

Low-Dose CT Lung Cancer Screening Practices and Attitudes among Primary Care Providers at an Academic Medical Center

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Abstract

Background: Low-dose computed tomography (LDCT) screening reduces lung cancer-specific and overall mortality. We sought to assess lung cancer screening practices and attitudes among primary care providers (PCPs) in the era of new LDCT screening guidelines.

Methods: In 2013, we surveyed PCPs at an academic medical center (60% response) and assessed: lung cancer screening use, perceived screening effectiveness, knowledge of screening guidelines, perceived barriers to LDCT use, and interest in LDCT screening education.

Results: Few PCPs ($n = 212$) reported ordering lung cancer screening: chest X-ray (21%), LDCT (12%), and sputum cytology (3%). Only 47% of providers knew three or more of six guideline components for LDCT screening; 24% did not know any guideline components. In multiple logistic regression analysis, providers who knew three or more guideline components were more likely to order LDCT (OR, 7.1; 95% confidence intervals, 2.0–25.6). Many providers (30%) were unsure of the effectiveness of LDCT.

Mammography, colonoscopy, and Pap smear were rated more frequently as effective in reducing cancer mortality compared with LDCT (all P values < 0.0001). Common perceived barriers included patient cost (86.9% major or minor barrier), harm from false positives (82.7%), patients' lack of awareness (81.3%), risk of incidental findings (81.3%), and insurance coverage (80.1%).

Conclusions: LDCT lung cancer screening is currently an uncommon practice at an academic medical center. PCPs report ordering chest X-ray, a nonrecommended screening test, more often than LDCT. PCPs had a limited understanding of lung cancer screening guidelines and LDCT effectiveness. Provider educational interventions are needed to facilitate shared decision-making with patients.

Impact: This study describes some of the first data available about PCPs' use of lung cancer screening tests since the publication of multiple professional guidelines endorsing LDCT. Knowledge gaps were identified that may hinder the uptake of evidence-based lung cancer screening guidelines. *Cancer Epidemiol Biomarkers Prev*; 24(4): 664–70. ©2015 AACR.

Introduction

Lung cancer is the leading cause of cancer deaths among men and women in the United States, accounting for 27% of all cancer deaths (1). Only 15% of lung cancers are diagnosed at the localized stage, resulting in a poor overall survival (5-year survival rate of 17%; ref. 1). Smoking cessation is critical for reducing cancer risk, but former smokers remain at increased risk for developing lung

cancer for the rest of their lives compared with never-smokers (2). Effective screening programs aimed at early detection are also needed to address this important public health problem.

In 2011, the National Lung Screening Trial (NLST), a multisite randomized controlled trial of 53,454 people comparing low-dose CT (LDCT) with chest X-ray, reported a 20% lung cancer-specific mortality reduction, as well as an overall mortality reduction of 6.7% in a high-risk cohort screened with annual LDCT for 2 years (3). Largely on the basis of this study, multiple professional organizations, including the American Cancer Society (ACS), the American Society of Clinical Oncology (ASCO), the National Comprehensive Cancer Network (NCCN), the American Lung Association (ALA), the American Association of Thoracic Surgery (AATS), and the American College of Chest Physicians (ACCP), have published guidelines recommending annual LDCT for patients 55 to 74 years of age with at least a 30 pack-year history of smoking who are current smokers or former smokers who have quit within the past 15 years (4–9). One group extends the stop age for screening to 79 years (8) and two organizations expand the start age for screening to include individuals who are 50 years or older with at least a 20 pack-year history and have an additional risk factor such as significant environmental exposures, COPD, pulmonary fibrosis, history of cancer, or family history of lung cancer (6, 8). The American Academy of Family Physicians concluded that there was insufficient evidence to recommend for or against LDCT screening in their Grade I recommendation (10).

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The U.S. Preventive Services Task Force (USPSTF) posted draft recommendations in the summer of 2013 and on December 31, 2013, issued Grade B recommendations for LDCT screening in high-risk individuals defined as those ages 55 to 80 years with at least a 30 pack-year history of smoking who either continue to smoke or have quit within the past 15 years (11).

In the United States, it is estimated that 8.7 million adults are eligible for LDCT screening (12) and as many as 12,000 lung cancer-related deaths could be avoided per year with implementation (13). One study of primary care providers (PCPs) conducted in 2006 to 2007, before the publication of the current guidelines recommending LDCT screening, suggested that the use of CT screening tests for lung cancer was low (22%), with higher use of a nonrecommended screening test (55% chest X-ray; ref. 14). More recent estimates of lung cancer screening use in the era of guideline recommendations have not been published. Barriers to implementing LDCT among PCPs are also unknown. Thus, we developed a questionnaire to examine PCPs' lung cancer screening practices, knowledge, and attitudes, which was sent to all PCPs at a single academic medical center that participated in the NLST. We hypothesized that few providers would report ordering LDCT within the last year, other cancer screening tests would be perceived as more effective in reducing cancer-specific mortality than LDCT, and few providers would know consensus guideline recommendations.

Materials and Methods

Participants

We surveyed PCPs from the departments of Internal Medicine, Family Medicine, and Obstetrics and Gynecology at a large, academic medical center between November 2013 and December 2013. We obtained provider emails through departmental websites and lists provided by administrators. Providers were e-mailed a link to complete a confidential online survey using the REDCap data collection platform (15). Eligible respondents were physicians, nurse practitioners, and physician assistants who provided primary care services to patients of 40 years of age or older within the past 12 months. Interns in their first year of training were not eligible. Respondents received up to four weekly reminder emails. The study was approved by the Institutional Review Board. All participants provided informed consent and were offered the chance to win one of five \$50 gift cards. A link to the ALA website on screening recommendations was provided upon survey completion.

Questionnaire

Before fielding, the survey was pilot tested with three practicing PCPs outside of the targeted institution, and minor revisions were made to improve clarity.

Lung cancer screening practices. Six items adapted from the NCI (Bethesda, MD) Colorectal and Lung Cancer Screening Questionnaire (16) assessed lung cancer screening practices in the past 12 months for asymptomatic, high-risk patients with chest X-ray, sputum cytology, and LDCT.

Knowledge of lung cancer screening recommendations. Six multiple-choice items developed for this survey assessed knowledge of the current consensus guideline components (ACS, ASCO, NCCN, ALA, AATS; refs. 4–8), including (i) initial age of eligibility (50 or 55 years), (ii) the upper age limit at which a patient is no longer

eligible for screening (75 or 80 years), (iii) minimum smoking history (20 or 30 pack years), (iv) smoking status (current or former smokers), (v) screening frequency (yearly), and (vi) ineligibility of patients with only a history of secondhand smoke exposure. Guideline knowledge questions and response options are shown in Online Supplementary Table S1. We accepted a start age of 50 years, end age of 80 years, and 20 pack years because of the more inclusive NCCN and AATS guidelines (6, 8). Respondents were also asked whether Medicare covers LDCT screening (yes/no), and to indicate whether the following guidelines are influential in their practice: ACS, ASCO, NCCN, USPSTF, AATS, ALA, and other.

Lung cancer screening barriers. Twelve items were adapted from the NCI Survey of Colorectal Cancer Screening Practices questionnaire (17) to assess potential barriers to LDCT screening at the patient, provider, and clinic/structural levels. Respondents were asked to rate each barrier as a major barrier, minor barrier, not a barrier, or don't know. Potential barriers were identified from the literature (5), previous provider surveys (16, 17), and by the study team. Patient barriers included patient anxiety, concern for radiation exposure, patient unawareness of screening, and cost. Clinical/structural barriers included lack of insurance coverage, provider time, and geographical unavailability. Provider barriers included the possibility for false-positive findings, potential harm from unnecessary diagnostic procedures, low perceived usefulness, insufficient evidence, and concern that screening may make smoking seem safer.

Cancer screening beliefs. Five items adapted from the NCI Survey of Colorectal Cancer Screening Practices (17) addressed providers' perceptions of the effectiveness of colonoscopy, LDCT, mammography, Pap smear, and prostate-specific antigen in "reducing cancer-related mortality in the average, healthy individual for whom they are recommended." Respondents rated each test as very effective, moderately effective, minimally effective, not effective, or don't know.

Future educational directions. Respondents were asked whether they were interested in continuing education regarding lung cancer screening (yes/no) and follow-up questions regarding modality (online lecture, on-site lecture, multidisciplinary conference, periodicals, pocket guides), and maximum time for training (10 minutes or less, 11–30 minutes, 31–60 minutes, or more than 60 minutes).

Provider and practice characteristics. Providers identified their medical position, years in training/practice, amount of time spent providing direct patient care, field of practice, gender, age, and race/ethnicity. Providers also estimated the percentage of current and former smokers in their practice, as well as the percentage of patients in their practice who are uninsured, insured by Medicaid, and Medicare. An underserved practice was defined as having greater than 50% uninsured or Medicaid patients.

Statistical analysis

Descriptive statistics were calculated to characterize provider and practice characteristics, frequency of lung cancer screening tests, beliefs of effectiveness, guideline knowledge, and perceived barriers. We used logistic regression to identify significant predictors (field of practice, medical position, percentage of time

spent in patient care, years in practice, underserved practice, low percentage of current or former smokers, Medicare coverage of 50% or more, and guideline knowledge) of reported use of LDCT, CXR, and perceived effectiveness of LDCT as moderately or very effective. Each predictor was evaluated one at a time. If the *P* value for the variable was 0.25 or less, it was entered into a multivariable logistic regression model. The McNemar test was used to compare the effectiveness of LDCT as compared with colonoscopy, mammography, Pap smear, and PSA. The Fisher exact test was used to evaluate whether reported LDCT, CXR, and sputum cytology use was associated with knowing ≥ 3 of 6 guidelines; it was also used to compare education modality by department among those who reported an interest in education. All statistical analyses were performed in SAS (v.9.3.); a two-sided α level of 0.05 was used to indicate statistical significance.

Results

Participants

Of 488 potentially eligible providers, 293 (60%) responded to the survey. Of these, 218 provided primary care services to patients 40 years of age or older within the past 12 months and continued the survey. Six of the 218 did not respond to the question about ordering LDCT and were excluded from this analysis, leading to a final sample size of 212; four of these participants provided incomplete surveys. In this analytic sample, attending physicians were slightly under-represented, comprising 52.1% of the e-mailed providers, but only 42.5% of the analytic sample [χ^2 (2 *df*) = 16.3, *P* = 0.0003]. Residents were slightly over-represented, comprising 34% of the e-mailed providers and 44.3% of the analytic sample.

Demographic characteristics of eligible providers are shown in Table 1. Most providers were physicians (87%) and reported practicing 10 years or less (76%), with similar percentages of attending and resident/fellow respondents (43 and 44%, respectively). The majority of the providers were from the Department of Internal Medicine (73%), age 40 or younger (69%), and white, non-Hispanic (70%). Most providers (75%) reported that they spend 50% or more of their time participating in direct patient care and did not practice in an underserved patient setting (70%). On average, respondents estimated that 37% of their patients are current smokers and 33% are former smokers.

Consensus guideline knowledge

Most providers (53%) knew fewer than three of six guideline components for LDCT screening (screen annually, begin age 50 or 55, end age 75 or 80, 20 or 30 pack years, current and former smokers, not secondhand smoke only); 24.3% did not know any of the guidelines. Smoking status (current and former) and not recommended for secondhand smoke exposure were the most frequently known guideline components (64.6% and 43.4%, respectively). The least known guideline components were screening interval of one year (24.5%) and eligible stop age (30.2%). Of note, 26.4% of providers knew that LDCT is not currently covered by Medicare.

Most PCPs (88.4%) reported that the USPSTF is influential to their practice. Other influential guideline organizations included the American Cancer Society (71.8%) and the ASCO (46.0%).

Perceived effectiveness of cancer screening

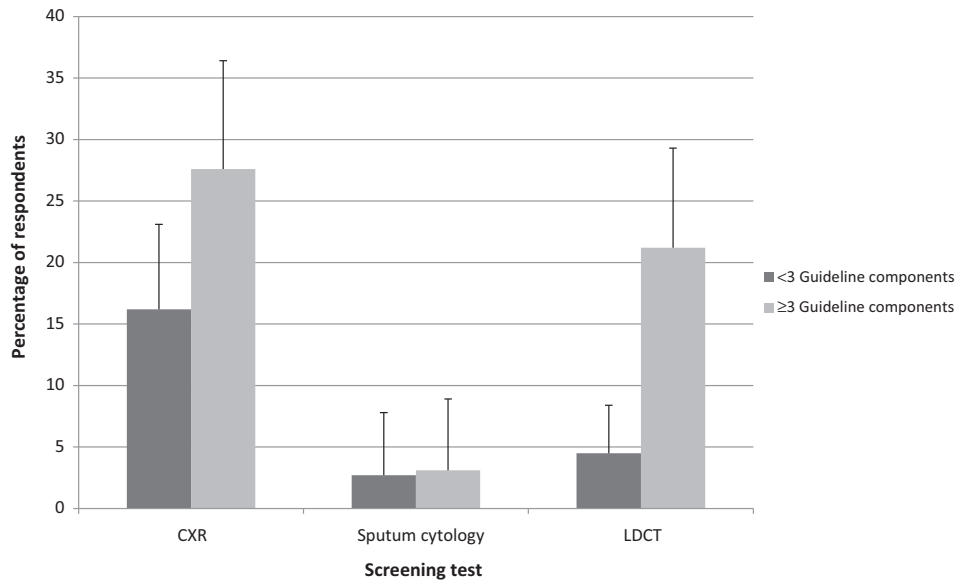
Less than one-half (42%) of respondents rated LDCT as very or moderately effective in reducing lung cancer-specific mortality;

Table 1. Demographic and practice characteristics of health care providers who provide primary care services to patients over 40 years of age at an academic medical center (*N* = 212)

Characteristic	<i>N</i> = 212
Medical position (<i>n</i> , %)	
Attending	90 (42.5%)
Resident/fellow	94 (44.3%)
Physician assistant/nurse practitioner	28 (13.2%)
Years in practice (<i>n</i> , %)	
<1–10 y	160 (75.5%)
11–20 y	24 (11.3%)
>20 y	28 (13.2%)
Primary field of practice (<i>n</i> , %)	
General internal medicine	72 (34.0%)
Internal medicine-hospitalist	14 (6.6%)
Internal medicine-subspecialist	68 (32.1%)
Family medicine	30 (14.2%)
Family medicine-subspecialist	5 (2.4%)
Obstetrics and gynecology	15 (7.1%)
Obstetrics and gynecology-subspecialist	7 (3.3%)
Unknown	1 (0.5%)
Gender (<i>n</i> , %)	
Male	100 (47.2%)
Female	110 (52.4%)
Unknown	2 (0.9%)
Age (<i>n</i> , %)	
20–30 y	78 (36.8%)
31–40 y	68 (32.1%)
41–60 y	47 (22.2%)
>60 y	19 (9.0%)
Ethnicity/race (<i>n</i> , %)	
Hispanic or Latino	5 (2.4%)
White, non-Hispanic	148 (69.8%)
Black or African American	23 (10.9%)
Asian	26 (12.3%)
Other	6 (2.8%)
Unknown	4 (2.8%)
Time spent providing direct patient care (<i>n</i> , %)	
<50%	51 (24.1%)
>50%	159 (75.0%)
Unknown	2 (0.9%)
Estimated percentage of current smokers [mean (SD)]	36.5 (18.8)
Unknown (<i>n</i>)	2
Estimated percentage of former smokers [mean (SD)]	33.2 (18.4)
Unknown (<i>n</i>)	4
Few eligible patients (<15% former or <15% current smokers), <i>n</i> (%)	
Yes	35 (16.5%)
No	175 (82.6%)
Unknown	2 (0.9%)

about one-quarter (28%) reported LDCT as minimally or not effective in reducing lung cancer-specific mortality, and almost one-third (30%) did not know the efficacy of LDCT in reducing cancer mortality. Providers who reported more than 15% of either current or former smokers in their practice [OR, 3.0; 95% confidence intervals (CI), 1.1–8.4] or who knew three or more of six guideline components (OR, 5.1; 95% CI, 2.6–9.9) were more likely to perceive LDCT as very or moderately effective in a multivariable model also adjusted for years in practice (OR, 1.3; 95% CI, 0.5–3.7 for 11–20 years vs. 1–10 years; OR, 2.6; 95% CI, 0.9–7.1 for > 20 years vs. 1–10 years) and having more than 50% of patients on Medicare (1.4; 95% CI, 0.6–3.0). Other screening modalities had significantly higher rates of perceived effectiveness (very or moderate) than LDCT (mammography 92.9%, colonoscopy 99%, Pap smear 95.7% vs. LDCT 41.9%, all *P* < 0.0001); PSA testing had a lower rate of perceived effectiveness (27.4%, *P* = 0.002).

Figure 1. Reported use of lung cancer screening modalities in the past year among PCPs in an academic medical center ($N = 212$) by guideline knowledge. Bars indicate upper 95% confidence interval for the estimate. CXR, chest X-ray.



Screening practices

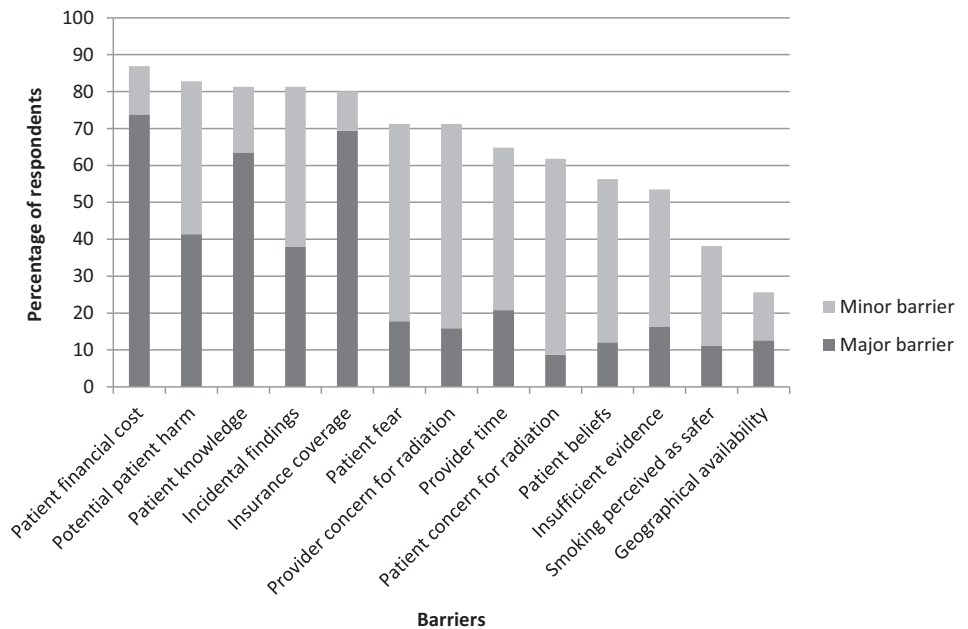
More providers reported using chest X-ray (21.3%; 95% CI, 16.0%–27.5%) than LDCT (12.3%, 95% CI, 8.2%–17.5%) or sputum cytology (2.9%; 95% CI, 1.1%–6.2%) for lung cancer screening. Knowledge of three or more guideline components was significantly associated with ordering LDCT ($P = 0.0002$) and chest X-ray ($P = 0.047$) but not sputum cytology (Fig. 1). In adjusted models, guideline knowledge (OR, 7.1; 95% CI, 2.0–25.6) was the only significant predictor of ordering LDCT in a multivariate model adjusted for medical position (OR, 3.0; 95% CI, 1.1–8.6 for attending vs. fellow/resident; OR, 1.5; 95% CI, 0.3–9.0 for PA/NP vs. fellow/resident) and having more

than 50% of patients on Medicare (OR 2.1, 95% CI, 0.8–5.7). No provider demographic characteristics were significantly associated with ordering of chest X-ray in logistic regression models.

Perceived barriers to lung cancer screening

Perceived barriers to LDCT lung cancer screening were common, with all reported as minor or major by at least 25% of providers (Fig. 2). The most commonly endorsed major and minor barriers to LDCT screening were patient cost (86.9%), potential harm from false-positive findings (82.7%), patients' lack of awareness (81.3%), risk of incidental findings that will

Figure 2. Primary care providers' ($N = 212$) perceived major and minor barriers to lung cancer screening with low-dose chest CT.



require further workup or monitoring (81.3%), and lack of insurance coverage (80.1%).

Future educational directions

Most providers (79.8%) were interested in further education on lung cancer screening. The most popular modalities included pocket guides (88.9%) and on-site lecture (75.6%). Obstetrics and Gynecology providers (92.9%) were more interested in an online lecture than Internal Medicine (72.2%) or Family Medicine providers (51.9%; $P = 0.02$). Of those interested in further education, most providers (57.0%) were willing to devote 31 minutes or more of their time to further education on lung cancer screening.

Discussion

Two years after multiple organizations have issued guideline recommendations for lung cancer screening with LDCT, few PCPs in an academic medical center are performing lung cancer screening with only 12% reporting LDCT and 21% reporting chest X-ray, which is a nonrecommended test. This finding is consistent with a previous national provider survey examining lung cancer screening practices conducted before current guideline recommendations, although overall use of both recommended and nonrecommended lung screening tests was lower in our sample (14). Few providers viewed LDCT as an effective screening modality or knew the guideline recommendations. The most common barriers reported by providers included patient cost, potential harm from false-positive findings, patients' lack of awareness, risk of incidental findings, and insurance coverage.

Guideline knowledge was strongly associated with use of LDCT in the past year, but surprisingly also with the use of chest X-ray. Reasons for this are unclear, as we did not identify any other significant correlates in univariate analyses, such as field of practice, medical position, etc. Use of chest X-ray may be partially attributed to concerns about financial cost and lack of insurance coverage. Providers may have used chest X-ray for high-risk patients who could not afford to pay for LDCT out of pocket. Screening with chest X-ray should become less common as LDCT screening coverage and programs increase.

Most providers in our survey believed that screening for lung cancer was less effective than screening for breast or colon cancer, which may contribute to low use of LDCT. However, the NLST provides evidence that lung cancer screening with LDCT is more effective than other commonly performed screening interventions by some metrics (3). One way to compare different screening tests is to examine the number needed to screen (NNS) to prevent one death (18). The NNS to avoid one lung cancer death is 320 individuals, based on three annual LDCT scans in a high-risk patient population. This compares favorably to mammography (NNS = 1339) for women ages 50 to 59 years over an 11 to 20-year period and flexible sigmoidoscopy (NNS = 871; ref. 18). Of note, the NNS for lung cancer is similar to those reported for common screenings for cardiovascular disease, including hypertension, hyperlipidemia, and coronary artery disease; only hypertension with a NNS of 274 to prevent one death over a 5-year period was less than the current NNS to prevent one lung cancer death (19).

Patient cost was the most commonly endorsed barrier to LDCT in our study, and is an important consideration for all screening programs. Few patients are willing to pay out of pocket for lung

cancer screening (20). Our survey was conducted just before USPSTF Grade B published recommendation (draft recommendations were available at the time; ref. 11). Individual, patient cost will likely become less of a barrier for those with private insurance as the Affordable Care Act mandates insurance coverage for USPSTF Grade B recommendations. In addition, the Centers for Medicare & Medicaid have issued a proposed decision that these agencies will cover the cost of lung cancer screening counseling, shared decision-making visits, and LDCT screening for individuals between the ages of 55 years and 74 years who are asymptomatic, current or former smokers who have quit within the past 15 years, and have at least a 30-pack-year history of smoking. These changes should drastically lower barriers associated with cost for persons covered by these insurance programs.

At a societal level, implementation of LDCT screening is estimated to cost 1.3 to 2.0 billion U.S. dollars annually (21). Putting this cost in context, the NIH estimated that lung cancer care costs the U.S. 12.1 billion dollars in 2010 and projections estimate it may cost as much as 19 billion dollars in 2020 (22). At least two modeling studies have found that the cost per-life year saved by LDCT screening compares favorably to cervical, breast, and colorectal cancer screening (23, 24). The most recent analysis of cost-effectiveness in the NLST estimated screening costs at less than \$100,000 per quality-adjusted life-year gained, which is the level experts accept as a reasonable societal cost (25). However, the authors also conclude that LDCT screening cost-effectiveness is uncertain for patients outside of the NLST study population (25).

Another major concern of PCPs was the potential harm from false-positive findings. Data from the NLST estimate that approximately 30% of patients who undergo LDCT screening will have at least one false-positive screening (3). Furthermore, about 3 out of every 1,000 people screened will have a major complication from the procedure and 3 to 5 people may be overdiagnosed with lung cancer (3). Current and future refinements in screening, such as increasing the threshold of a "positive" screen to 6 mm in the NCCN guidelines (26) and the use of calculators to predict the probability of lung cancer (27), will help lower the rate of false-positive screens.

Early detection with LDCT is just one component of a successful screening program; integrated smoking cessation is also critical. Smoking cessation intervention is strongly recommended by all guidelines for primary lung cancer prevention. (4–9, 11). A recent modeling study estimated that incorporating smoking cessation into screening may improve cost-effectiveness by 20% to 45% (24). Most PCPs in our study were not concerned that screening may make smoking seem safer; this assessment is consistent with recent evidence suggesting that LDCT screening does not change patients' perception or provide false reassurance to patients (28).

Physician recommendation is a critical predictor of patient screening behaviors (29). One study of minority populations found that the majority (82%) would undergo LDCT screening if recommended by their physician (20). We found limited knowledge of guideline recommendations among PCPs, which likely prevents providers from facilitating shared decision-making conversations about the potential benefits, harms, and uncertainties of lung cancer screening with their patients. In our study, we observed that providers who knew three or more guideline components were significantly more likely to order LDCT screening for patients. Interventions and educational efforts to increase provider knowledge are crucial to increase uptake of LDCT lung cancer screening.

To our knowledge, this study is one of the first to report rates of lung cancer screening among PCPs since the publication of multiple professional guidelines endorsing LDCT lung cancer screening; however, there are several limitations. Consistent with prior studies (14), we relied on provider report of screening behavior, which may be subject to social desirability and/or recall bias. As insurance coverage for LDCT becomes more common, future studies may want to examine uptake using administrative databases and electronic medical records. Second, the results of this survey reflect the practices and attitudes of a single academic medical center. The majority of respondents to our survey were young (residents and attending physicians less than the age of 41 years). Therefore, our results represent younger providers with less clinical experience, predominantly from the field of internal medicine. This may not generalize to all U.S. providers particularly those practicing in community settings. Future studies at the state or national level are needed to better assess current U.S. lung cancer screening practices and attitudes.

Our results demonstrate that most PCPs need additional education about guideline recommendations for LDCT lung cancer screening and are likely to be open to receiving such education. Educational opportunities should address current barriers, including financial cost, insurance coverage, data on frequency of false-positive results, and complications arising from screening to provide PCPs with the knowledge needed to have shared decision-making conversations about lung cancer screening with their patients.

Disclosure of Potential Conflicts of Interest

C. Chiles is chair of the Thoracic Imaging Committee of the American College of Radiology, and is a member of the NCI Thoracic Malignancy Steering Committee. No potential conflicts of interest were disclosed by the other authors.

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References

- American Cancer Society. Cancer Facts & Figures 2014. Atlanta: American Cancer Society; 2014. [Accessed January 12, 2014]. Available from URL: <http://www.cancer.org/research/cancerfactsstatistics/cancerfactsfigures2014>.
- Peto R, Darby S, Deo H, Silcocks P, Whitley E, Doll R. Smoking, smoking cessation and lung cancer in the UK since 1950: combination of national statistics with two case control studies. *BMJ* 2000;321:323–9.
- The National Lung Screening Trial Research Team. Reduced lung-cancer mortality with low-dose computed tomographic screening. *New Engl J Med* 2011;365:395–407.
- Wender R, Fontham ETH, Barrera E Jr, Colditz GA, Church TR, Ettinger DS, et al. American Cancer Society lung cancer screening guidelines. *CA Cancer J Clin* 2013;63:106–17.
- Bach PB, Mirkin JN, Oliver TK, Azzoli CG, Berry DA, Brawley OW, et al. Benefits and harms of CT screening for lung cancer: a systematic review. *JAMA* 2012;307:2418–29.
- National Comprehensive Cancer Network. NCCN Clinical Practice Guidelines in Oncology: Lung Cancer Screening. Version 1. 2013 [Accessed on January 12, 2014].
- American Lung Association. Providing Guidance on lung cancer screening. The American Lung Association Interim Report on Lung Cancer Screening. [Accessed on January 12, 2014]. Available from URL: <http://www.lung.org/lung-disease/lung-cancer/lung-cancer-screening-guidelines/lung-cancer-screening.pdf>.
- Jaklitsch MT, Jacobson FL, Austin JH, Field JK, Jett JR, Keshavjee S, et al. The American Association for Thoracic Surgery guidelines for lung cancer screening using low-dose computed tomography scans for lung cancer survivors and other high risk groups. *J Thorac Cardiovasc Surg* 2012; 144:33–8.
- Detterbeck FC, Mazzone PJ, Naidich DP, Bach PB. Diagnosis and Management of lung cancer, 3rd ed: American College of Chest Physicians evidence-based clinical practice guidelines. *Chest* 2013;143:e78S–e92S.
- American Academy of Family Physicians. AAFP Clinical Preventive Service Recommendation: Lung Cancer 2013. Available from URL: <http://www.aafp.org/patient-care/clinical-recommendations/all/lung-cancer.html>
- Moyer VA. Screening for lung cancer: U.S. Preventive Services Task Force recommendation statement. *Ann Intern Med* 2014;160:330–8.
- Doria-Rose VP, White MC, Klabunde CN, Nadel MR, Richards TB, McNeel TS, et al. Use of lung cancer screening tests in the United States: results from the 2010 National Health Interview Survey. *Cancer Epidemiol Biomarkers Prev* 2012;21:1049–59.
- Ma J, Ward EM, Smith R, Jemal A. Annual number of lung cancer deaths potentially avertable by screening in the United States. *Cancer* 2013; 119:1381–5.
- Klabunde CN, Marcus PM, Han PKJ, Richards TB, Vernon SW, Yuan G, et al. Lung cancer screening practices of primary care physicians: results from a national survey. *Ann Fam Med* 2012;10:102–10.

15. Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. A metadata-driven methodology and workflow process for providing translational research informatics support. *J Biomed Inform* 2009;42:377–81.
16. National Cancer Institute Survey of Primary Care Physicians' Cancer Screening Recommendations and Practices: Colorectal and Lung Cancer Screening Questionnaire. 2006. [Accessed on June 9, 2014]. Available from URL: http://healthservices.cancer.gov/surveys/screening_rp/screening_rp_colo_lung_inst.pdf.
17. National Cancer Institute Survey of Colorectal Cancer Screening Practices-Primary Care Physician Questionnaire. [Accessed on June 9, 2014]. Available from URL: <http://healthservices.cancer.gov/surveys/colorectal/prim0520.pdf>.
18. Humphrey LL, Deffebach M, Pappas M, Baumann C, Artis K, Mitchell JP, et al. Screening for lung cancer with low-dose computed tomography: a systematic review to update the U.S. Preventive Services Task Force recommendation. *Ann Intern Med* 2013;159:411–20.
19. Rembold CM. Number needed to screen: development of a statistic for disease screening. *BMJ* 1998;317:307–12.
20. Jonnalagadda S, Bergamo C, Lin JJ, Lurslurchachai L, Diefenbach M, Smith C, et al. Beliefs and attitudes about lung cancer screening among smokers. *Lung Cancer* 2012;77:526–31.
21. Goulart BHL, Bensink ME, Mummy DG, Ramsey SD. Lung cancer screening with low-dose computed tomography: costs, national expenditures, and cost-effectiveness. *J Natl Compr Canc Netw* 2012;10:267–75.
22. Mariotto AB, Yabroff KR, Shao Y, Feuer EJ, Brown ML. Projections of the cost of cancer care in the United States: 2010–2020. *J Natl Cancer Inst* 2011;103:117–28.
23. Pyenson BS, Sander MS, Jiang Y, Kahn H, Mulshine JL. An actuarial analysis shows that offering lung cancer screening as an insurance benefit would save lives at relatively low cost. *Health Affair* 2012;31:770–9.
24. Villanti AC, Jiang Y, Abrams DB, Pyenson BS. A cost-utility analysis of lung cancer screening and the additional benefits of incorporating smoking cessation interventions. *PLOS ONE* 2013;8:e71379.
25. Black WC, Gareen IF, Soneji SS, Sicks JD, Keeler EB, Aberle DR, et al. Cost-effectiveness of CT screening in the National Lung Screening Trial. *New Engl J Med* 2014;371:793–802.
26. National Comprehensive Cancer Network. NCCN Clinical Practice Guidelines in Oncology: Lung Cancer Screening. Version 1.2015 Available from URL: http://www.nccn.org/professionals/physician_gls/pdf/lung_screening.pdf.
27. McWilliams A, Tammemagi MC, Mayo JR, Roberts H, Liu G, Soghrati K, et al. Probability of cancer in pulmonary nodules detected on first screening CT. *New Engl J Med* 2013;369:910–9.
28. Park ER, Gareen IF, Jain A, Ostroff JS, Duan F, Sicks JD, et al. Examining whether lung cancer screening changes risk perceptions: National Lung Screening Trial participants at 1-year follow up. *Cancer* 2013;119:1306–13.
29. Zapka JG, Lemon SC. Interventions for patients, providers, and health care organizations. *Cancer* 2004;101:1165–87.