Pattern of Imaging after Lung Cancer Resection
1992–2005

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Abstract

Rationale: Imaging intensity after lung cancer resection performed with curative intent is unknown.

Objectives: To describe the pattern and trends in the use of computed tomography (CT) and positron emission tomography (PET) scans in patients after resection of early-stage lung cancer.

Methods: Retrospective analysis of the linked Surveillance, Epidemiology and End Results (SEER)–Medicare database. Subjects included 8,621 Medicare beneficiaries (age, ⩾66 yr) who underwent lung cancer resection with curative intent between 1992 and 2005. A surveillance CT or PET examination was defined as CT or PET imaging performed in an outpatient setting on patients who did not undergo chest radiography in the preceding 30 days.

Measurements and Main Results: Overall, imaging use was higher within the first 2 years versus Years 3–5 after surgical resection. Use of surveillance CT scans increased sharply from 13.7 to 57.3% of those diagnosed in 1996–1997 and 2004–2005, respectively. PET scan use increased threefold, from 6.2% in 2000–2001 to 19.6% in 2004–2005. In multivariable analyses, we observed a 32% increase in the odds of undergoing surveillance CT or PET imaging for every year of diagnosis between 1998 and 2005. There was no substantial decline in the odds of having a surveillance CT or PET scan during each successive follow-up period, suggesting no change in the intensity of surveillance over the first 5 years after surgical resection. The proportion of surveillance CT imaging performed at freestanding imaging centers increased from 18.0% in 1998–1999 to 30.6% in 2004–2005.

Conclusions: The use of CT and PET imaging for surveillance after curative-intent surgical resection of early-stage lung cancer increased sharply in the United States between 1997–1998 and 2005. In the absence of evidence demonstrating favorable outcomes, this practice was likely driven by prevailing expert opinion embedded in clinical practice guidelines made available during that time. Research is clearly needed to determine the role and optimal approach to surveillance thoracic imaging after surgical resection of lung cancer.

Keywords: lung cancer; lung resection; surveillance imaging; positron emission tomography

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In 2007, more than 70 million computed tomography (CT) scans were performed in the United States (1), making this imaging modality the most common source of medically related exposure to radiation (2, 3). There are concerns about the risks of radiation exposure from medical imaging, which can vary substantially by the type of facility used and test performed (1). An estimated 29,000 new cases of cancers diagnosed yearly may be related to medical radiation exposure (4).

Imaging for intrathoracic malignancies contributes substantially to the overall annual risk of radiation-induced cancers. CT and positron emission tomography (PET) scans have become an integral part of the evaluation of patients with lung cancer (5–11). Both imaging modalities are used in the initial diagnostic evaluation as well as for post-treatment surveillance to monitor for recurrence, response to therapy, or disease progression.

Annually, approximately 50,000 patients undergo surgical resection for early-stage lung cancer (12). Guidelines sponsored by several national professional organizations recommend routine surveillance of these patients with chest radiographic or chest CT imaging performed at specified intervals after resection (8–10, 13–17). These recommendations vary considerably and range from regularly scheduled clinic visits (15, 17) with or without a chest radiograph at 3- to 6-month intervals (10) to a semiannual chest CT scan after the initial resection (9, 14). In general, recommended surveillance is more frequent in the first 2 years after resection compared with latter years.

The rationale for post-treatment surveillance is timely detection of recurrence or identification of a second primary lung cancer, which can be amenable to treatment (repeat surgery, chemotherapy, or radiation) with potential improvement in survival. However, current single-institution studies of routine surveillance after curative-intent surgery have shown a reduction in the lag time for diagnosis of recurrence without a meaningful improvement in overall or lung cancer–specific survival (11, 18–21).

Little is known about practice patterns in the use of chest CT imaging for surveillance after lung resection. This is important because health care regulators are concerned about the appropriateness and the escalating cost of medical imaging in the United States (22) and elsewhere. Using national Surveillance, Epidemiology, and End Results (SEER)–Medicare data, we described patterns in the use of CT and PET scans in patients with lung cancer after resection for curative intent. We identified patient characteristics associated with surveillance imaging after initial cancer resection, and examined trends in the use of imaging for this purpose between 1992 and 2005. We hypothesized that CT and PET imaging was used with increasing frequency for postresection surveillance of early-stage lung cancer over the period studied.

Methods

Source of Data

This study was approved by the University of Texas Medical Branch Institutional Review Board and informed consent was not obtained, due to the nature of the study. SEER–Medicare-linked data were used in this study (23). The SEER tumor registry data from 1992 to 2005 were linked to the Medicare claims from the year 1991 to 2006, including Medicare Provider Analysis and Review (MEDPAR) files, Outpatient Standard Analytic File (OUTSAF), and Medicare Carrier files. Information on hospitals in which subjects received lung cancer resection was obtained by combining the Hospital Files from Years 1996, 1998, and 2000–2006. Hospital Files were created by the National Cancer Institute (NCI) and they include selected variables from the Healthcare Cost Report (HCRIS) and the Provider of Service (POS) survey obtained from the Center for Medicare and Medicaid Services (CMS).

Study Cohort

We limited our analyses to the original SEER registries to study the time trend of imaging. Registries that joined the SEER program after the year 2000 (greater California, Kentucky, Louisiana, and New Jersey) were not included. Patients with American Joint Committee Cancer (AJCC) stages I, II, and IIIA non–small cell lung cancer, diagnosed from 1992 to 2005, and aged 66 years and older at time of diagnosis were identified (n = 44,169). Patients who were ever enrolled in health management organizations, or had an interruption in the continuous enrollment of Medicare Parts A and B during the 12 months before or 4 months after cancer diagnosis were excluded (n = 15,916).

We included patients who had a claim for lung resection (International Classification of Disease-9 [ICD-9] codes 32.3, 32.4, and 32.5) from MEDPAR within 4 months of a cancer diagnosis (n = 11,682). Among the 11,682 patients, we excluded those who received neoadjuvant chemotherapy and/or radiation therapy before resection or adjuvant chemotherapy and/or radiation therapy within 4 months of resection (n = 2,874), and those who died within 4 months (n = 187), leaving 8,621 subjects in the study.

We monitored these patients up to 63 months after resection or until death, in five surveillance periods of 12 months each: Months 4–15, Months 16–27, Months 28–39, Months 40–51, and Months 52–63. We chose to start the follow-up time 4 months after surgery because most postoperative complications occur in this time frame. Subjects who did not survive to the end of each surveillance period were excluded, leaving 7,223, 5,804, 4,651, 3,677, and 2,898 subjects for the first, second, third, fourth, and fifth years of follow-up, respectively.

Measures

We categorized cohort subjects by age, sex, race, Medicaid eligibility as a surrogate for socioeconomic status, SEER region, year of diagnosis, AJCC cancer stage, tumor grade, and tumor histology using the SEER Patient Entitlement and Diagnosis Summary File (PEDSF). For subjects diagnosed during 1992–1995, income was defined as the per-capita income for census tract based on the 1990 U.S. Census Bureau survey; for subjects diagnosed during 1996–2005, income was defined as the per-capita income for census tract based on the 2000 U.S. Census Bureau survey.

Smoking-related pulmonary comorbidities including bronchitis (ICD-9 diagnosis codes 490 and 491), emphysema (ICD-9 diagnosis code 492), asthma (ICD-9 diagnosis code 493), bronchiectasis (ICD-9 diagnosis code 494), and chronic obstructive pulmonary disease (chronic obstructive pulmonary disease, ICD-9 diagnosis code 496) were obtained from the inpatient and outpatient claims data in the year before cancer diagnosis. Hospital type, bed size, and medical school affiliation where subjects received lung cancer resection were obtained from the Hospital File.

Imaging Studies

The claims for chest CT scans (ICD-9 procedure codes 87.41 and 87.42; CPT codes 71250, 71260, 71270, 71275) and PET scans (CPT codes 78811, 78812, 78813, 78814, 78815, 78816; HCPCS codes G0125, G0210–G0218, G0220–G0228, G0231–G0234, G0253, G0254, G0296) were identified from inpatient and outpatient billing data. We divided the reason for imaging studies into two categories: those for evaluation of symptoms and those for routine surveillance in the absence of symptoms.

For the purpose of this study, CT or PET scans performed during hospitalization or within 30 days of a chest radiograph (ICD-9 procedure codes 87.44 and 87.49; CPT codes 71010, 71015, 71020, 71021, 71022, 71030, 71034, and 71035) were considered evaluation studies, whereas a surveillance CT or PET was defined as one done in an outpatient setting without a chest radiograph in the preceding 30 days.

Settings

To study the setting of surveillance CT imaging, claims identified from OUTSAF or claims from Carrier files with the place of service of "Inpatient hospital," "Outpatient hospital," or "Emergency room–hospital" were considered to be performed in a hospital setting. All others were considered to be performed in freestanding imaging centers. The number of surveillance CT scans declined over the surveillance period; therefore we analyzed the test setting for only the first surveillance period (Months 4–15 after the resection).

Statistical Analyses

We calculated the percentage of patients who underwent an examination (chest CT scan, PET scan, chest radiograph, and any examination) for each month of follow-up in the 5-year surveillance period and plotted the results. We also examined the percentage of patients receiving imaging studies during each successive year of follow-up. The effect of patient characteristics on receipt of chest CT or PET scan was estimated by a generalized estimated equation (GEE) model with adjustment for relevant characteristics.

Because each patient could have up to five surveillance periods, a GEE model was constructed to account for multiple observations per patient (24). The unadjusted result showed a decrease in imaging over time (*see* Table 2), and therefore a first-order autoregressive correlation within patient was specified in the GEE model. The interaction between the year of diagnosis and other patient characteristics was evaluated in the multivariable logistic regression model using data from the first surveillance period (4–15 mo after resection). All analyses were performed with SAS version 9.2 (SAS Inc., Cary, NC).

Results

Between 1992 and 2005, 8,621 patients underwent surgical resection for primary non–small cell cancer of the lung. Of these, 7,223 survived at least 15 months after surgery. Table 1 presents the baseline characteristics of the entire cohort (n = 7,223). Most (87%) had AJCC stage

Table 1. Baseline characteristics of patients who underwent curative surgery for lung cancer and survived for 15 months between 1992 and 2005

	Number of Patients* (*n*)	Percentage of Total (*100%*)		Number of Patients* (*n*)	Percentage of Total (*100%*)
Patient characteristics			Tumor characteristics		
Age, yr			Stage		
66–69	1,813	25.1	I	6,323	87.5
70–74	2,484	34.4	II	602	8.3
75–79	1,960	27.1	IIIA	298	4.1
⩾80	966	13.4	Tumor grade		
Sex			Well differentiated	880	12.2
Male	3,482	48.2	Moderately differentiated	2,572	35.6
Female	3,741	51.8	Poorly/undifferentiated	2,827	39.1
Race			Unknown	944	13.1
White	6,367	88.2	Histologic type		
Black	334	4.6	Adenocarcinoma	4,226	58.5
Other	522	7.2	Squamous	2,179	30.2
Low socioeconomic status			Large cell	374	5.2
No	6,529	90.4	Other	444	6.2
Yes	694	9.6	Hospital characteristics		
Smoking-related pulmonary comorbidity†			Surgery hospital type		
0	5,646	78.2	Nonprofit	5,769	79.9
1	1,201	16.6	For profit	642	8.9
⩾2	376	5.2	Public	812	11.2
SEER region			Surgery hospital size		
San Francisco	450	6.2	⩽200 beds	845	11.7
Connecticut	1,170	16.2	201–350 beds	2,377	32.9
Detroit	1,266	17.5	351–500 beds	1,377	19.1
Hawaii	184	2.6	>500 beds	2,624	36.3
Iowa	967	13.4	Medical school affiliation		
New Mexico	204	2.8	Major	2,670	37.0
Seattle	813	11.3	Limited	1,245	17.2
Utah	168	2.3	Graduate	624	8.6
San Jose	337	4.7	No affiliation	2,684	37.2
Los Angeles	1,183	16.4			
Atlanta and rural Georgia	481	6.7			
Year of diagnosis					
1992–1996	2,913	40.3			
1997–2001	2,551	35.3			
2002–2005	1,759	24.35			

Definition of abbreviation: SEER = Surveillance, Epidemiology and End Results.
*Total number of patients: 7,223 (100%).
†Smoking-related pulmonary comorbidity: bronchitis, emphysema, asthma, bronchiectasis, or chronic obstructive pulmonary disease.

I lung cancer, and the most common pathological subtype was adenocarcinoma (58.5%). Smoking-related pulmonary comorbidities were uncommon. Surgeries were performed mainly at nonprofit, mid-size to large hospitals affiliated with medical student or resident training.

Figure 1 displays the monthly imaging rates after lung cancer resection in patients who did not receive neoadjuvant or adjuvant therapy (n = 8,621). We examined the use of any chest radiograph, chest CT scan, or PET scan studies starting 4 months after surgery. Overall, the rate of imaging studies was highest in the first 24 months after surgery. Two clear patterns emerged. Imaging patterns in the post-treatment period demonstrated small peaks at 6-month intervals and larger peaks at 12-month intervals, suggesting regular surveillance.

Table 2 presents imaging rates during the 5-year follow-up for each successive 12-month interval, starting at Month 4 after surgery. Chest radiography was the most common imaging study performed during follow-up. Some 91.4, 86.3, 82.9, 81.6, and 79.0% of the patients had at least one chest radiograph taken during the first, second, third, fourth, and fifth year of follow-up, respectively. Similarly, overall use of CT scans declined each successive year of follow-up. For example, 41.2, 37.2, 32.8, 31.5, and 27.3% of the patients had a CT scan done in the first, second, third, fourth, and fifth year of follow-up. In addition, 19.4% of patients received two or more chest CT scans during the first surveillance year whereas 10.7% of patients received two or more chest CT scans during the fifth surveillance year.

Figure 2 shows the growth in overall CT scan, PET scan, and surveillance CT scan use by year of diagnosis. The use of CT scans (overall and surveillance only) increases sharply after 1997. Among patients diagnosed with lung cancer in 1996 and 1997, 13.7% had at least one surveillance CT scan compared with 57.3% of those diagnosed in 2004 and 2005. PET scans were not introduced until 1998. After this point, use of PET scans increased steadily over the remaining time period. PET scan use increased threefold in this population, from 6.2% in 2000–2001 to 19.6% in 2004–2005. This growth in PET scan imaging coincided with Medicare approval in 2000 for PET scanning to evaluate lung nodules.

Table 3 presents the odds of receiving any CT or PET scan (column 2) or surveillance CT or PET scan (column 3) during the 5-year follow-up period, using a multivariable GEE model. We restricted the multivariable analyses to patients diagnosed after 1997 (n = 3,748), as most of the growth occurred starting in 1998. Between 1998 and 2005, for every successive year of diagnosis, the odds of receiving any CT or PET scan increased by 25%. There was large variation in the receipt of any CT or PET scan during the follow-up period by SEER region. Patients in the highest quartile of income status had 57% higher odds of having any CT or PET scan during the follow-up period compared with those in the lowest income quartile. Those with advanced stage (II and IIIA) non–small cell lung cancer were more likely to have any CT or PET scan. There was a decline in the receipt of any CT or PET scan during each successive follow-up year. For example, the odds of receiving any CT or PET scan declined by 7% in Year 2 and by 23% in Year 5 of the follow-up period, compared with Year 1.

The growth in use of surveillance CT or PET scanning was greater. We observed a 32% increase in the odds of receiving surveillance CT or PET for every year increase in the year of diagnosis. We observed a decline with follow-up time in unadjusted surveillance CT rate (Figure 1). However, after adjusting for year of diagnosis, patient, tumor, and hospital characteristics, we found no substantial decline in the odds of having a surveillance CT or PET scan during each successive follow-up period, suggesting no change in the intensity of surveillance in the early or late follow-up period (Table 3).

There was significant interaction between the year of diagnosis and SEER region during the first surveillance period. The use of surveillance CT or PET scanning grew in all SEER regions; however, the magnitude of growth varied substantially. Table 4 presents the unadjusted rates of receipt of any CT or PET scan or surveillance CT or PET scan and adjusted odds ratio of per-year increase in diagnosis year by SEER region. As shown, the largest increase in the use of any CT or PET scan was seen in Los Angeles, from 38.2% in 1998–1999 to 83.5% in those diagnosed in

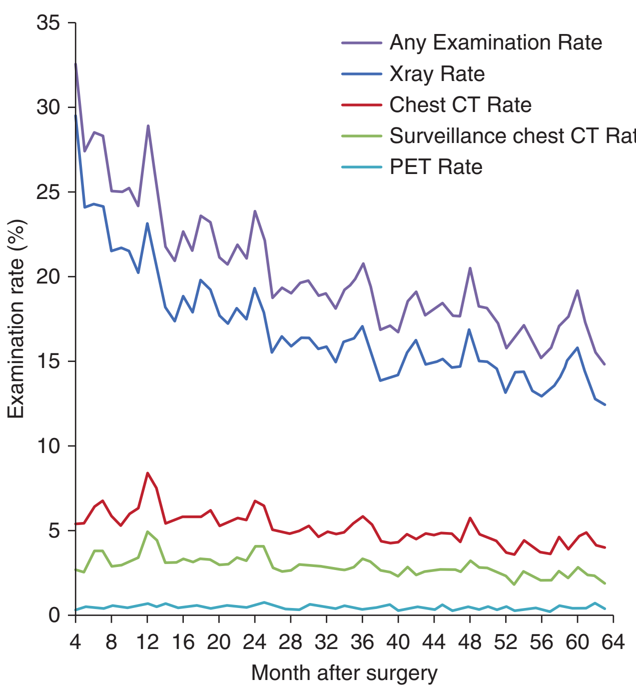

Figure 1. Monthly examination rate after lung resection in patients with lung cancer and without neoadjuvant or adjuvant chemo-/radiation therapy. The denominator of the monthly rate is the number of patients who were alive after a resection of stage I to IIIA non–small cell lung cancer. The pattern for the various imaging techniques suggests peaks in rates at 12-month intervals. CT = computed tomography; PET = positron emission tomography.

Table 2. Imaging studies: rates after lung resection for each successive year of follow-up

Period after Surgery: **n:**	**4–15 mo** **7,223**	**16–27 mo** **5,804**	**28–39 mo** **4,651**	**40–51 mo** **3,677**	**52–63 mo** **2,898**
Any examination, %	96.1	92.0	89.0	87.2	84.1
X-ray, %					
Any examination	91.4	86.3	82.9	81.6	79.0
One or two examinations	40.2	51.0	53.8	54.3	55.1
Three or four examinations	33.3	23.1	18.2	15.9	14.2
Five or more examinations	17.9	12.3	11.0	11.3	9.8
Chest CT, %					
Any examination	41.2	37.2	32.9	31.5	27.3
One examination	21.8	20.8	19.2	19.7	16.6
Two or more examinations	19.4	16.4	13.7	11.9	10.7
PET scan, %					
Any examination	4.7	4.6	3.8	3.8	3.8
Chest CT or PET scan, %					
Any examination	41.8	37.8	33.1	31.9	27.8

Definition of abbreviations: CT = computed tomography; PET = positron emission tomography.

2004–2005. Adjusted odds of receipt of any CT or PET scan for every year increase in the year of diagnosis ranged from 1.18 (95% confidence interval [CI], 1.03–1.37) in San Jose to 1.51 (95% CI, 1.38–1.66) in Los Angeles. For surveillance CT or PET, between 1998 and 2005, the year-to-year increase in odds of having a surveillance CT or PET scan was 1.20 (95% CI, 1.09–1.31) in those residing in Iowa compared with 1.49 (95% CI, 1.36–1.62) in those residing in Los Angeles.

Finally, we examined the use of freestanding imaging centers for surveillance CT during the first surveillance period in patients who underwent a resection for curative intent for lung cancer and survived to the end of the first follow-up period (up to 15 mo). As shown in Figure 3, the proportion of surveillance CT scanning performed at freestanding imaging centers grew from 18.0% in 1998 to 30.6% in 2005.

Discussion

This is the first population-based study to examine the pattern of surveillance imaging after lung cancer resection. The main results are summarized as follows: use of surveillance CT and PET scan imaging increased by 32% per year between 1998 and 2005. There are large variations in surveillance intensity across SEER regions. The proportion of surveillance studies done at freestanding imaging centers almost doubled between 1998 and 2005.

The growth of surveillance imaging is likely multifactorial. Four societies recommend surveillance imaging at least biannually and taper frequency of imaging after the first 2 years and again at 5 years. The dissemination of these guidelines likely accounts for the surveillance imaging patterns seen in our study (Figure 1).

We observed growth in the use of CT and PET scanning among those who were diagnosed in the years leading up to 2005.

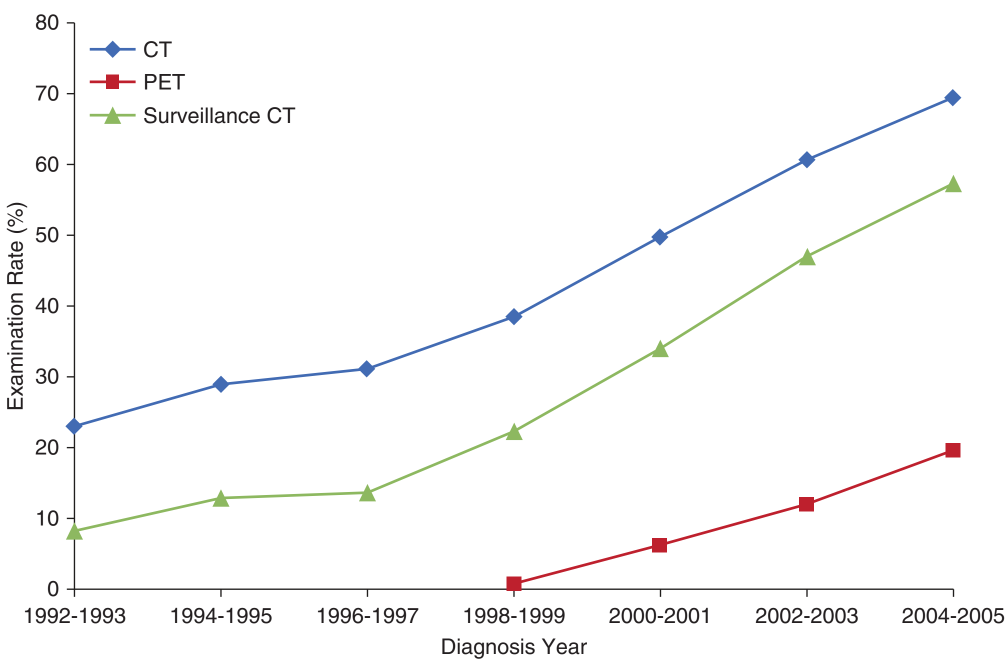

Figure 2. Rates of imaging studies by the year of cancer diagnoses. The plot was based on patients with lung cancer who survived at least 15 months after lung resection. Surveillance computed tomography (CT) was defined as a CT scan performed in an outpatient setting without a preceding chest radiograph in the previous 30 days. The rate was defined as the number of persons who ever received an examination (CT, surveillance CT, or positron emission tomography [PET] scan) divided by the total number of those diagnosed in a given 2-year period.

Table 3. Multivariable analyses of effect of patient and cancer characteristics on odds of undergoing chest CT or PET imaging during the follow-up period for patients diagnosed between 1998 and 2005*

Patient Characteristic	Odds Ratio (95% CI)		Patient Characteristic	Odds Ratio (95% CI)	
	Any CT or PET	Surveillance CT or PET†		Any CT or PET	Surveillance CT or PET†
Year of diagnosis	1.25 (1.22–1.29)	1.32 (1.29–1.36)	Stage		
Age, yr			I	Ref	Ref
66-69	Ref	Ref	II	1.73 (1.42–2.10)	1.80 (1.47–2.20)
70–74	0.87 (0.75–1.01)	0.89 (0.76–1.04)	IIIA	1.43 (1.09–1.86)	1.52 (1.16–1.99)
75–79	0.81 (0.69–0.94)	0.82 (0.70–0.96)	Tumor grade		
⩾80	0.56 (0.47–0.67)	0.52 (0.43–0.63)	Well differentiated	Ref	Ref
Sex			Moderately differentiated	1.17 (0.98–1.39)	1.14 (0.95–1.36)
Male	Ref	Ref	Poorly/undifferentiated	1.13 (0.94–1.35)	1.10 (0.92–1.33)
Female	0.95 (0.85–1.06)	1.00 (0.89–1.12)	Histologic type		
Race			Squamous	Ref	Ref
White	Ref	Ref	Adenocarcinoma	0.95 (0.83–1.07)	0.96 (0.84–1.10)
Black	0.86 (0.65–1.14)	0.99 (0.74–1.32)	Large cell	0.77 (0.59–1.01)	0.89 (0.66–1.20)
Other	1.38 (1.07–1.77)	1.35 (1.04–1.75)	Smoking-related pulmonary comorbidity		
Low socioeconomic status			0	Ref	Ref
No	Ref	Ref	1	1.03 (0.89–1.18)	0.94 (0.81–1.10)
Yes	0.83 (0.68–1.02)	0.81 (0.65–1.00)	⩾2	1.29 (1.00–1.66)	1.03 (0.80–1.33)
SEER region			Hospital type		
San Francisco	0.64 (0.48–0.85)	0.61 (0.45–0.82)	Nonprofit	Ref	Ref
Connecticut	Ref	Ref	For profit	0.95 (0.78–1.15)	0.94 (0.75–1.16)
Detroit	0.97 (0.80–1.17)	0.66 (0.54–0.81)	Public	0.97 (0.81–1.16)	0.99 (0.81–1.19)
Hawaii	0.52 (0.33–0.81)	0.42 (0.26–0.68)	Hospital size		
Iowa	0.70 (0.56–0.87)	0.50 (0.39–0.64)	⩽200 beds	Ref	Ref
New Mexico	0.70 (0.50–0.98)	0.63 (0.43–0.91)	201–350 beds	0.96 (0.79–1.18)	1.05 (0.84–1.31)
Seattle	0.83 (0.67–1.04)	0.77 (0.61–0.97)	351–500 beds	0.83 (0.66–1.04)	0.91 (0.71–1.16)
Utah	0.57 (0.39–0.84)	0.48 (0.31–0.75)	>500 beds	1.00 (0.80–1.26)	1.01 (0.79–1.30)
San Jose	0.63 (0.46–0.85)	0.60 (0.44–0.84)	Medical school affiliation		
Los Angeles	1.33 (1.07–1.65)	1.31 (1.05–1.64)	No affiliation	Ref	Ref
Atlanta and rural Georgia	1.00 (0.75–1.32)	0.92 (0.68–1.24)	Major	1.12 (0.94–1.35)	1.23 (1.02–1.49)
Income (quartiles)			Limited	1.47 (1.23–1.75)	1.43 (1.19–1.72)
Q1	Ref	Ref	Graduate	0.99 (0.79–1.23)	1.08 (0.85–1.37)
Q2	1.11 (0.92–1.34)	1.11 (0.90–1.36)	Surveillance year		
Q3	1.28 (1.06–1.55)	1.43 (1.17–1.74)	First year	Ref	Ref
Q4	1.57 (1.29–1.91)	1.69 (1.37–2.08)	Second year	0.93 (0.86–1.01)	1.03 (0.94–1.12)
			Third year	0.87 (0.79–0.96)	1.05 (0.95–1.16)
			Fourth year	0.89 (0.79–0.99)	1.03 (0.91–1.16)
			Fifth year	0.77 (0.67–0.88)	0.99 (0.86–1.14)

Definition of abbreviations: CI = confidence interval; CT = computed tomography; PET = positron emission tomography; SEER = Surveillance, Epidemiology and End Results.
*Total number of patients: 3,748.
†A CT or PET scan performed in an outpatient setting without a chest radiograph in the preceding 30 days is considered a surveillance CT or PET.

This growth is consistent with increases seen in the use of these imaging modalities nationally (25). The relative ease of obtaining imaging, increased availability, advancement in technology with better image quality, and efficiency are factors promoting the increased use of CT and PET scans. The number of freestanding imaging centers across the United States more than doubled from 2,661 in 1997 to 6,455 in 2008 (22). This rapid growth in supply took place in response to equally rapid growth in demand for outpatient imaging.

From 2000 through 2006, Medicare Part B (physician services) spending for imaging increased from $6.7 billion to $13.8 billion, a compound annual growth rate of 13% per year (22). As a result, provisions to curb overuse of imaging in private offices were incorporated into the Deficit Reduction Act (DRA) of 2005, which took effect January 1, 2007. The extent to which these changes in medical imaging reimbursement curb the use of imaging studies is yet to be determined.

Both patient and physician preferences may explain surveillance imaging patterns. Physicians may employ a more intensive surveillance strategy because they overestimate the value of follow-up and its impact on long-term survival; they believe that early recurrences are treatable; they find it time-consuming or difficult to communicate futile care to patients; or they are simply providing care in concordance with the clinical practice guidelines, or perhaps influenced by financial incentives, especially if they have a share in the imaging center (26). Patients, on the other hand, may choose frequent follow-up because they overestimate their chances of survival, they fail to understand the limited options for recurrence or the consequences of foregoing aggressive care, or they desire

Table 4. Regional variation in undergoing chest CT or PET imaging during the first surveillance period for patients diagnosed between 1998 and 2005,* by the year of diagnosis

SEER Region	Any CT or PET					Surveillance CT or PET				
	Unadjusted Rate (%)				Odds Ratio† of Each Year increase in Diagnosis Year (95% CI)	Unadjusted Rate (%)				Odds Ratio† of Each Year Increase in Diagnosis Year (95% CI)
	1998 to 1999	2000 to 2001	2002 to 2003	2004 to 2005		1998 to 1999	2000 to 2001	2002 to 2003	2004 to 2005	
San Francisco	39.2	35.1	60.7	63.8	1.27 (1.11–1.45)	21.6	24.6	51.8	55.3	1.39 (1.21–1.61)
Connecticut	40.7	54.5	64.3	75.4	1.25 (1.15–1.35)	30.8	44.8	54.5	70.0	1.30 (1.20–1.41)
Detroit	48.2	54.8	64.9	75.0	1.21 (1.12–1.31)	16.5	34.5	48.9	63.3	1.44 (1.32–1.56)
Hawaii	36.7	50.0	48.1	53.8	1.11 (0.93–1.32)	20.0	27.3	33.3	34.6	1.11 (0.92–1.35)
Iowa	37.7	43.2	46.6	64.7	1.20 (1.11–1.31)	17.9	26.5	29.8	37.3	1.20 (1.09–1.31)
New Mexico	40.0	28.0	48.1	61.9	1.19 (0.99–1.43)	28.6	20.0	44.4	57.1	1.30 (1.07–1.58)
Seattle	26.9	47.2	63.6	73.4	1.42 (1.28–1.57)	17.6	31.5	49.6	58.2	1.42 (1.28–1.58)
Utah	27.3	53.8	43.8	60.0	1.22 (0.99–1.50)	13.6	30.8	28.1	53.3	1.30 (1.03–1.65)
San Jose	39.0	47.7	51.0	60.0	1.18 (1.03–1.37)	22.0	31.8	32.7	60.0	1.39 (1.18–1.62)
Los Angeles	38.2	60.0	79.1	83.5	1.51 (1.38–1.66)	27.0	47.0	62.6	75.2	1.49 (1.36–1.62)
Atlanta and rural Georgia	32.3	43.3	67.7	69.0	1.37 (1.20–1.57)	22.6	31.7	50.0	66.7	1.43 (1.24–1.64)

Definition of abbreviations: CI = confidence interval; CT = computed tomography; PET = positron emission tomography; SEER = Surveillance, Epidemiology and End Results.
*Total number of patients: 3,748.
†Estimated from the interaction logistic model adjusted for patient, tumor, and hospital characteristics.

to be a “good patient” and not question physician recommendations (11).

These attitudes, combined with results of a study by Westeel and colleagues, reporting that an intensive surveillance regimen may be cost-effective for additional years of life gained, may have contributed to imaging use (27). However, no currently published data support intensive surveillance based on improvement of patient outcomes. Results are pending for the IFCT-0302 trial, a randomized multicenter study comparing survival among completely resected patients with non–small cell lung cancer for two surveillance schemes: one with CT imaging and bronchoscopy and the other with physical examination and chest radiographs (28).

The usefulness of surveillance imaging must also be questioned. False positive rates, anxiety associated with false positive tests, and risk of radiation exposure from CT scanning should be balanced against the benefits of routine surveillance. Although most recurrences are intrathoracic, up to one-third are extrathoracic recurrences. The latter group is unlikely to benefit from thoracic surveillance imaging (6, 29–31). Each annual surveillance CT scan adds approximately $1,412 to the cost of additional investigation without affecting outcomes (32). Kent and colleagues, using a decision analysis model, showed that postresection CT surveillance is not cost-effective (33).

Six current guidelines have been published for surveillance of patients with non–small cell lung cancer after curative-intent therapy. These were developed with limited evidence and were largely based instead on the consensus of expert panels. Conflicting data on the use of surveillance chest imaging stem from debate over detection of recurrence versus second primary lung cancer and synchronous versus metachronous primary lesions. The growing use of stereotactic body radiation therapy in the treatment of recurrence (34–36) and/or metachronous cancers (37) and second primary lung cancers (38) may help redefine the role of surveillance in patients with lung cancer.

Large regional variation seen in the use of CT or PET imaging during follow-up care is consistent with other studies of regional variation in health care use among Medicare beneficiaries (39, 40). Physicians practicing in high-spending regions are more likely to recommend tests of unproven benefit compared with those in low-spending

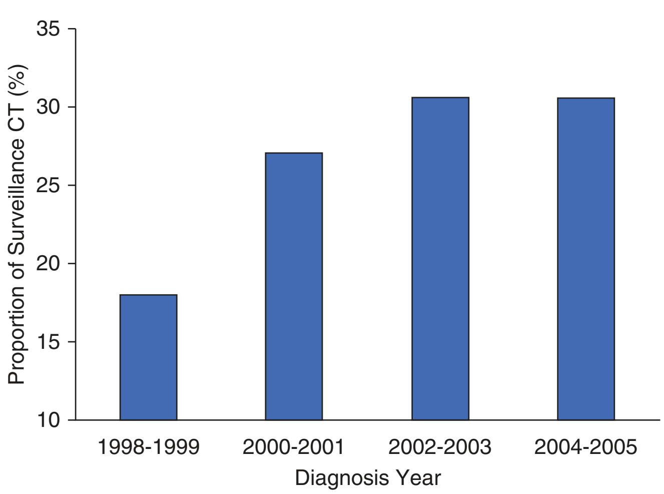

Figure 3. Proportion of surveillance computed tomography (CT) performed in free-standing imaging centers. This plot shows the surveillance CTs performed in patients at a free-standing imaging center during the first surveillance period (4–15 mo after surgery).

regions (41). A survey of members of the Society of Thoracic Surgeons found that surgeons practicing in the Los Angeles/ Long Beach, California area had the highest frequency of follow-up test use across all modalities, TNM stage, and year postsurgery (42). Tampa/St. Petersburg, Florida generally had the lowest frequency across modalities, TNM stage, and year postsurgery. Similarly, cardiothoracic surgeons from large metropolitan areas (population size, 2.5–10 million) used more intensive follow-up strategies than those from small metropolitan areas (43). This difference likely reflects the practice pattern of surgeons based on their training; most surgeons tend to practice close to their place of training. Similar information on the practice patterns of medical oncologists or pulmonary physicians for lung cancer survivors is lacking. Future studies should examine the role of the primary care physician and subspecialist in the follow-up care of patients with lung cancer.

Limitations

Our study has several limitations. We limited our analyses to Medicare fee-for-service beneficiaries. The results may not be applicable to younger individuals or those enrolled in managed care organizations.

Lung cancer staging and treatment has changed during the study period and continues to evolve—especially in the 10 years since the study period elapsed. Specifically, adjuvant chemotherapy is now the standard of care for patients with stage IIB and IIIA non–small cell lung cancer after surgical resection. However, 87.5% patients in our cohort were at stage I and we excluded patients who received neoadjuvant or adjuvant chemotherapy and/or radiotherapy. The administrative data are useful in determining the number of procedures received by a patient. It is not always evident from administrative claims whether a test was ordered for routine or diagnostic indications.

Our decision to exclude from our surveillance cohort patients who underwent chest radiography in the 30 days preceding CT or PET imaging may be arbitrary. However, a chest radiograph is an office procedure easily obtained in a clinical setting for assessment of symptomatic patients. To further characterize the abnormality, a CT scan is ordered. Certain patients may have had a CT scan without a chest radiograph for diagnostic rather than surveillance purposes and this may have resulted in overestimation of the use of CT scanning for surveillance. In contrast to overestimation, underestimation may also occur if routine chest radiography was performed within 30 days of surveillance CT. However, these changes would affect the magnitude of growth but not the overall trend.

Summary

Chest CT and PET imaging for surveillance after curative-intent surgical resection of lung cancer increased rapidly in the United Stated during the years leading up to 2005. In the absence of evidence to support or refute surveillance imaging, growth was likely driven by guidelines based on expert opinion that were developed and disseminated by various national organizations during that time. There is a clear need for better evidence on the role of routine surveillance chest imaging after lung cancer resection. ■

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