6 months ranged from $2687 (no active treatment) to $9360 (chemo-radiotherapy); costs varied by stage at diagnosis and histologic type. Patient liability represented up to 21.6% of care costs and increased over the period 1992–2003 for most stage and treatment categories, even when care costs decreased or remained unchanged. The greatest monthly patient liability was incurred by chemo-radiotherapy patients, which ranged from $1617 to $2004 per month across cancer stages.

Conclusions: Costs for lung cancer care are substantial, and Medicare is paying a smaller proportion of the total cost over time.

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Introduction

Accurate estimates of costs are necessary for cost-effectiveness analyses of cancer control interventions, such as mass screening programs or chemoprevention. Detailed estimates of costs are required to project future costs in the event that an intervention or screening program causes a change in incidence, case mix, or treatment patterns. Cost analyses are also necessary to evaluate the societal benefit from investments in therapies [1].

Medicare beneficiaries who are diagnosed with cancer can face substantial financial burdens. Out-of-pocket spending exceeded 25% of annual income for low-income beneficiaries with cancer in 1995 [2], and increased among all beneficiaries between 1997 and 2003 [3,4]. Correlations between increases in out-of-pocket costs and changes in treatment patterns could indicate disparities in care and should be assessed.

Lung cancer is the most common cancer diagnosis in the United States; there were 215,000 new cases in 2008 [5]. Lung cancer accounts for 20% of Medicare's total expenditures for cancer treatments [6]. We sought to estimate costs for all phases of lung cancer (pre-diagnosis, staging, initial treatment, continuing care, and terminal care) for use in a policy model of lung cancer that simulates patient lifetimes in monthly increments. Cost estimates in the literature were incomplete for our purposes for several reasons: categories of phases of care or treatment were collapsed or not reported; costs were those to Medicare or other payers only (i.e., excluding costs paid by beneficiaries); samples were small or nongeneralizable (e.g., HMOs); or covered periods before 1991 [6–11]. We estimated monthly (as opposed to annual) costs to be consistent with the policy model. Also, a patient with lung cancer has a median survival of less than 1 year and 12-month phases of care could obscure the U-shaped cost pattern typical in cancer [1,11,12]. Additionally, Yabroff et al. [13] reviewed 60 analyses of cancer treatment costs and found that 50% of them used "unclear" methods.

Using the Surveillance, Epidemiology, and End Results (SEER)-Medicare database for years 1991 through 2003, we estimated direct lung cancer care costs for individuals diagnosed with lung cancer between 1992 and 2002. We stratified costs by stage at diagnosis, histologic type (nonsmall cell vs. small cell), treatment, and phase of care (prediagnosis, staging, initial, continuing, and terminal). Treatment costs include Medicare reimbursements, co-insurance reimbursements, and patient-liability costs (deductibles and "co-payments" that are the patient's responsibility but may be paid in part or whole by employer-sponsored supplemental coverage, Medicaid dual-eligibility, or through patient-purchased Medigap coverage), which are not typically included in analyses of Medicare costs. Using linear regression analysis, we tested the hypotheses that costs were influenced by the age of the patient, that costs changed over time, and that the effect of age on cost may have changed over time. In addition, we compared the trends we observed for total and lung cancer–attributable costs to the trends for the patient liability.

Methods

SEER-Medicare data and inclusion/exclusion criteria

SEER-Medicare data consist of cancer registry files from SEER linked to claims data from Medicare, which is the primary health insurer for 97% of the US population more than 65 years old [14,15]. During the entire time frame used in this longitudinal analysis (1991 through 2003, inclusive), the SEER program collected data from 13 regions—including Connecticut, Hawaii, Iowa, New Mexico, Utah, Atlanta, Detroit (Michigan), San Francisco-Oakland (California), Seattle-Puget Sound (Washington), Los Angeles (California), San Jose-Monterey (California), rural Georgia, and the Alaska Native Tumor Registry—that represented approximately 14% of the total US population. In 2000, SEER expanded to 17 regions, with the addition of Greater California, Kentucky, Louisiana, and New Jersey, in total representing 26% of the US population [16]. In this analysis, we used all the data available for each year. A detailed description of the SEER-Medicare linked database, including its use in compliance with HIPAA regulations, is available at: http://healthservices.cancer.gov/seermedicare/.

We included Medicare beneficiaries more than 65 years old who were diagnosed with an American Joint Committee on Cancer (AJCC) stages I–IV lung cancer between May 1, 1992, and December 31, 2002 and had no previous or subsequent cancer diagnosis. We included individuals continuously enrolled in both Part A and Part B Medicare coverage from 15 months prior to cancer diagnosis through death or the end of the study period (December 31, 2003). We excluded individuals enrolled in managed care at any time during the study period because health maintenance organizations do not submit detailed claims to Medicare. Patients who received Medicare benefits because of disability or end-stage renal disease were also excluded. Individuals with no claims for an entire phase of cancer care (defined below) were excluded from the analysis of that phase because we assumed they were receiving a minimum amount of treatment, supportive care, or were monitored by another component of the health system, such as Veterans Affairs. Finally, patients were excluded if the month of diagnosis was unknown, if diagnosis was made at autopsy, or if the date of death recorded in the Medicare database differed from the date of death recorded in the SEER database by more than 3 months.

Defining treatments

Treatment groups were defined based on lung cancer treatments received from up to 2 months prior to diagnosis and including 6 months post-diagnosis for individuals diagnosed in AJCC stages I through III. For individuals diagnosed with stage IV cancer, treatment group was assigned based on treatments ever received. Costs are reported for treatment groups with >10% of patients in the type/stage category, except for supportive care only (reported for all categories).

We defined resection as local surgery, wedge resection, pneumonectomy, or lobectomy. Procedures were identified using International Classification of Diseases–9th Revision–

Clinical Modification (ICD-9-CM) procedure and Current Procedure Terminology (CPT) codes: local surgery (ICD-9-CM 32.09 or 32.1x; CPT 32520); wedge resection (ICD-9-CM 32.29 or 32.3x; CPT 32500); pneumonectomy (ICD-9-CM 32.5x or 32.6x; CPT 32440, 32442, or 32445); and lobectomy (ICD-9-CM 32.4x; CPT 32480, 32482, 32484, or 32486). We additionally included ICD-9-CM codes 32.9x, 40.11, or 40.19 and CPT codes 32999 or 38786.

We defined a patient as having received any chemotherapy if there was a hospice, home health, inpatient, outpatient, physician, or durable medical equipment claim with any code for chemotherapy administration (ICD-9-CM procedure 99.25, ICD-9-CM diagnosis V58.1, CPT 96400-96549, Healthcare Common Procedure Coding System (HCPCS) codes C1166, C1167, C1178, C9110, C9205, C9207, C9213-C9216, C9411, C9414-C9419, C9420-C9438, G0355, G0356, G0359-G0362, J7150, J8500-J8799, J8999-J9999, Q0083-Q0085, S9325-S9329, S9330-S9379, S9494-S9497 or revenue center codes 0331, 0332, 0335) [14].

We identified patients who received radiation therapy using Medicare claims for radiation treatment planning or administration in any of the Medicare claims files (same files used for chemotherapy) (ICD-9-CM procedures 92.20-92.29; ICD-9-CM diagnosis V58.0, CPT 77000-77999, 79000-79999, HCPCS S8049, or revenue center codes 0330, 0333, 0339).

Defining phases of care

Costs were assigned to phases of care (Fig. 1) that were clinically identifiable. Due to the short median survival of patients with lung cancer, a 12-month initial or terminal phase used in cost assessments of longer-surviving patients were not appropriate because the entire length of time of lung cancer treatment may be considered "terminal phase" care [6,9,17–20]. When shorter phases of care are used (e.g., a 6-month initial phase), the "U-shape" common to the cost of caring for patients with cancer [1,6,21,22] can be observed in patients with lung cancer [10,23].

For all patients, the prediagnosis phase was defined as the 12-month period beginning 15 months prior to diagnosis (where diagnosis was defined as pathological evidence of lung cancer). The 3 months immediately prior to diagnosis were excluded to avoid including the costs of treating symptoms of an undiagnosed cancer.

For patients not undergoing resection, the month of diagnosis was defined as the staging phase. A month-long staging phase was based on typical clinical practice at our institution. Treatment was divided into three phases: initial (6-month period beginning the month after diagnosis and excluding the month before death); continuing (subsequent post-diagnosis period and excluding the month of death); and terminal (the month in which death occurred).

For patients undergoing resection, we defined the month of surgery as the 30 days that began on the date of surgery. Because isolating the cost of surgery from that of postoperative care is necessary to assign costs accurately in simulation models with stochastic mortality events, we defined the initial phase for resection as the 6-month period beginning 30 days post-resection (Fig. 1). The monthly staging phase cost as defined for other treatments was impossible to calculate for resection because of heterogeneity in the time required for preoperative assessment. More than half (53%) of surgical patients received surgery within a month of diagnosis, making a monthly staging phase cost impossible to define. For the remaining 47% of patients whose surgery occurred in a month after diagnosis, we excluded costs occurring between the month of diagnosis and the date of admission.

The terminal phase was defined as the month of death to permit distinction between phases of care even in patients

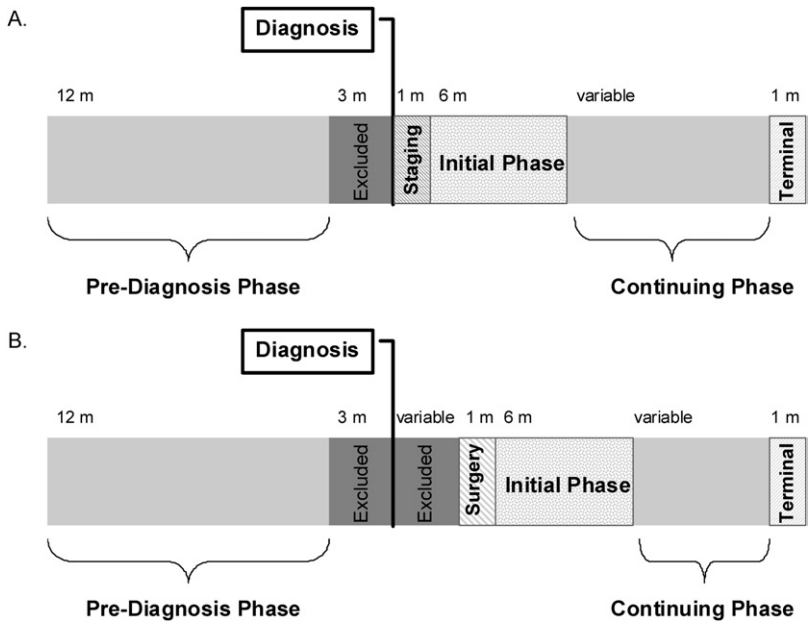

Fig. 1 – (A) Phases of care for patients undergoing non-surgical treatments. (B) Phases of care for patients undergoing resection. The median time between diagnosis and surgery was 18 days; however, for 20% of patients the time between diagnosis and surgery was more than 6 weeks.

with limited survival. Because we had organized the data into calendar months starting from month of diagnosis, we used an actuarial approach (see Supplemental Methods) to calculate the expected cost for the last month of life.

Defining lung cancer types and causes of death

Patients were grouped into small-cell lung cancers (SCLC) (International Classification of Diseases Oncology, 3rd edition [ICD-O-3] codes 8041, 8042, 8043, 8044) versus non-small-cell lung cancers (NSCLC; ICD-O-3 codes 8010, 8012, 8070, 8071, 8072, 8140, 8481, 8560), because treatment varies by histologic type. SCLC was staged as either limited (AJCC stages I–III) or extensive stage (AJCC stage IV).

Individuals whose death was observed on or before December 31, 2003, were classified by cause of death (lung cancer [excluding operative deaths], ICD-9-CM diagnosis 162.xx; cardiac-related causes, ICD-9-CM 390.xx-398.xx, 402.xx, and 404.xx-429.xx; and all other causes) according to death certificate information in SEER. Death within 30 days of surgical resection for lung cancer was defined as an operative death.

Defining costs

Costs were estimated as the sum of Medicare reimbursements (payments from Medicare to the service provider), co-insurance reimbursements (payments from a co-insurer to the service provider [in cases in which Medicare is the secondary insurer because the patient is still primarily insured through his or her employer]), and patient-liability costs (deductibles and "co-pays" that are the patient's responsibility but may be paid in part or whole by employer-sponsored supplemental coverage, Medicaid dual-eligibility, or through patient-purchased Medigap coverage). The portion of the patient's liability that the patient pays out-of-pocket at the time of service (vs. the portion that is paid by Medigap coverage purchased by the patient to reduce point-of-service expenses) cannot be determined in the SEER-Medicare files. Variables used in the analysis are presented in the Appendix 1 Supplemental Methods found at: 10.1016/j.jval.2010.10.006.

The cost of operative death for this study was equal to the sum of payments (from Medicare, other payers, and the patient) for patients who died within 30 days of resection and included the cost of resection.

Cancer-attributable costs are typically estimated using a case-control approach, drawing controls from the random 5% sample of Medicare enrollees residing in SEER areas [1,24]. We have not taken this approach because patients with lung cancer may differ from the general population with respect to health behaviors, particularly related to smoking [25]. Thus, to calculate cancer-attributable costs in this study, each patient served as his or her own control: we subtracted each patient's mean monthly prediagnosis cost from the monthly costs for the initial and continuing phases of care.

Consistent with other analyses using this data set [6,17] and following the recommendations by Brown et al. [1] , payments were converted to constant 2006 US dollars by adjusting Part A claims using the Centers for Medicare and Medicaid Services (CMS) Prospective Payment System Hospital Price index and Part B claims using the Medicare Economic Index [26,27]. All costs are presented in constant (inflation adjusted) 2006 US dollars and, thus, if costs are observed to increase over time, this indicates that costs are increasing at a faster rate than are overall Medicare payments per patient.

Statistical analysis

To compare trends in treatment costs with trends in patient-liability costs over the time period 1992–2003 while adjusting for changes in patient ages, linear and exponential models for each stage and treatment category were fit with treatment cost and (separately) patient-liability costs as the dependent variable and coefficients for year of diagnosis, age at diagnosis, and an interaction term between age and year. Using significant ($\alpha = 0.05$) coefficients from linear models, costs were standardized to correspond to a patient diagnosed at age 72 in 2000; 72 was the median age of diagnosis. When neither age nor year of diagnosis (or the interaction) was significant, costs for a patient diagnosed at age 72 in 2000 is equivalent to the average cost of the entire cohort. Signs of significant terms from the linear model with only significant terms are reported; coefficients are available in Supplemental Results. Exponential models had similar terms but in all cases explained less variability than linear models and are not reported. All data were analyzed using SAS 9.1.3 (Cary, NC, USA).

Results

Sample characteristics

A total of 60,231 lung cancer patients were included in the sample (Table 1). Most (58.9%) patients were diagnosed between 70 and 80 years of age. Thirteen percent (n= 7939) of patients lacked either histologic type or stage-at-diagnosis information and were excluded from stratified analyses of treatment category and costs. Most (83%) patients included in the initial phase were diagnosed with NSCLC, with 34.9% of NSCLC patients diagnosed with Stage I or II disease. A substantial portion (16%, n=9617) of all patients died within 2 months of diagnosis and were included only in the terminal phase. Death occurred within the window of analysis for 45,777 patients (76% of total), with 81.2% of deaths attributed to lung cancer and 4.4% of deaths attributed to cardiovascular causes. Few patients (1.2% of total) died because of operative causes.

Costs of prediagnosis (baseline) and terminal phase care costs

A patient diagnosed with lung cancer at 72 years of age in 2000 would have incurred an average of $645/month in health care expenditures prior to diagnosis, $107 (16.6%) of which were the patient's responsibility (Table 2). Prediagnosis health care costs for a 72-year-old patient increased by 22% over 10 years, whereas the patient-liability portion increased 119% over the same period.

The cost of care in the last month of life for a 72-year-old individual diagnosed in the year 2000 was $14,987 for death from lung cancer and $19,173 for death from cardiac causes (Table 2). Over 10 years, the costs of death from lung cancer

Table 1 – Description of study subjects.

	Number	Percent
Numbers of patients per phase*		
Prediagnosis	60,231	
Diagnosis and staging	42,675	
Initial	37,886	
Year of diagnosis†		
1992	1883	5.0
1993	2857	7.5
1994	2921	7.7
1995	2948	7.8
1996	2921	7.7
1997	2784	7.3
1998	2851	7.5
1999	2826	7.5
2000	5854	15.5
2001	5051	13.3
2002	4990	13.2
Age at diagnosis†		
65–69 years	7137	18.8
70–74 years	12,235	32.3
75–79 years	10,096	26.6
80+ years	8418	22.2
Histologic type and stage at diagnosis†		
NSCLC, stages I and II	10,987	29.0
NSCLC, stage III	11,405	30.1
NSCLC, stage IV	9117	24.1
SCLC, limited stage	3224	8.5
SCLC, extensive stage	3153	8.3
Continuing	18,933	
Terminal‡	45,777	
Lung cancer deaths	37,170	81.2
Cardiac deaths	2030	4.4
Operative deaths	565	1.2
All other cause deaths	6012	13.1

NSCLC, non-small-cell lung cancer; SCLC, small-cell lung cancer.
* See Methods and Figure 1 for definitions of phases of care.
† Limited to the 37,886 patients included in the initial phase analysis.
‡ ICD-9 codes 162 (lung cancer); 390–8,402,404–429 (cardiac).

and cardiac causes (for patients with lung cancer) increased by 8.6% and 23.3%, respectively. For both causes of death, increasing age at diagnosis was associated with a decreased cost of the terminal phase: a reduction of $160 per each additional year of age for lung cancer death and a reduction of $213 per each additional year of age for cardiac death. Neither age-at-diagnosis nor year-of-diagnosis predicted the cost of operative death (mean $38,088; standard error [SE], $1150).

Costs of cancer care

Total costs and patient-share costs for a 72-year-old patient in the year 2000 are provided for the staging phase (Table 3), the initial phase (Table 4), and the continuing care phase (Table 5); also see Figure 2. Net cancer-attributable costs are provided for the initial phase. Significant ($P < 0.05$) terms from linear regressions with age, year of diagnosis, and an interaction term (age*year) are listed with a sign to indicate positive (+) or negative (−) correlations (see Supplemental Data for coefficients).

Staging phase

For patients who received no treatment, the cost of health care in the month of lung cancer diagnosis ranged from $10,631 to $13,404. After subtracting average prediagnosis costs of $645 per month, we can estimate that diagnosis and staging cost $10,000 to $13,000 in standard clinical practice during the study period. The patient-liability in the month of lung cancer diagnosis was similar (range, $1261–$1534) across patients who received no treatment, regardless of histologic type or stage of diagnosis.

Table 2 – Average monthly health care costs during the prediagnosis and terminal phases.

Cost, age	1992	2000	2003	10-year* % change
Total cost, prediagnosis phase				
65	455.89	553.62	590.27	26.8
70	520.80	618.54	655.19	23.5
72	546.77	644.50	681.15	22.3
75	585.72	683.45	720.10	20.9
80	650.64	748.37	785.02	18.8
Patient-liability, prediagnosis phase				
65	46.40	98.71	118.33	140.9
70	52.57	104.88	124.49	124.4
72	55.04	107.34	126.96	118.8
75	58.74	111.04	130.66	111.3
80	64.90	117.21	136.83	100.7
Total cost, lung cancer death				
65	15,151	16,110	16,470	7.9
70	14,348	15,308	15,667	8.4
72	14,027	14,987	15,346	8.5
75	13,546	14,505	14,865	8.9
80	12,744	13,703	14,063	9.4
Total cost, cardiac death				
65	17,652	20,665	21,794	21.3
70	16,587	19,599	20,729	22.7
72	16,160	19,173	20,302	23.3
75	15,521	18,533	19,663	24.3
80	14,455	17,467	18,597	26.0

Notes: Costs are estimated for a 72-year-old patient in the year 2000 using the linear regression of the form: Monthly Cost = Constant + β_{Age} *(Age in years) + β_{Year} *(Calendar Year – 1992) + $\beta_{Age*Year}$ *(Age in years) *(Calendar Year – 1992). Terms were included in the final model using a threshold of $\alpha = 0.05$. Age and calendar year of diagnosis were significant ($P < 0.0001$) predictors of both prediagnosis total costs and patient liability; the interaction term was not significant and so was excluded from the final models. Regression coefficients are presented in Supplementary Table 2A. Total cost is the sum of average monthly costs from all sources regardless of payer [Total Cost = Cancer - Attributable Costs + Non-Cancer Attributable Costs = Patient Liability + Medicare or other primary insurer liability]. Patient liability is defined as the amount of total health care expenses that are the responsibility of the patient for both cancer-attributable and non-cancer health care, such as deductibles and "co-payments." Patient liability may be paid in part or whole by employer-sponsored supplemental coverage, Medicaid dual-eligibility, or through patient-purchased Medigap coverage.
* Calculated using calculated values for 1992 and 2002.

Table 3 – Average monthly costs (total and patient liability) for the staging phase by histologic type, stage at diagnosis, and treatment strategy.

	Total cost		Patient liability	
	Age-, year-standardized (72 years in 2000)	Significant terms	Age-, year-standardized (72 years in 2000)	Significant terms
NSCLC				
Stages I and II*				
No treatment	10,631		1261	Year (+)
Radiotherapy	12,411	Age (−)	1887	Year (+)
Stage III				
No treatment	13,404		1444	Year (+)
Radiotherapy	14,439	Age (−)	2190	Year (+)
Chemotherapy & radiotherapy	14,133	Year (−)	2643	Age (−), year (+)
Stage IV				
No treatment	11,908	Year (−)	1534	Age (−), year (+)
Radiotherapy	16,619	Age (−), year (+)	2370	Age (−), year (+)
Chemotherapy	14,062	Age (−)	2305	Age (−), year (+)
Chemotherapy & radiotherapy	16,599	Age (−)	2909	Age (−), year (+)
SCLC				
Limited Stage				
No treatment	11,279	Year (−)	1398	Year (+)
Chemotherapy	16,467		2365	Age (−), year (+)
Chemotherapy & radiotherapy	16,105	Age (−), year (−)	2702	Age (−), year (+)
Extensive Stage				
No treatment	11,158		1479	Year (+)
Chemotherapy	16,309	Age (−)	2433	Age (−), year (+)
Chemotherapy & radiotherapy	17,321		2312	Year (+)

Notes: Treatment categories with less than 10% of patients are not shown, see the Supplementary Results for the proportion of patients who received other treatments. Costs are estimated for a 72-year-old patient in the year 2000 using the linear regression of the form: Monthly Cost = Constant + β_{Age} *(Age in years) + β_{Year} *(Calendar Year – 1992) + $\beta_{Age*Year}$ *(Age in years)*(Calendar Year – 1992). Terms were included in the final model using a threshold of $\alpha = 0.05$. Regression coefficients are presented in Supplementary Table 3A. When no terms were significant, we present the mean over all patients. Total cost is the sum of average monthly costs from all sources regardless of payer [Total Cost = Cancer-Attributable Costs + Non-Cancer Attributable Costs = Patient-Liability + Medicare or other primary insurer liability]. Patient-liability is defined as the amount of total health care expenses that are the responsibility of the patient for both cancer-attributable and non-cancer health care such as deductibles and "co-payments." Patient liability may be paid in part or whole by employer-sponsored supplemental coverage, Medicaid dual-eligibility, or through patient-purchased Medigap coverage.

NSCLC, non-small-cell lung cancer; SCLC, small-cell lung cancer.

* We did not calculate a staging phase for resection surgery because for many patients it overlapped with the month of surgery (median time from diagnosis until surgery was 18 days, see Figure 1B).

For patients with NSCLC who received radiotherapy and/or chemotherapy, staging phase costs ranged from $12,411 to $16,619 and decreased with age, except for stage III chemoradiotherapy. Staging phase costs for treating patients with SCLC ranged from $16,105 to $17,321. The interaction term of age at diagnosis and year of diagnosis was never significant, indicating there was no evidence for a change in the effect of age on the costs of treatment over time. Higher staging phase costs for patients who subsequently received treatment may be explained by differences in the patients not captured in this analysis (baseline health status), less aggressive staging regimens for patients who have stated their preference not to receive active treatment, or the inclusion of some initial treatment costs in the staging phase.

The share of staging phase costs that was the responsibility of beneficiaries increased significantly over the time frame of our analysis for all treatments, histologic types, and stages, even when overall staging phase costs remained stable or declined. Among patients who subsequently received active treatment, the patient-liability was 13.3% to 18.7% of the overall staging phase costs.

Initial phase

In all cases where age at diagnosis was a significant predictor of initial phase cost, increasing age at diagnosis resulted in a reduction in cost. The interaction term of age at diagnosis and year of diagnosis was never significant indicating there was no evidence for a change in the effect of age on the costs of care over time.

Except in one case (stage IV NSCLC), the initial phase costs for patients who received no treatment were not significantly associated with patient age or year of diagnosis and were similar across histologic types and stages of diagnosis. The monthly cost of care for patients in the initial phase who received no active treatment (supportive care only) ranged from $2687 to $3565, and the lung cancer-attributable portion ranged from $1779 to $2680. Monthly patient liability for a typical lung cancer patient receiving no active treatment was similar across histologic types and stages at diagnosis, ranging from $215 to $286 a month, an increase of two- to threefold over the patient-liability portion of health care costs prior to lung cancer diagnosis.

A 72-year-old patient in 2000 receiving an active course of treatment incurred a liability ranging from $899 to $2004 per

Table 4 – Initial phase monthly costs (total, cancer attributable, and patient share) by histologic type, stage at diagnosis, and treatment.

	Number (%)	Total cost		Net cancer-attributable cost		Patient liability	
		Age-, year-standardized (72 years in 2000)	Significant terms	Age-, year-standardized (72 years in 2000)	Significant terms	Age-, year-standardized (72 years in 2000)	Significant terms
NSCLC							
Stages I and II	10,987						
No treatment	1253 (11.4)	2687		1779		286	Year (+)
Surgery*	5265 (47.9)	5255		4654		215	Year (+)
Radiotherapy	2080 (18.9)	5671	Age (−)	4323	Age (−), year (−)	1148	Year (+)
Stage III	11,405						
No treatment	1723 (15.1)	3234		2327		275	Year (+)
Radiotherapy	3014 (26.4)	5794	Age (−)	4855	Age (−), year (−)	1158	Year (+)
Chemotherapy & radiotherapy	2763 (24.2)	9257	Age (−)	8752	Age (−)	2004	Age (−), year (+)
Stage IV	9117						
No treatment	1269 (13.9)	3398	Age (−)	2557	Age (−)	264	Year (+)
Radiotherapy	2576 (13.1)	5391	Age (−)	4857	Age (−)	899	Age (−), year (+)
Chemotherapy	1192 (28.3)	7677	Age (−), year (+)	7132	Age (−), year (+)	1326	Age (−), year (+)
Chemotherapy & radiotherapy	3209 (35.2)	8927	Age (−), year (+)	8466	Age (−), year (+)	1698	Age (−), year (+)
SCLC							
Limited Stage	3224						
No treatment	243 (7.5)	3565		2680		277	
Chemotherapy	713 (22.1)	8291	Age (−), year (+)	7533	Age (−), year (+)	1229	Year (+)
Chemotherapy & radiotherapy	1673 (51.9)	9360	Age (−)	8831	Age (−)	1948	Age (−), year (+)
Extensive Stage	3153						
No treatment	170 (5.4)	2878		2182		215	
Chemotherapy	777 (24.6)	7487		6760		1214	Age (−), year (+)
Chemotherapy & radiotherapy	1824 (57.8)	8840	Year (+)	8354	Age (−), year (+)	1617	Year (+)

Notes: Treatment categories with less than 10% of patients are not shown, see the Supplementary Results for the proportion of patients who received other treatments. Patients who lived fewer than 2 months contributed a month to the staging phase and to the terminal phase but not to the initial phase. Costs are estimated for a 72-year-old in the year 2000 using the linear regression of the form: Monthly Cost = Constant + β_{Age} *(Age in years) + β_{Year} *(Calendar Year – 1992) + $\beta_{Age*Year}$ *(Age in years) *(Calendar Year – 1992). Terms were included in the final model using a threshold of $\alpha = 0.05$. Regression coefficients are presented in Supplementary Table 4A. When no terms were significant, we present the mean over all patients. Total cost is the sum of average monthly costs from all sources regardless of payer [Total Cost = Cancer-Attributable Costs + Non-Cancer Attributable Costs = Patient-Liability + Medicare or other primary insurer liability]. Net cancer-attributable cost is defined as the individual patient's monthly cost of health care incurred in excess of the average pre-diagnosis cost of health care. Patient liability is defined as the amount of total health care expenses that are the responsibility of the patient for both cancer-attributable and non-cancer health care such as deductibles and "co-payments." Patient liability may be paid in part or whole by employer-sponsored supplemental coverage, Medicaid dual-eligibility, or through patient-purchased Medigap coverage.

NSCLC, non-small-cell lung cancer; SCLC, small-cell lung cancer.

* 6 months following surgery month, see Figure 1B.

month, with the highest amount being incurred by NSCLC patients with stage III disease receiving chemoradiotherapy.

Patients receiving chemotherapy and chemoradiation had high costs in the initial period: monthly cancer-attributable costs for a 72-year-old patient diagnosed in 2000 ranged from $6760 to $8831 and in most cases increased over time, but decreased with increasing patient age. Radiotherapy costs decreased over time. Patients receiving chemotherapy and chemoradiation incurred the greatest patient-liability, ranging from $1214 to $2004 per month (15%-22% of total health-care costs). Except for supportive care, the patient-liability amount increased over time even when overall costs did not. For example, no increase in costs were observed over time for treating stage III NSCLC patients with chemoradiotherapy, yet patients were responsible for an additional monthly liability of $96 with each additional year of diagnosis.

Month of surgery

Both increasing age at diagnosis ($P = 0.0021$) and earlier year of diagnosis ($P < 0.0001$) were significant predictors of increasing total cost (Table 4B at: 10.1016/j.jval.2010.10.006, for regression coefficients). The average lung cancer patient (72 years old) diagnosed in 2000 would have incurred approximately $26,235 in health care expenditures in the month of surgery, including $1400 in patient liability. Even though the total cost of health care in the month of surgery decreased by $282 each year (a decrease of 10% over 10 years), patient-liability costs increased $59 with each additional year of diagnosis (a 63% increase over 10 years).

Neither overall health care costs ($5255/month) nor net cancer-attributable costs ($4654/month, beginning 30 days after surgery) were predicted by age or year of diagnosis (Table 4). Patient-liability costs for those with surgery were similar to those incurred

Table 5 – Continuing phase monthly costs (total, cancer-attributable, patient-share) by histologic type, stage at diagnosis, and treatment.

	N (%)	Total cost		Net cancer-attributable cost		Patient-liability cost	
		Age-, year-standardized (72 years in 2000)	Significant terms	Age-, year-standardized (72 years in 2000)	Significant terms	Age-, year-standardized (72 years in 2000)	Significant terms
NSCLC							
Stages I and II	7521						
No treatment	665 (8.8)	4498		3721		414	Year (+)
Surgery	4335 (57.6)	2602	Year (−)	1996	Year (−)	341	
Radiotherapy	1079 (14.3)	5403		4428		590	Age (−), year (+)
Stage III	5364						
No treatment	663 (12.4)	5139	Year (−)	4313	Year (−)	422	
Radiotherapy	1176 (21.9)	6941		6309		762	Age (−), year (+)
Chemotherapy & radiotherapy	1302 (24.3)	8196	Year (−)	7758	Year (−)	1073	Age (−)
Stage IV	2924						
No treatment	334 (11.4)	5538	Age (−), year (−), Age* year (+)	4733	Age (−), year (−), Age* year (+)	451	
Radiotherapy	598 (20.5)	8287	Age (−)	7789	Age (−)	807	Year (+)
Chemotherapy	411 (14.1)	10,026		9425		1465	Age (−)
Chemotherapy & radiotherapy	1215 (41.6)	11,178	Age (−)	10,767	Age (−)	1609	Age (−), year (+)
SCLC							
Limited stage	1732						
No treatment	100 (5.8)	5975		5127		583	
Chemotherapy	336 (19.4)	9445		8834		1296	
Chemotherapy & radiotherapy	972 (56.1)	8807		7922	Year (−)	1204	
Extensive stage	1392						
No treatment	51 (3.7)	4850		4507		380	
Chemotherapy	285 (20.5)	10,660		9941		1541	Year (+)
Chemotherapy & radiotherapy	914 (65.7)	12,344		11,829		1900	Year (+)

Notes: Treatment categories with fewer than 10% of patients are not shown, see the Supplementary Results for the proportion of patients who received other treatments. Patients who lived between 2 and 7 months contributed a month to the staging phase and to the terminal phase and between 1 and 6 months to the initial phase, but no months to the continuing phase. Costs are estimated for a 72-year-old patient in the year 2000 using the linear regression of the form: Monthly Cost = Constant + β_{Age} *(Age in years) + β_{Year} *(Calendar Year – 1992) + $\beta_{Age*Year}$ *(Age in years)*(Calendar Year – 1992). Terms were included in the final model using a threshold of $\alpha = 0.05$. Regression coefficients are presented in Supplementary Table 5A. When no terms were significant, we present the mean overall patients. Total cost is the sum of average monthly costs from all sources regardless of payer [Total Cost = Cancer-Attributable Costs + Non-Cancer Attributable Costs = Patient-Liability + Medicare or other primary insurer liability]. Net cancer-attributable cost is defined as the individual patient's monthly cost of health care incurred in excess of the average prediagnosis cost of health care. Patient-liability is defined as the amount of total health care expenses that are the responsibility of the patient for both cancer-attributable and non-cancer health care such as deductibles and "co-payments". Patient-liability may be paid in part or whole by employer-sponsored supplemental coverage, Medicaid dual-eligibility, or through patient-purchased Medigap coverage.
NSCLC, non-small-cell lung cancer; SCLC, small-cell lung cancer.
* Continuing phase costs were for the 6 months following the month of surgery.

by patients who received no treatment ($215/month), and increased over time ($6 per additional year of diagnosis).

Continuing phase

Overall health care and lung cancer-attributable health care costs during the continuing phase were either not affected by or decreased with increasing age and increasing calendar year of diagnosis. In one case, patients with stage IV NSCLC who received no treatment, the interaction term of age and year of diagnosis was a significant predictor of cost that indicated the effect of age on overall health care was not constant over time. Similar patterns of change in patient liability were observed in the continuing phase of lung cancer treatment as were observed in other periods of care (staging, initial phase, and surgery); the amount of the liability increased or remained stable over time even when overall health care costs were stable or decreased over time.

Discussion

Estimation of medical costs paid by insurers and patients is necessary to conduct cost-effectiveness analyses of lung cancer control interventions from the societal perspective, in which all costs are included without regard for who accrues them [28]. Distinct from recent publications that estimated

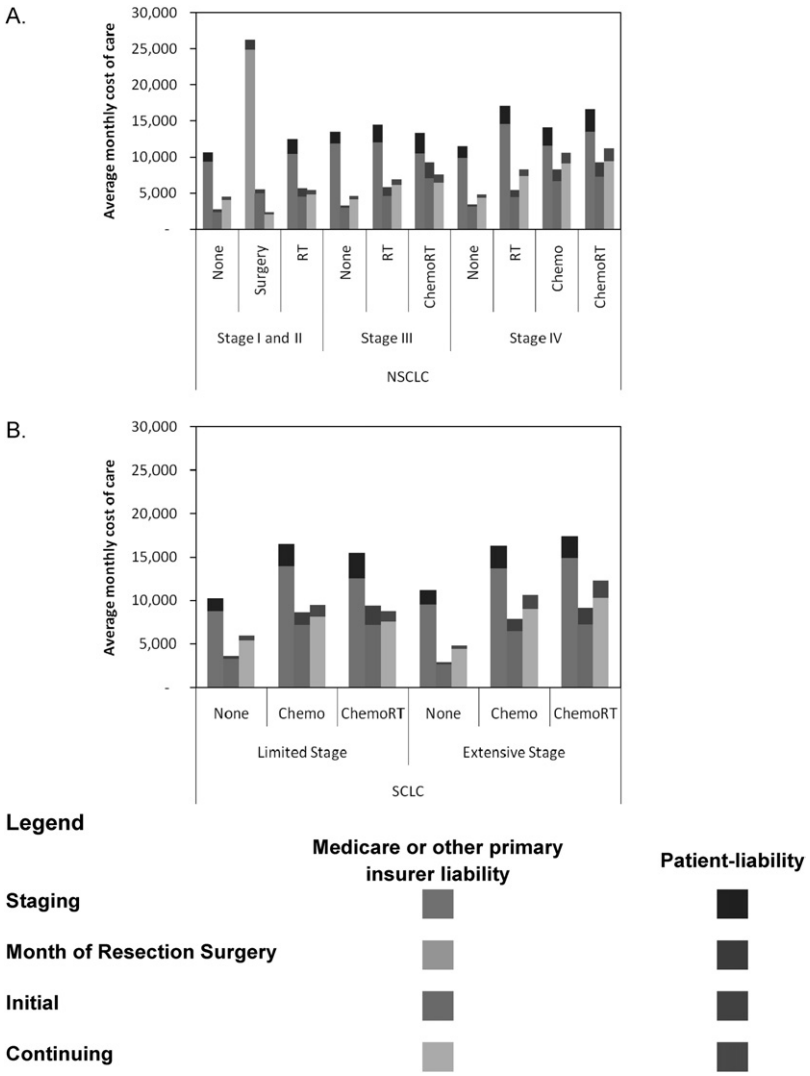

Fig. 2 – Average monthly costs (total and patient-liability) for a 72-year-old patient in the year 2000 as estimated by linear regression stratified by histologic type, stage at diagnosis, and treatment strategy for (A) non-small-cell lung cancer (NSCLC) and (B) small-cell lung cancer (SCLC). *Chemo*, chemotherapy; *Chemo*RT, chemotherapy and radiotherapy; *RT*, radiotherapy.

annual cancer-related costs to Medicare [7,29], our cost estimates contribute detail to the literature about financial responsibilities faced by Medicare beneficiaries treated for lung cancer, the most common cause of cancer death in the United States. Our estimates provide monthly health care costs (stratified by patient age, phase of care, histologic type, stage at diagnosis, and calendar year of diagnosis).

We found that the amount and the proportion of overall costs that are the responsibility of patients to pay or to insure against (such as by purchasing Medigap coverage) increased significantly from 1992 to 2003, even for treatments with stable or decreasing overall costs, thus confirming earlier studies [3,4] that suggest an increase in cost-shifting to beneficiaries. Among categories in which we observed an increase in the overall cost of health care, the increase in the patient liability represented 37.9% to 95.7% of the total increase in overall costs. The same pattern of an increasing patient liability was apparent for most phases of care and most treatment categories. Monthly initial phase costs that were the responsibility of a 72-year-old patient treated in 2000 with combined chemotherapy and radiotherapy were estimated between $1617 and $2004, representing 72% to 89% of the median monthly per-capita income for Americans over 65 years of age ($2258, all in 2006$) [30]. Note, however, that patient-liability costs in traditional Medicare are not necessarily paid out-of-pocket by the patient. During the period of this analysis, approximately one-third of beneficiaries had employer-sponsored supplemental coverage that reduced point-of-service obligations, approximately 30% had Medigap coverage, and 20% were dually eligible for Medicaid [31]. Medigap is the only supplemental coverage available to all beneficiaries. In 1999, the average annual cost of a Medigap policy was $1311 per year [32]. Consistent with what would be expected as the patient liability increases, employer-sponsored supplemental coverage is decreasing in

frequency and in generosity of benefits; the cost of Medigap coverage is increasing [31,32]. Our findings echo questions raised in prior studies about the sustainable affordability of health care for Medicare beneficiaries as the proportion of costs paid by Medicare decreases over time [4,33,34].

Whether the patient liability is paid by the patient as a point-of-service expense or paid through supplemental coverage the patient previously purchased to insure against point-of-service expenses will affect decisions at the point of service and may impact total cost and patient-liability differently depending on the mix of services the patient chooses [35,36]. In the SEER-Medicare data set, we cannot distinguish between payments made directly by patients and payments paid on their behalf by supplemental insurance. Thus, these data do not allow us to determine whether patients chose less effective treatments with lower out-of-pocket costs. Lack of patient and physician familiarity with the cost burdens that patients face with each treatment option limit the potential for patients to make decisions based on cost. However, if fewer patients have supplemental coverage in the future and as patients become more aware of their payment responsibilities, the repercussions of high out-of-pocket costs could conceivably cause a shift in treatment choice, leading to underuse of recommended services in favor of less effective but more affordable services [37–39]. Furthermore, high medical costs can reduce access to health care for other household members [2]. Recommended therapies have previously been shown to be less common in under-represented minority groups compared to whites [40–44]. Increases in out-of-pocket burdens on low-income patients may result in increased demand for Medicaid services or reduced use of health care services by the economically disadvantaged who are more often members of under-represented minority groups [30], magnifying disparities [45].

Only patients diagnosed with stages I/II NSCLC followed the classic pattern of higher costs in the initial phase followed by lower costs in the continuing care phase. In part, this may be explained by the short life expectancy associated with lung cancer and our definition of the terminal phase as only the last month of life. The average number of months in the continuing phase was short and many patients were principally in preterminal phases that may have included expensive pain control treatments (e.g., fentanyl) or extended palliative care in hospice. We observed a general trend of increasing costs in the terminal phase of care which is consistent with trends of increasing use of aggressive care (emergency room visits, intensive care unit admissions, systemic therapy) near the end of life in lung cancer and other diseases [8,46,47]. Consistent with published estimates [48,49], we found decreasing terminal costs with age.

Pharmaceuticals (over the counter or prescription) were not included in our estimates because 2003 pre-dated Medicare Part D. The time span of the analysis does not cover important treatment advances such as cisplatin-based adjuvant chemotherapy [50] and pre-dated clear-cut evidence of survival benefits from chemotherapy in late-stage NSCLC [51] and the introduction of targeted therapies such as angiogenesis [52], epidermal growth factor receptor inhibitors [53,54], and other new anticancer agents [55,56]. More patients today likely receive chemotherapy or targeted therapies, which have costs that could dwarf those used in the time period of this study [57–60]. The impact of Medicare Part D on the relative trends of patient liability and total cost of cancer care remain unknown and need to be evaluated. If the trends we observed (i.e., patient liability increasing faster than total costs) continued, scientific advancements in lung cancer care may represent clinical advancements only for those with generous supplemental insurance. SEER-Medicare data for cases diagnosed in 2007 will first be made available in 2011. Shortening the time frame required to collect, generate, disseminate and analyze the data, plus greater detail about cumulative patient liability and out-of-pocket costs, would improve our ability to gauge the impacts of costs on health decisions and health outcomes.

Patient and caregiver time costs and transportation costs to undergo treatment were not available here, but should be included in a cost-effectiveness analysis conducted from the societal perspective. Cancer therapies are increasingly delivered in the outpatient setting, shifting substantial costs to caregivers [13,61,62]. Despite excluding the 3 months prior to diagnosis, patients in the sample had undiagnosed cancer and could have been receiving treatment related to disease symptoms [63]. We defined a 30-day staging phase to isolate staging costs from treatment costs, but this may have improperly categorized some staging costs as initial phase costs or some initial treatment costs as staging costs. Staging costs were not estimated for patients undergoing resection, but the wide variation in staging practices [41,64] suggests that a microcosting approach based on procedure codes would be preferable in cost-effectiveness analyses to permit distinction between patient management algorithms.

Other limitations of the analysis include those common to analyses of SEER-Medicare data [14], such as omission of patients less than 65 years old, patients enrolled in HMOs, and an inability to identify individuals, such as veterans, for whom Medicare may have incomplete claims data. We did not investigate how these patients' costs differ from those patients with traditional Medicare. Medicare data are observational and are not collected specifically for health services research, and SEER areas are not entirely representative of the United States [14]. Our regression analyses were intended to compare time trends in cost components (vs. explaining variability in costs) so they did not contain clinical covariates other than age and yielded very small R^2 values. The total reimbursement amounts are determined by CMS and providers are required by law (with limited exceptions) to collect the full amount [65], although SEER-Medicare files do not contain variables that confirm payment.

The costs of lung cancer care are substantial and Medicare is paying a smaller proportion of the total cost over time. Our analysis concurs with findings from other studies showing that Medicare beneficiaries are responsible for paying an ever-larger share of the costs [4]. Awareness of trends in cost sharing is important to prevent worsening of sociodemographic disparities in access and quality of care, yet the cost analysis literature contains major gaps [66]. Finally, our analysis addressed common limitations of published cost analyses, such as omission of validation studies or technical appendices with sufficient detail to make methods transparent and reproducible.

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Supplementary Data

Supplementary data associated with this article can be found, in the online version, at 10.1016/j.jval.2010.10.006.

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