

Use of Lung Cancer Screening Tests in the United States: Results from the 2010 National Health Interview Survey

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Abstract

Background: Before evidence of efficacy, lung cancer screening was being ordered by many physicians. The National Lung Screening Trial (NLST), which showed a 20% reduction in lung cancer mortality among those randomized to receive low-dose computed tomography (LDCT), will likely lead to increased screening use.

Methods: We estimated the prevalence of chest X-ray and CT use in the United States using data from the 2010 National Health Interview Survey (NHIS). Subjects included 15,537 NHIS respondents aged ≥ 40 years without prior diagnosis of lung cancer. Estimates of the size of the U. S. population by age and smoking status were calculated. Multivariate logistic regression examined predictors of test use adjusting for potential confounders.

Results: Twenty-three percent of adults reported chest X-ray in the previous year and 2.5% reported chest X-ray specifically to check for lung cancer; corresponding numbers for chest CT were 7.5% and 1.3%. Older age, black race, male gender, smoking, respiratory disease, personal history of cancer, and having health insurance were associated with test use. Approximately, 8.7 million adults in the United States would be eligible for LDCT screening according to NLST eligibility criteria.

Conclusions and Impact: Monitoring of trends in the use of lung screening tests will be vital to assess the impact of NLST and possible changes in lung cancer screening recommendations and insurance coverage in the future. Education of patients by their physicians, and of the general public, may help ensure that screening is used appropriately, in those most likely to benefit. *Cancer Epidemiol Biomarkers Prev*; 21(7); 1049–59. ©2012 AACR.

Introduction

Lung cancer is a potentially attractive candidate for screening. It is the leading cause of cancer mortality in men and women, with nearly 160,000 deaths in the United States annually (1). Furthermore, while lung cancer has an overall 5-year survival rate of only 16%, it has a better prognosis (5-year survival rate, 52%) when detected at a localized stage (2). However, randomized controlled trials (RCT) initiated in the 1970s failed to show a reduction in lung cancer mortality in individuals screened by more-versus less-intensive regimens of chest X-ray and/or sputum cytology (refs. 3–5; reviewed in ref. 6). More

recently, the Prostate, Lung, Colorectal, and Ovarian (PLCO) Cancer Screening Trial found no benefit of chest X-ray screening in reducing lung cancer mortality, as compared with usual care (7). Despite lack of clinical trial evidence to support its use, however, chest X-ray has been continued to be used by many physicians as a lung cancer screening test (8).

By the 1990s, interest began to develop in a newer screening test, low-dose helical computed tomography (LDCT), after it was found to be much more sensitive in detecting early-stage lung cancers than chest X-ray (9). In November 2010, the National Lung Screening Trial (NLST), a large, National Cancer Institute (NCI)-sponsored RCT, reported a 20% reduction in lung cancer mortality among heavy smokers randomized to receive annual chest LDCT as compared with annual chest X-ray (10). NLST results have renewed interest in lung cancer screening. Although most guidelines do not currently recommend lung cancer screening by any modality (11–13), in October 2011, the National Comprehensive Cancer Network (NCCN) became the first professional society in the United States to recommend LDCT screening for select patients at high-risk (14). If other organizations update their guidelines to recommend LDCT, this will likely lead to increased screening in high-risk populations in the future.

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In an effort to develop data resources to monitor the use of lung cancer screening tests in the United States, the NCI and the Centers for Disease Control and Prevention's (CDC) Division of Cancer Prevention and Control co-sponsored the inclusion of several questions on chest X-ray and CT use in the Cancer Control Supplement to the 2010 National Health Interview Survey (NHIS; ref. 15). These data are timely, in that they provide a baseline estimate of how commonly chest X-ray and CT were used in the United States at a time largely before the results of the NLST trial were known and when lung cancer screening was not covered by insurance. The data are also novel, as a national data monitoring system for lung cancer screening does not exist. It is likely that the use of LDCT for lung cancer screening will increase in the United States in the coming years as a result of the NLST findings. Therefore, having a baseline estimate of the use of these tests will be important in monitoring trends. In this analysis, we examine the use of chest X-ray and CT in the United States in 2010. We also estimate the size of the U.S. population that might be considered for lung cancer screening with LDCT, based on population characteristics that correspond to NLST eligibility criteria.

Materials and Methods

Study population and data collection

The NHIS is an annual survey of the civilian, non-institutionalized population of the United States conducted by the National Center for Health Statistics of the CDC (16, 17). A nationally representative sample of households is selected using a multistage cluster sample design, and trained interviewers from the U.S. Census Bureau administer the survey in-person using computer-assisted personal interviewing. Oversampling of Hispanic, black, and Asian populations is conducted to allow for more precise estimation of health characteristics in these minority groups.

The NHIS Family Core component is used to collect information on everyone in each family living in participating selected households. Subsequently, information about health status and behaviors is ascertained for one randomly selected adult in each family (Sample Adult Core). Starting in 2000, supplemental questions about cancer (the Cancer Control Supplement), including questions on screening behaviors, are fielded periodically in the core adult questionnaire. For the 2010 survey, interviews were conducted among 34,329 households, with 27,157 adults interviewed as part of the Sample Adult component. The overall response rate for the family was 78.7% and the conditional response rate for the selected adult was 77.3%, yielding a final response rate of 60.8%.

The 2010 Cancer Control Supplement included questions pertaining to the use of chest X-rays and CT scans. These questions asked about the overall use of both types of test within the year before the interview and further whether they were done "to check for lung cancer, rather than for some other reason" (full text of all questions

available in ref. 15). Other relevant variables included personal history of lung cancer (including age at diagnosis), and sociodemographic characteristics, smoking history, occupation, health status, and health care access variables (Tables 1 and 2). For this analysis, smokers were divided into 2 categories: "higher risk" smokers were those with a 30 pack-year or more smoking history and were either current smokers or former smokers who had quit within 15 years before interview, whereas "lower risk" smokers had either a fewer than 30 pack-year history and/or had quit more than 15 years ago. By this definition, respondents who were classified as higher risk met the smoking eligibility requirement for the NLST trial (10).

Race and ethnicity responses were combined to form the categories Hispanic (of any race), and non-Hispanic white, black, Asian, and other race; other race included American-Indians, Alaska natives, and those who reported multiple races without mention of a primary race. Health insurance status was classified as uninsured, public insurance only, or any private insurance. Those with Medicare Part A/B and also private insurance were classified as privately insured and those with Medicare Part A (hospital coverage) only were combined with uninsured. Missing data for race were imputed using hot-deck imputation (in which a missing value is replaced with an observed value from a similar respondent), and missing data for family income were imputed using multiple imputation (16, 17).

Because the lung cancer testing questions were only asked of respondents aged 40 years and older, those younger than 40 years ($n = 10,200$) were excluded from this analysis. In addition, we excluded those who reported a diagnosis of lung cancer at an age 2 or more years younger than the age at interview ($n = 44$), as they would not have been candidates for lung cancer screening in the year before interview. Those with lung cancer diagnosed at their age of interview or 1 year younger could have had their cancer detected because of a reported chest X-ray or chest CT and are thus included. We also excluded 33 respondents with an unknown lung cancer status and 2 for whom the difference between age at interview and age at lung cancer diagnosis could not be determined. Finally, we excluded those who refused to answer the lung cancer testing questions and those whose response was categorized as "not ascertained"; not ascertained was used when individuals discontinued their interview at some point after completing the first 3 sections of the Sample Adult component. We did include those who answered "don't know," although less than 1% of respondents fell into this category. After the additional exclusion of those with "refused" or "not ascertained" responses, 15,537 adults aged 40 and older were included in the chest X-ray analyses and 15,534 were included in the chest CT analyses.

Statistical analysis

All analyses were weighted to account for household sampling probabilities and nonresponse. National

Table 1. Use of chest X-ray in the past 12 months, overall and to check for lung cancer

	Total n	Any chest X-ray			Chest X-ray to check for lung cancer		
		n	Weighted %	95% CI	n	Weighted%	95% CI
Total	15,537	3,642	22.9	22.2–23.6	406	2.5	2.2–2.8
Sociodemographic characteristics							
Age, y							
40–49	4,425	649	14.8	13.5–16.1	45	0.9	0.7–1.3
50–59	4,228	944	21.5	20.1–22.9	106	2.4	2.0–3.0
60–69	3,401	941	27.5	25.8–29.3	120	3.4	2.8–4.2
70–79	2,089	661	32.7	30.4–35.1	81	4.0	3.2–5.1
80+	1,394	447	33.9	30.9–37.1	54	3.7	2.6–5.4
Sex							
Male	6,738	1,671	24.2	23.1–25.4	229	3.1	2.7–3.6
Female	8,799	1,971	21.7	20.7–22.7	177	1.9	1.6–2.2
Race/ethnicity							
White	9,739	2,342	23.2	22.4–24.1	250	2.5	2.2–2.9
Black	2,494	721	28.0	25.9–30.2	90	3.3	2.6–4.1
Hispanic	2,317	400	18.1	16.3–20.1	43	1.7	1.2–2.5
Asian	875	151	17.2	14.2–20.7	18	1.4	0.8–2.4
Other	112	28	19.7	12.5–29.8	5	2.5	1.0–6.4
Currently employed							
No	7,645	2,265	29.7	28.4–31.0	267	3.3	2.9–3.8
Yes	7,887	1,376	17.3	16.4–18.3	139	1.8	1.5–2.2
Education							
Less than high-school graduate	2,814	688	24.6	22.6–26.8	87	2.9	2.2–3.8
High-school graduate/GED	4,325	1,047	23.2	21.7–24.7	116	2.4	1.9–3.0
Some college/associate degree	4,276	1,075	25.5	24.0–27.0	109	2.5	2.0–3.2
Bachelor's degree or more	4,050	817	19.3	18.0–20.7	91	2.3	1.8–2.8
Family income							
<\$20,000	3,640	1,001	27.4	25.6–29.3	121	2.9	2.3–3.7
\$20,000–\$34,999	2,959	737	25.9	24.0–28.0	84	2.9	2.3–3.8
\$35,000–\$54,999	2,964	694	24.1	22.2–26.1	82	2.7	2.1–3.6
\$55,000–\$74,999	1,784	401	23.2	21.0–25.4	45	2.5	1.7–3.5
\$75,000+	4,190	809	18.8	17.6–20.1	73	1.9	1.5–2.4
Risk factors							
Smoking							
Never	8,480	1,709	19.2	18.2–20.2	137	1.4	1.2–1.7
Former, <30 pack-years	2,712	680	24.8	23.0–26.7	78	2.8	2.2–3.6
Former, 30+ pack-years, quit >15 y	411	136	36.2	30.9–41.9	19	5.2	3.2–8.5
Former, 30+ pack-years, quit ≤15 y ^a	708	268	36.9	32.6–41.4	52	7.5	5.6–10.1
Current, <30 pack-years	1,786	446	23.8	21.7–26.2	50	2.4	1.8–3.1
Current, 30+ pack-years ^a	926	261	28.5	25.5–31.6	54	5.8	4.2–7.8
Unknown	514	142	29.0	24.2–34.4	16	1.9	1.2–3.2
Attempted to quit smoking in the last 12 mo (current smokers)							
No	1,586	353	22.3	20.0–24.8	56	3.6	2.6–5.0
Yes	1,188	365	29.6	26.8–32.6	52	3.5	2.6–4.7
Secondhand smoke exposure							
No	12,803	2,937	22.2	21.4–23.1	310	2.3	2.0–2.6
Yes	2,696	699	26.0	23.9–28.2	96	3.4	2.7–4.3
Occupational exposure to vapors/gas/dust/fumes (among employed, past 12 mo)							
No	6,400	1,104	16.9	16.0–18.0	97	1.7	1.3–2.1
Yes	2,294	479	21.1	19.3–23.1	55	2.2	1.6–3.0

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Table 1. Use of chest X-ray in the past 12 months, overall and to check for lung cancer (Cont'd)

	Total n	Any chest X-ray			Chest X-ray to check for lung cancer		
		n	Weighted %	95% CI	n	Weighted%	95% CI
Family history of lung cancer							
No	13,667	3,134	22.4	21.7–23.2	343	2.4	2.1–2.7
Yes	826	262	30.5	26.9–34.4	35	3.5	2.4–5.1
Unknown	1,044	246	23.0	20.3–25.9	28	2.4	1.6–3.8
Personal history of cancer other than lung							
No	13,599	2,931	21.1	20.3–21.8	278	1.9	1.6–2.2
Yes	1,938	711	35.6	32.9–38.5	128	6.4	5.2–7.8
Health status							
Respiratory conditions diagnosed by a health professional							
None	13,062	2,619	19.6	18.9–20.4	270	1.9	1.7–2.2
Any	2,463	1,017	40.0	37.7–42.4	136	5.4	4.4–6.6
Emphysema (ever)	458	274	59.9	54.5–65.2	57	12.4	9.3–16.5
Asthma (ever)	1,835	715	37.0	34.5–39.6	95	4.8	3.9–6.0
Asthma (attack in past 12 mo)	678	319	46.1	41.7–50.5	46	6.3	4.6–8.6
Chronic bronchitis (past 12 mo)	853	438	51.3	47.4–55.3	54	6.8	4.9–9.5
Limitations in activities due to lung/breathing problem							
No	14,947	3,319	21.8	21.0–22.5	352	2.2	2.0–2.5
Yes	510	305	58.4	53.7–63.0	52	9.4	6.9–12.7
General health status							
Excellent/very good/good	12,487	2,439	19.4	18.6–20.2	248	1.9	1.7–2.2
Fair/poor	3,041	1,201	40.4	38.3–42.6	158	5.2	4.3–6.2
Health care access							
Insurance status, age < 65							
Uninsured ^b	2,007	235	12.2	10.7–14.0	23	1.3	0.7–2.1
Public only	1,693	579	33.6	30.9–36.4	73	4.2	3.2–5.5
Private ^c	6,846	1,304	18.8	17.7–19.8	117	1.7	1.4–2.1
Insurance status, age ≥ 65							
Uninsured ^b	92	17	18.9	11.4–29.8	1	1.8	0.3–11.6
Public only	2,398	746	32.5	30.0–35.0	102	3.8	2.9–4.8
Private ^c	2,471	759	31.3	29.2–33.4	90	3.9	3.1–4.9
Usual source of health care other than ER							
No	1,783	211	11.1	9.5–13.0	22	1.1	0.7–1.9
Yes	13,748	3,429	24.3	23.5–25.1	384	2.6	2.3–2.9
Number of office visits to doctor or other health professional in last year							
0	2,268	125	5.3	4.3–6.5	9	0.4	0.2–1.1
1	2,144	246	10.7	9.2–12.2	34	1.4	1.0–2.1
2–5	6,519	1,392	20.6	19.4–21.8	147	2.1	1.8–2.6
6+	4,553	1,864	41.0	39.5–42.6	215	4.5	3.8–5.2

NOTE: Source: 2010 NHIS.

^a"Higher risk" smokers, defined according to the eligibility criteria for the NLST of LDCT.^bIncludes Medicare Part A only.^cIncludes Medicare Part A and B with supplemental private insurance.

estimates of the proportion receiving a chest X-ray or CT in the last year, both overall and to check for lung cancer, and their accompanying 95% confidence intervals (CI), were calculated for the entire population and for various subgroups. Multivariate logistic regression was used to examine respondent characteristics associ-

ated with test use while adjusting for potential confounders. Because of concern about possible residual confounding (specifically incomplete adjustment for smoking behavior), regression models restricted to never-smokers were also fit. For the logistic models, those with emphysema (with or without other respiratory

Table 2. Use of chest CT in the past 12 months, overall and to check for lung cancer

	Total n	Any chest CT			Chest CT to check for lung cancer		
		n	Weighted%	95% CI	n	Weighted%	95% CI
Total	15,534	1,244	7.5	7.1–8.0	213	1.3	1.1–1.5
Sociodemographic characteristics							
Age, y							
40–49	4,425	199	4.2	3.5–4.9	25	0.5	0.3–0.7
50–59	4,225	283	6.2	5.4–7.2	44	1.0	0.7–1.5
60–69	3,401	358	10.6	9.5–11.9	73	2.2	1.7–2.8
70–79	2,089	246	11.4	9.9–13.1	41	2.0	1.4–2.8
80+	1,394	158	11.6	9.8–13.7	30	1.8	1.2–2.7
Sex							
Male	6,736	638	8.9	8.2–9.7	125	1.6	1.3–2.0
Female	8,798	606	6.2	5.7–6.8	88	1.0	0.8–1.2
Race/ethnicity							
White	9,737	781	7.5	6.9–8.1	135	1.3	1.1–1.6
Black	2,493	274	9.9	8.6–11.4	45	1.5	1.1–2.2
Hispanic	2,317	135	6.1	5.0–7.5	22	0.8	0.5–1.2
Asian	875	46	6.1	4.2–8.9	9	1.0	0.5–2.2
Other	112	8	3.7	1.7–8.1	2	1.1	0.3–4.5
Currently employed							
No	7,645	868	11.0	10.2–11.9	160	2.0	1.7–2.4
Yes	7,884	375	4.6	4.1–5.2	53	0.7	0.5–0.9
Education							
Less than high-school graduate	2,814	253	8.6	7.4–9.9	44	1.4	1.0–1.9
High-school graduate/GED	4,325	371	8.0	7.1–8.9	69	1.4	1.1–1.9
Some college/associate degree	4,276	356	8.1	7.3–9.0	54	1.3	0.9–1.7
Bachelor's degree or more	4,047	255	6.0	5.3–6.9	43	1.0	0.7–1.4
Family income							
<\$20,000	3,640	395	10.4	9.1–12.0	77	1.8	1.4–2.4
\$20,000–\$34,999	2,959	247	8.3	7.0–9.7	41	1.4	1.0–1.9
\$35,000–\$54,999	2,963	234	8.4	7.3–9.7	40	1.5	1.1–2.1
\$55,000–\$74,999	1,784	130	7.4	6.1–8.9	15	0.9	0.5–1.6
\$75,000+	4,188	238	5.5	4.8–6.3	41	1.0	0.7–1.4
Risk factors							
Smoking							
Never	8,479	564	6.0	5.4–6.6	71	0.8	0.6–1.0
Former, <30 pack-years	2,711	248	8.9	7.8–10.2	49	1.7	1.3–2.4
Former, 30+ pack-years, quit >15 y	411	63	17.4	13.6–22.0	9	2.4	1.1–4.9
Former, 30+ pack-years, quit ≤15 y ^a	708	105	14.6	12.0–17.7	34	4.4	3.2–6.1
Current, <30 pack-years	1,786	133	6.4	5.4–7.6	22	1.0	0.7–1.4
Current, 30+ pack-years ^a	926	84	9.0	7.1–11.2	19	1.8	1.1–3.1
Unknown	513	47	7.8	5.8–10.3	9	1.1	0.5–2.2
Attempted to quit smoking in the last 12 mo (current smokers)							
No	1,586	106	6.1	4.9–7.7	18	1.0	0.6–1.7
Yes	1,188	116	8.9	7.3–10.8	25	1.7	1.1–2.5
Secondhand smoke exposure							
No	12,799	1,028	7.5	7.0–8.1	181	1.3	1.1–1.6
Yes	2,696	211	7.6	6.5–8.8	32	1.1	0.7–1.6
Occupational exposure to vapors/gas/dust/fumes (among employed, past 12 mo)							
No	6,398	301	4.6	4.1–5.3	46	0.8	0.6–1.1
Yes	2,293	141	5.8	4.8–7.0	15	0.6	0.4–1.1

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Table 2. Use of chest CT in the past 12 months, overall and to check for lung cancer (Cont'd)

	Total n	Any chest CT			Chest CT to check for lung cancer		
		n	Weighted%	95% CI	n	Weighted%	95% CI
Family history of lung cancer							
No	13,667	1,056	7.3	6.8–7.9	182	1.2	1.0–1.5
Yes	827	93	9.2	7.2–11.8	18	1.7	1.0–3.0
Unknown	1,040	95	8.5	6.5–11.1	13	1.3	0.7–2.4
Personal history of cancer other than lung							
No	13,595	899	6.1	5.7–6.6	116	0.8	0.6–1.0
Yes	1,939	345	17.3	15.3–19.5	97	4.7	3.7–5.9
Health status							
Respiratory conditions diagnosed by a health professional							
None	13,058	892	6.5	6.0–7.0	133	1.0	0.8–1.2
Any	2,464	349	13.1	11.7–14.7	78	2.9	2.3–3.7
Emphysema (ever)	458	107	21.2	17.3–25.8	36	7.3	5.1–10.3
Asthma (ever)	1,836	253	12.7	11.1–14.5	55	2.8	2.0–3.8
Asthma (attack in past 12 mo)	678	126	18.3	15.1–22.0	28	4.1	2.7–6.2
Chronic bronchitis (past 12 mo)	853	151	17.6	14.7–20.8	37	4.3	3.0–6.2
Limitations in activities due to lung/breathing problem							
No	14,944	1,118	7.0	6.6–7.6	178	1.1	0.9–1.3
Yes	510	122	22.7	18.7–27.3	35	6.8	4.7–9.9
General health status							
Excellent/very good/good	12,485	725	5.6	5.1–6.1	119	0.9	0.7–1.1
Fair/poor	3,040	518	17.2	15.6–18.9	94	3.2	2.6–4.1
Health care access							
Insurance status, age < 65							
Uninsured ^b	2,007	59	3.1	2.3–4.0	6	0.3	0.1–0.8
Public only	1,692	231	11.9	10.2–13.7	49	2.3	1.6–3.2
Private ^c	6,844	389	5.7	5.1–6.4	55	0.9	0.6–1.2
Insurance status, age ≥ 65							
Uninsured ^b	92	7	9.3	4.1–19.9	2	2.5	0.5–10.6
Public only	2,397	274	10.8	9.5–12.2	50	1.9	1.4–2.6
Private ^c	2,472	284	11.9	10.5–13.4	51	2.2	1.6–2.9
Usual source of health care other than ER							
No	1,783	53	2.6	1.9–3.7	8	0.4	0.2–0.8
Yes	13,745	1,190	8.1	7.6–8.6	205	1.4	1.2–1.6
Number of office visits to doctor or other health professional in last year							
0	2,268	19	0.8	0.5–1.4	3	0.1	0.0–0.4
1	2,144	61	2.6	1.9–3.5	13	0.4	0.2–0.7
2–5	6,518	393	5.5	4.9–6.2	59	0.8	0.6–1.1
6+	4,551	766	16.3	15.1–17.6	137	2.9	2.4–3.5

NOTE: Source: 2010 NHIS.

^aHigher risk" smokers, defined according to the eligibility criteria for the NLST of LDCT.^bIncludes Medicare Part A only.^cIncludes Medicare Part A and B with supplemental private insurance.

conditions) were considered separately from those with other respiratory conditions only, due to increased test use in those with emphysema in these data. Finally, sampling probabilities were used to derive estimates of the size of the U.S. population according to combined categories of age and smoking, to estimate the number of U.S. adults who would be screen-eligible according to

various criteria. All analyses were conducted using SAS version 9.1.3 and SUDAAN version 10.0.1.

Results

Overall, 23% of adults reported receipt of a chest X-ray in the year before interview and 2.5% reported chest X-ray

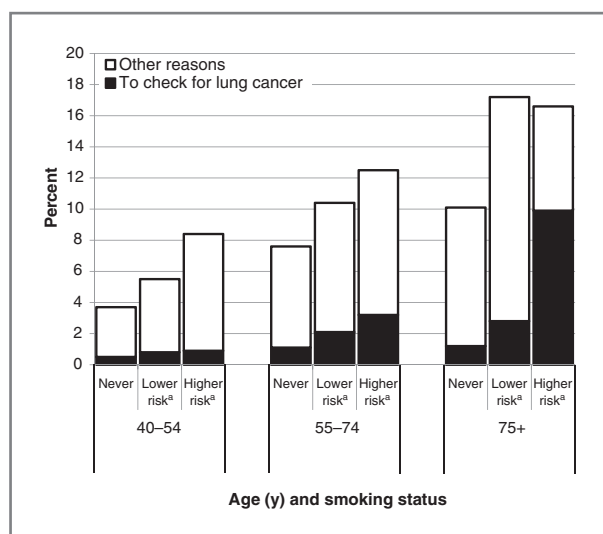


Figure 1. Use of chest CT in the last 12 months by age and smoking status, overall and to check for lung cancer. Source: 2010 NHIS. ^aRisk defined according to eligibility criteria used in the NLST of LDCT. Those at higher risk include current and former smokers with at least a 30 pack-year history; in addition, for classification as high risk, former smokers must have quit within the last 15 years.

to check for lung cancer; the corresponding numbers for chest CT were 7.5% and 1.3%, respectively (Tables 1 and 2). This represents 31.8 million individuals receiving chest X-rays (3.4 million to check for lung cancer) and 10.5 million receiving chest CTs (1.8 million to check for lung cancer) annually. A slightly higher proportion of chest CTs (17%) compared with chest X-rays (11%) were done to check for lung cancer.

While the absolute percentages differed, relative patterns of use in various subgroups were largely similar for chest X-ray and CT, both for all tests and tests done to check for lung cancer (Tables 1 and 2). Higher use tended to occur in older individuals, males, blacks, smokers (especially former, heavy smokers), those who had attempted to quit smoking, those with exposure to secondhand smoke or occupational exposure to other respiratory irritants, those with a family history of lung cancer or a personal history of cancer other than lung cancer, those with respiratory conditions or fair/poor health status, those with health insurance coverage, and those with a usual source of health care and with a greater number of doctor visits. Lower use occurred among Asians and Hispanics, those with higher income, and uninsured individuals.

Use of chest CT according to combined age and smoking categories is shown in Fig. 1. The lowest prevalence of CT use (3.7%) was reported by never-smokers aged 40–54 and the highest (17%) in lower risk smokers aged 75 and above. Examinations done to check for lung cancer tended to represent a minority (<one quarter) of all chest CTs; the one exception was higher risk smokers aged 75 and above, for whom 60% of examinations were done to check for lung cancer.

Adjustment for potential confounders largely did not alter the relationships between covariates and the use of chest X-ray or CT to check for lung cancer (Table 3), with one notable exception. After adjustment for other factors, income was not associated with chest X-ray use or chest CT use. Results were similar in logistic models that considered tests done for any reason and/or restricted to never-smokers (data not shown).

Estimates of the size of the U.S. civilian, non-institutionalized population according to age and smoking status are shown in Table 4. There are approximately 8.7 million people in the United States who would meet the NLST eligibility criteria for chest CT screening. An additional 6.7 million are higher risk smokers age 40 and over but outside of NLST's screening age range of 55–74 years, and 44.7 million are lower risk current/former smokers of any age.

Discussion

We found that during a time period largely before the announcement of NLST results that LDCT reduces lung cancer mortality by 20%, large numbers of chest X-rays and CTs were conducted in the United States. We estimate that among U.S. adults aged 40 and above without lung cancer, approximately 30 million (~one quarter) had received a chest X-ray in the previous year, and approximately 10 million (8%) had received a chest CT. According to respondent self-report, the majority of these examinations (83% of chest CTs, 89% of chest X-rays) were not conducted to check for lung cancer. The NHIS did not ascertain the indication for examinations done for other reasons; however, current and former smokers and those with respiratory conditions were much more likely to have had a chest imaging examination. Use was also more common in older individuals, males, non-Hispanic blacks, and those with health insurance.

NHIS is the only recent national survey of the general population to examine the use of lung cancer screening tests in the United States. However, a 2006–2007 national survey of U.S. primary care physicians (PCP) did assess physicians' knowledge, beliefs, and practices about lung cancer screening tests (8, 18). In that survey, 55% of PCPs reported that in the past year, they had ordered chest X-ray to screen an asymptomatic patient for lung cancer and 22% had ordered screening LDCT (8). Recommendations for screening were likely influenced at least partially by perceived efficacy of chest imaging. A majority of PCPs believed that chest X-ray and/or LDCT was very or somewhat effective in reducing lung cancer mortality in current smokers and one quarter believed that major guidelines supported lung cancer screening. In addition, over two thirds of PCPs indicated that they had been asked about lung cancer screening by one or more patients in the last 12 months (18). This type of screening use outside of guideline recommendations is typical in environments in which organized screening programs are lacking, as illustrated

Table 3. Factors associated with use of chest X-ray and chest CT to check for lung cancer, multivariate logistic regression

	Chest X-ray OR (95% CI)	Chest CT OR (95% CI)
<i>Sociodemographic characteristics</i>		
<i>Age, y</i>		
40–49	1.00 (referent)	1.00 (referent)
50–59	2.08 (1.36–3.19)	1.69 (0.92–3.11)
60–69	2.30 (1.56–3.40)	2.63 (1.46–4.75)
70–79	2.53 (1.61–3.97)	1.95 (1.02–3.74)
80+	3.17 (1.82–5.52)	2.24 (1.08–4.66)
<i>Sex</i>		
Female	1.00 (referent)	1.00 (referent)
Male	1.67 (1.29–2.15)	1.83 (1.29–2.59)
<i>Race/ethnicity</i>		
White	1.00 (referent)	1.00 (referent)
Black	1.84 (1.38–2.45)	1.69 (1.08–2.64)
Hispanic	1.04 (0.71–1.54)	1.15 (0.69–1.94)
Asian	0.89 (0.48–1.66)	1.43 (0.64–3.16)
Other	1.05 (0.41–2.71)	0.94 (0.21–4.11)
<i>Family income</i>		
<\$20,000	1.00 (referent)	1.00 (referent)
\$20,000–\$34,999	1.05 (0.73–1.53)	0.71 (0.43–1.18)
\$35,000–\$54,999	1.13 (0.75–1.71)	0.89 (0.54–1.46)
\$55,000–\$74,999	1.16 (0.72–1.86)	0.55 (0.27–1.12)
\$75,000+	1.00 (0.65–1.54)	0.69 (0.41–1.17)
<i>Risk factors</i>		
<i>Smoking</i>		
Never	1.00 (referent)	1.00 (referent)
Lower risk ^a smokers	1.73 (1.30–2.29)	1.52 (1.01–2.29)
Higher risk ^a smokers	3.31 (2.29–4.80)	2.16 (1.34–3.48)
Unknown	0.75 (0.43–1.30)	0.66 (0.27–1.60)
<i>Personal history of cancer other than lung</i>		
No	1.00 (referent)	1.00 (referent)
Yes	2.93 (2.19–3.93)	5.36 (3.64–7.88)
<i>Health status</i>		
<i>Respiratory conditions diagnosed by a health professional</i>		
None	1.00 (referent)	1.00 (referent)
Emphysema (ever)	2.80 (1.72–4.54)	2.72 (1.56–4.75)
Other	1.89 (1.35–2.65)	1.79 (1.13–2.83)
<i>Limitations in activities due to lung/breathing problem</i>		
No	1.00 (referent)	1.00 (referent)
Yes	1.62 (1.05–2.49)	2.61 (1.49–4.55)
<i>Health care access</i>		
<i>Insurance status</i>		
Uninsured ^b	1.00 (referent)	1.00 (referent)
Public only	1.82 (1.02–3.26)	2.75 (1.13–6.69)
Private ^c	1.55 (0.86–2.80)	2.84 (1.16–6.97)

NOTE: Source: 2010 NHIS. ORs are adjusted for all other variables in the table.

^aRisk defined according to eligibility criteria used in the NLST of LDCT. Those at higher risk include current and former smokers with at least a 30 pack-year history; in addition, for classification as high risk, former smokers must have quit within the last 15 years.

^bIncludes Medicare Part A only.

^cIncludes Medicare Part A and B with supplemental private insurance.

in a recent comparison of cervical cancer screening in the United States and the Netherlands (19). And given that PCPs were discussing lung cancer screening with patients several years before the release of the NLST findings, interest in lung cancer screening can only be expected to grow in the coming years.

We estimate that 4.1 million adults in the United States were tested for lung cancer by either chest X-ray or chest CT in 2010. Several factors may promote increased awareness and use of lung cancer screening in the future. Some medical providers have used the NLST results to aggressively market LDCT, in some cases recommending screening even in those for whom there is no proven benefit (20). This continues a more long-term trend of increased direct-to-consumer marketing of screening tests, including LDCT, for which consumers pay out of pocket (21). In addition, the NCCN recently became the first organization in the United States to issue guidelines in support of lung cancer screening for select, high-risk patients (14). Other groups, such as the U.S. Preventive Services Task Force (USPSTF), are engaged in updating their recommendations (22), although the USPSTF is not expected to issue a revised recommendation before the end of 2012. Recommendations, particularly those of the USPSTF, will likely have an impact on whether lung cancer screening is covered by insurance, and ultimately insurance coverage may be the biggest driver of use.

Despite the growing interest in LDCT screening, however, it is important to note that the NLST findings provide direct evidence of a screening benefit for a select group of heavy smokers aged 55 to 74 years. On the basis of the results from the 2010 NHIS, we estimate that approximately 8.7 million people in the United States would qualify for screening based on NLST age and smoking criteria. For an additional 51 million U.S. smokers older than 40 years, the risk–benefit balance is unknown, and any decision to initiate screening in this sizeable group could have adverse consequences in terms of screening harms and cost. Harms of LDCT screening include radiation exposure, which may induce some cancers (23–25). Brenner estimated that an annual LDCT screening program in current and former smokers aged 50 to 75 could result in a 1.8% increase in their lifetime incidence of lung cancer (23). In addition, surgical treatment following the diagnosis of lung cancer is associated with nontrivial mortality (3%–6%; refs. 26, 27). This is a particularly important issue in lung cancer screening, as screening may identify indolent cancers that would otherwise not lead to death

(i.e., "overdiagnosed" cancers; refs. 28, 29). Finally, LDCT has a high false-positive rate; in the NLST, 24% of subjects in the LDCT arm had at least one positive screen, but less than 1% were ultimately diagnosed with lung cancer (10). False-positive examinations result in patient anxiety and in invasive medical procedures that can result in considerable morbidity

Table 4. U.S. population estimates for adults aged 40 years and older, without lung cancer, according to age and smoking status

Age, y	Higher-risk ^a smokers		Lower-risk ^a smokers					Never smokers
	Current	Former	Current		Former			
	30+ pack-years	30+ pack-years	10–29 pack-years	<10 pack-years	30+ pack-years	10–29 pack-years	<10 pack-years	
40–54	4,149,000	1,430,000	5,881,000	4,905,000	153,000	4,163,000	6,456,000	39,017,000
55–74	4,513,000	4,233,000	3,023,000	1,942,000	2,197,000	5,744,000	5,775,000	29,660,000
75+	464,000	705,000	164,000	185,000	1,434,000	1,446,000	1,244,000	10,064,000

NOTE: Source: 2010 NHIS.

^aRisk defined according to eligibility criteria used in the NLST of LDCT. Those at higher risk include current and former smokers with at least a 30 pack-year history; additionally, for classification as high risk, former smokers must have quit within the last 15 years.

(30–33). It should also be noted that the balance of benefits and harms may differ in community settings as compared with the highly controlled environment of the NLST trial.

Extrapolation of the NLST results to other age groups and/or lower-risk smokers would also have substantial cost implications. A recent cost-effectiveness analysis estimated that annual LDCT screening would cost \$126,000 to \$169,000 per quality-adjusted life-year gained (34), which is considerably higher than cost-effectiveness values reported for other commonly conducted cancer screening tests (35, 36). These costs, which would be considerable even if only the relatively small population of higher risk smokers aged 55 to 74 years were targeted, would increase rapidly if screening were recommended more broadly. Therefore, the extrapolation of NLST's findings to other groups should be done with extreme caution because of screening harms, cost, and unproven benefit.

Several limitations of this analysis should be noted. Institutionalized and noncivilian populations are not sampled as part of the NHIS. Therefore, we may have underestimated the size of the U.S. population that would be eligible for screening according to NLST criteria. In addition, overall participation was about 60% and adults who completed part of the survey but did not answer the lung cancer testing questions were excluded from this analysis. Chest X-ray or CT use among survey respondents may not be representative of those for whom no data were available. Also, NHIS data are self-reported, and some prior validation studies have shown that adults tend to over-report screening behaviors in surveys (37). Finally, the questions pertaining to chest X-ray and CT do not ascertain use of lung cancer screening *per se*. The specific wording referred to tests done to "check" rather than to "screen" for lung cancer. Tests done in response to symptoms suspicious for lung cancer may therefore have been considered as having been done to check for lung cancer. This wording was chosen because subjects may not cor-

rectly understand the distinction between screening and diagnostic examinations.

Despite these limitations, the 2010 NHIS provides these first nationally representative estimates of the prevalence of chest X-ray and CT use in the United States. Continued monitoring of trends in use in the coming years will be vital. As has been shown for other cancer screening tests, overuse could occur in some groups and underuse in others (38), and the NLST results, while encouraging, present an enormous public health challenge. We estimate that there are 60 million current and former smokers aged 40 years and above in the United States, many of whom may look to their medical providers to advise them whether or not to be screened for lung cancer. Those who may be interested in lung cancer screening by LDCT should be made aware of the risks of screening, and that in some cases, these risks may be greater than the potential benefits. Education of patients by their physicians, and of the general public through a variety of communication channels, may help to ensure that screening is used appropriately, for those most likely to benefit.

Disclosure of Potential Conflicts of Interest

No potential conflicts of interests were disclosed. The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention or the National Cancer Institute.

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