CHEST

Components Necessary for High-Quality Lung Cancer Screening

A 10-Year Update

Julie A. Barta, MD, ATSF; Douglas Arenberg, MD, FCCP; Leah Backhus, MD; Frank Detterbeck, MD, FCCP, FACS; Michael K. Gould, MD, FCCP; Viswam S. Nair, MD, MS; Mary Pasquinelli, DNP; Charles A. Powell, MD, MBA; Kim Sandler, MD; Gerard Silvestri, MD, FCCP; Matthew Triplette, MD, MPH; Anil Vachani, MD; Renda S. Wiener, MD, MPH; and Peter J. Mazzone, MD, MPH

Lung cancer screening (LCS) has evolved over the past decade with research advances and clinical experience helping to define target populations for screening, improve lung nodule detection and management, and identify structural components of programs that improve the quality of screening delivery. The 2015 American College of Chest Physicians and American Thoracic Society policy statement "Components Necessary for High-Quality Lung Cancer Screening" identified 9 essential components for high-quality LCS. Ten years later, optimizing the balance between the benefits and harms of LCS and ensuring equitable screening among all population groups remain fundamental objectives. In this 2025 update, we aimed to summarize new knowledge and highlight critical components that are needed for providing high-quality LCS. A multidisciplinary group of LCS experts was assembled to review evidence from the past 10 years. The original components were reviewed and updated to develop 8 refined components that should be considered essential structural elements of screening programs. Each component recommended by the authors is supported by an evidence update. Applying this framework will allow screening programs across the country to ensure implementation of high-quality, net-benefit LCS.

CHEST 2025; 168(5):1257-1270

KEY WORDS: cigarette smoking; low-dose CT; lung cancer; lung cancer screening; tobacco treatment

ABBREVIATIONS: ACR = American College of Radiology; ACS = American Cancer Society; CHEST = American College of Chest Physicians; CMS = Centers for Medicare and Medicaid Services; LCS = lung cancer screening; LCSR = Lung Cancer Screening Registry; LDCT = low-dose CT; Lung-RADS = Lung CT Screening Reporting and Data System; NCCN = National Comprehensive Cancer Network; NLST = National Lung Screening Trial; SDM = shared decision-making; USPSTF = United States Preventive Services Task Force

AFFILIATIONS: From the Department of Medicine (J. A.B.), Division of Pulmonary and Critical Care Medicine, Jane and Leonard Korman Respiratory Institute, Thomas Jefferson University, Philadelphia, PA; the Department of Medicine (D. A.), Division of Pulmonary and Critical Care Medicine, University of Michigan, Ann Arbor, MI; the Department of Cardiothoracic Surgery (L. B.), Division of Thoracic Surgery, Stanford University, Palo Alto, CA; the Department of Surgery (F. D.), Yale University, New Haven, CT; the Department of Health System Science (M. K. G.), Kaiser Permanente Bernard J. Tyson School of Medicine, Pasadena, CA; the Clinical Research Division (V. S. N. and M. T.), Fred Hutchinson Cancer Center, Seattle, WA; the Department of Medicine (M. P.), Division of Pulmonary, Critical Care, Sleep, and Allergy, University of Illinois, Urbana, IL; the Department of Medicine (C. A. P.), Division of Pulmonary, Critical Care, and Sleep Medicine, Icahn School of Medicine at Mount Sinai, New York, NY; the Department of Radiology (K. S.), Vanderbilt University Medical Center, Nashville, TN; the Department of Medicine (G. S.), Division of Pulmonary and Critical Care Medicine, Medical University of South Carolina, Charleston, SC; the Department of Medicine, Division of Pulmonary, Allergy, and Critical Care Medicine, Philadelphia VA and University of Pennsylvania (A. V.), Philadelphia, PA; the Department of Medicine, Division of Pulmonary, Allergy, Sleep, and Critical Care Medicine, Boston VA and Boston University (R. S. W.), Boston, MA; and Respiratory Institute (P. J. M.), Cleveland Clinic, Cleveland, OH.

CORRESPONDENCE TO: Julie A. Barta, MD, ATSF; email: Julie.Barta@jefferson.edu

DOI: https://doi.org/10.1016/j.chest.2025.06.006

The overarching goal of lung cancer screening (LCS) is to reduce lung cancer mortality by optimizing the balance of benefits and harms of screening at the individual and population levels. Systematic delivery of high-quality LCS can improve uptake and adherence while lowering the risk of harms.[1-4] In the decade since publication of the American College of Chest Physicians (CHEST) and American Thoracic Society policy statement "Components Necessary for High-Quality Lung Cancer Screening," implementation of LCS has expanded across the United States.[5] Research has advanced knowledge in the field, highlighting the complexities of implementing high-quality LCS and identifying structural components that help to overcome screening barriers.[6] LCS uptake and adherence remain far lower than needed to achieve the anticipated magnitude of lung cancer mortality benefit suggested by the results of randomized trials.[7,8]

As national, regional, and local efforts expand LCS access across the United States, it will be critical to ensure that evidence-based, high-quality programs are implemented. Opportunities remain to improve the net benefit from LCS, including the appropriate selection of high-risk individuals for LCS and the avoidance of harms resulting from procedures to evaluate benign findings.[9,10]

The objectives of this article are to summarize evidence related to the implementation of high-quality LCS that has emerged since the 2015 statement and to outline standard implementation components of high-quality LCS programs. The 8 components described can be applied in a variety of screening environments and should be considered essential for maximizing the net benefit of LCS.

Methods

A multidisciplinary group of pulmonologists, thoracic surgeons, thoracic radiologists, and health services researchers with expertise in LCS was assembled to identify and describe the components necessary for high-quality screening in the United States. Members of the expert panel were identified first based on participation in the 2015 policy statement, including those with confirmed continued expertise in LCS and without disqualifying conflicts of interest. Additional members were nominated by the existing panel to ensure that diverse and multidisciplinary viewpoints from varying geographies, institutional environments, and practice patterns would be represented.

Evidence updates and program components were developed as expert recommendations that are essential for implementation of high-quality LCS. An iterative process was carried out, starting with identification of 9 proposed program components building on the original 9 components included in the 2015 statement. This was followed by a targeted review of the literature on LCS implementation between 2015 and 2024, focusing on new guidelines and key research advances. Key words specific to each proposed program component were searched in MEDLINE through PubMed to generate an initial outline of subtopics and high clinical impact, practice-changing updates for each component. The writing group met in June 2024 to review and revise the outline to support drafting the manuscript. By panel discussion and general consensus, the proposed components were revised to the final 8 components. After this, smaller revision groups comprising 3 to 4 experts in each component provided input for each section of the manuscript between July and September 2024. The component sections were combined and edited and ultimately approved by the entire writing group in December 2024.

Results

Component 1: Lung Cancer Screening Target Population

2015 Component: Who Is Offered Lung Cancer Screening?: Evidence Update: A comprehensive assessment of both the harms and benefits at the population and individual levels is needed to identify best the LCS target population. Multiple organizations have suggested criteria for defining LCS target populations, including the US Preventive Services Task Force (USPSTF), CHEST, the American Cancer Society (ACS), and the National Comprehensive Cancer Network (NCCN) (Table 1). The USPSTF expanded the LCS target population in 2021 to include younger individuals (age 50-80 years) and those with fewer pack-years of smoking (≥ 20 pack-years), resulting in more equitable sensitivity for identifying Black individuals at risk of lung cancer for inclusion in the target population.[11] CHEST recommends annual low-dose CT (LDCT) imaging for individuals meeting USPSTF 2021 criteria, but also suggests screening individuals projected

TABLE 1] Current Guidelines for Lung Cancer Screening

Organization	Year of Publication	Target Population	Strength of Recommendation or Evidence Base
US Preventive Services Task Force	2021	• Age 50-80 y • ≥ 20 pack-years of smoking • Currently smoke or quit within the past 15 y	Grade B recommendation[a]: the USPSTF recommends the service
CHEST	2021	• Asymptomatic individuals ≥ 50-55 y of age and ≤ 77-80 y of age • ≥ 20-30 pack-years of smoking • Continue to smoke or quit within the past 15 y • Projected high net benefit from LCS based on validated clinical risk prediction, life expectancy, or life-year gained calculations	• Strong recommendation, moderate quality evidence for 55-77 y of age and 30 pack-years of smoking[b] • Weak recommendation, moderate-quality evidence for 50-80 y of age and 20 pack-years of smoking and high net benefit individuals[b]
American Cancer Society	2023	• Age 50-80 y • ≥ 20 pack-years of smoking • Currently smoking or formerly smoked	Strong recommendation, moderate quality evidence[b]
National Comprehensive Cancer Network	Version 2.2024	• Age ≥ 50 y • ≥ 20 pack-year history of smoking cigarettes	Category 2A: based on lower-level evidence, uniform NCCN consensus[c] exists that the intervention is appropriate

CHEST = American College of Chest Physicians; LCS = lung cancer screening; NCCN = National Comprehensive Cancer Network; USPSTF = US Preventive Services Task Force.

[a]Defined as "high certainty that the net benefit is moderate or there is moderate certainty that the net benefit is moderate to substantial."

[b]CHEST and the American Cancer Society use the Grading of Recommendations, Assessment, Development, and Evaluations approach to categorize recommendations. A strong recommendation with moderate-quality evidence can be defined as one in which "benefits clearly outweigh risk" and "moderate confidence in the effect estimate" exists. A weak recommendation with moderate-quality evidence can be defined as one in which "benefits [are] closely balanced with risks" and "moderate confidence in the effect estimate" exists.

[c]Defined as ≥ 85% support among members of the NCCN panel.

to have high net benefit from screening based on lung cancer risk prediction and life expectancy or life-year gained estimates.[6] The ACS in 2023 supported further expansion of the LCS target population by eliminating the quit-year criterion based on modeling studies and population cohort data demonstrating persistently elevated lung cancer risk beyond 15 years of smoking cessation.[12] The NCCN, which has eliminated the upper age criterion as well as quit-years in its LCS eligibility guideline and added an alternative criterion in the form of number of years smoked (evidence and consensus category 2B), encourages the use of risk calculators and consideration of lung cancer risk factors in addition to age and smoking history to facilitate assessment of risk before screening.[13]

Individual risk-based LCS has the potential to improve screening efficiency and may reduce disparities in LCS eligibility. At a risk threshold of 1.7% over 6 years, The Prostate, Lung, Colorectal, and Ovarian Cancer Screening Trial Modified Logistic Regression Model for Lung Cancer Prediction (PLCOm2012) lung cancer risk model was shown to increase the number of lung cancers detected by 20% compared with USPSTF 2013 criteria.[14] Some studies suggested that individual benefit models, such as the Life-Years From Screening With Computed Tomography study, may reduce racial and ethnic disparities compared with USPSTF criteria,[15-19] although these findings have not been confirmed in all studies.[19-21] Practical challenges that may be faced by providers and organizations when implementing individual risk- or benefit-based LCS must be considered. Using alternative simple criteria for LCS eligibility, such as years smoked, can facilitate identification of individuals for whom LCS would be of high benefit.[22,23] Strategies to incorporate lung cancer risk factors and coexisting chronic illness that increase competing causes of morbidity when defining the LCS target population, as well as tools to assist with their implementation, require further development and validation.[9,11,24]

From a practical standpoint, payers also dictate the target population. The Centers for Medicare and Medicaid Services (CMS) and private insurers who have adopted USPSTF 2021 criteria have defined target populations. Both baseline and annual LDCT imaging costs for individuals meeting these criteria are covered.[25] Coverage of individuals who meet the expanded ACS, CHEST, or NCCN criteria remains limited, reflecting differences in value judgments regarding tradeoffs between the impact and reach of screening.

Future strategies for identifying the LCS target population may include molecular biomarkers alone or in combination with clinical factors.[26] Single-cancer and multicancer early detection tests are in various stages of development and may hold promise for tailored approaches to LCS, but they require evaluation of clinical validity and usefulness.[27-30]

Program Component: LCS programs should define their LCS target population, prioritizing individuals likely to have a net benefit from screening such as those identified by USPSTF 2021 and CMS. Individual programs may consider the expanded populations identified by the ACS, CHEST, or NCCN. Target population determination should consider lung cancer mortality risk, health status, insurance coverage, and health equity.

Component 2: Lung Cancer Screening Uptake and Adherence

2015 Component: How Often and For How Long to Screen; Patient and Provider Education: Evidence Update: LCS uptake across the United States is currently 18% to 20%.[31] This is far lower than screening rates for breast, cervical, and colorectal cancer, which ranged from 72% to 76% of the target population in 2021.[32] Compounding this issue, screening uptake is higher in those with more comorbid conditions or poor health who may be less likely to have a net benefit from screening. Uptake, which typically is defined as the proportion of individuals receiving LCS among those in the current age-based and smoking history-based target population, varies by race (range of up-to-date LCS prevalence, 12.8%-20.0%), geography (range at the state level, 9.7%-31.0%), insurance status (range by health insurance type, 3.7%-26.3%), comorbid conditions ($\geq$ 3 comorbidities vs none, 24.6% and 8.7%, respectively), and other factors.[31,33-36] Barriers to LCS uptake can include these and other individual-level factors, but factors related to clinicians and health care systems also contribute heavily to low screening uptake. For example, LCS access varies by distance to screening facilities, within and between states and regions and across rural-urban environments.[37,38] This complex interplay of individual and structural barriers can compound disparities in screening.

Adherence is a critical component of high-quality screening. Adherence with annual screening is estimated to be approximately 20% to 40% in most settings (higher in Veterans Health Administration facilities), which is

TABLE 2] Proposed Strategies to Increase LCS Uptake and Adherence

Strategy	Approaches
Leverage the EHR	• Identify eligible individuals for LCS • LCS program referrals and LDCT imaging orders • Track LCS participants • Clinical documentation • Interdisciplinary communication to facilitate clinical workflows • Patient communication via EHR portals
Enhance community outreach	• Collaborate with population science and public health colleagues • Tailor materials and processes to community needs • Leverage community health workers • Host LCS awareness and education events in the community • Expand reach through social media platforms
Engage PCP	• Provide LCS education for PCPs • Identify PCP champions for LCS • Automate LCS referrals to streamline processes • Communicate LCS results and management recommendations
Improve methods for patient education	• Direct communication via patient EHR portals • Develop patient-facing materials tailored to underserved populations • Ensure educational materials are linguistically appropriate and culturally tailored
Use navigators to guide patients	• Navigate individuals through the LCS process (SDM, LDCT imaging, continued annual screening) • Provide patient education on LCS results • Leverage telemedicine tools • Support patients with positive screening results through lung nodule management processes

EHR = electronic health record; LCS = lung cancer screening; LDCT = low-dose CT; PCP = primary care provider; SDM = shared decision-making.

markedly lower than the > 95% adherence rates observed in the National Lung Screening Trial (NLST) and The Dutch–Belgian Lung-Cancer Screening Trial (Nederlands–Leuvens Longkanker Screenings Onderzoek [NELSON]) trial.[7,8,35,39] In the NLST, approximately one-half of LCS-detected lung cancers were identified during subsequent incident rounds of screening.[40,41] One study modeled differing rates of adherence and found that at an adherence rate of 46%, the mortality reduction attributable to LCS was reduced by one-half compared with that seen in randomized controlled trials.[42] Standard time frames for measuring LCS adherence depending on Lung CT Screening Reporting and Data System (Lung-RADS) category have been proposed.[43] Factors associated with a lower odds of annual or short-interval LCS adherence include belonging to a racial minority group, current smoking status, and lower income, whereas factors associated with greater odds of LCS adherence include higher educational attainment and centralized screening approaches.[3,4,35,39,44-46] Highly structured LCS pilot programs have reported much higher rates of uptake (84.7% of confirmed eligible individuals) and adherence (90.1%-93.0% of individuals due for short-interval and annual LDCT scans).[1,2] Methods under evaluation to improve LCS uptake and adherence include leveraging the electronic health record, engaging primary care providers, enhancing community outreach, improving methods for patient education, and using navigators or community health workers to facilitate LCS (Table 2).[47-51]

Program Component: LCS programs should develop strategies to increase LCS uptake, adherence, and appropriate follow-up for individuals—including individuals in underserved populations—that maximizes the net benefit of screening.

Component 3: Shared Decision-Making, Including Tobacco Treatment

2015 Component: Patient and Provider Education; Smoking Cessation: Evidence Update: Shared decision-making (SDM) for LCS participation includes a discussion with individuals about LCS benefits and harms, the LCS process (including the importance of adherence), and smoking cessation, using strategies designed to foster value-based patient decisions, which are a universally important component of health care delivery. SDM should be patient centered, with a focus on improving LCS knowledge and self-efficacy to guide

TABLE 3] Tools for Shared Decision-Making

Variable	Resources and Tools	Source or Publications
Clinician-facing materials		
Decision Precision tool	• Includes the LYFS-CT risk model to calculate net benefit of LCS • Integrates with electronic health records including Epic • Provides sample SDM scripts and generates clinical documentation	https://screenlc.com/dpp-vue/index.html
SDM education for clinicians		
CHEST Shared Decision-Making in Lung Cancer Screening e-Learning	• Online modules with CME credit tailored to primary care clinicians	https://www.chestnet.org/store/products/standard-products/elearning/updated-shared-decision-making-in-lung-cancer-screening
Patient-facing materials		
Should I Screen	• Patient education including LCS eligibility criteria, cost, and harms and benefits • PLCOm2012 risk calculator	https://shouldiscreen.com
Saved By The Scan Campaign	• Developed by the Ad Council • Patient resources including a facility finder and insurance coverage information • USPSTF 2021 eligibility quiz	https://www.lung.org/lung-health-diseases/lung-disease-lookup/lung-cancer/saved-by-the-scan
Screen Your Lungs	• USPSTF 2021 eligibility quiz • LCS center locator	https://screenyourlungs.org

CHEST = American College of Chest Physicians; CME = continuing medical education; LCS = lung cancer screening; LYFS-CT = Life-Years From Screening with Computed Tomography; PLCOm2012 = The Prostate, Lung, Colorectal, and Ovarian Cancer Screening Trial Modified Logistic Regression Model for Lung Cancer Prediction; SDM = shared decision-making; USPSTF = US Preventive Services Task Force.

patients as they decide for or against screening.[52] Variability exists in how SDM is delivered—including the clinician type (primary care provider vs patient or nurse navigator), delivery setting (in person vs telemedicine), and use of decision aids—that ultimately can impact patient knowledge, decision conflict, and screening behaviors.[50,53-56] Patient-level factors also have been associated with differences in SDM outcomes, with 1 cross-sectional study of screened patients demonstrating that individuals with non-White race or lower educational attainment exhibited lower LCS knowledge and that individuals with non-White race or former smoking status experienced greater decisional conflict.[53,57] Randomized controlled trials of novel SDM tools and decision aids have demonstrated improved LCS discussion, patient knowledge, LCS referral, and LDCT imaging ordering and completion (Table 3).[47,58-60] However, many questions remain around the most effective methods for providing SDM. A need exists for culturally tailored strategies and materials to engage individuals with low health literacy or whose preferred language is not English. More research is needed regarding how clinicians can provide nuanced counseling that is both comprehensive and efficient while engaging patients.[61]

Providing tobacco dependence treatment is a critical component of high-quality screening, and LCS is most effective at reducing lung cancer mortality—and most cost-effective—when paired with successful smoking abstinence.[62,63] Provision of tobacco treatment resources is required by the CMS as part of a comprehensive SDM process.[6,25] Evidence suggests this may be underperformed in SDM in clinical settings.[64] Three clinical trials from the National Cancer Institute-funded Smoking Cessation Within the Context of Lung Cancer Screening collaboration have been published.[65,66] The Optimizing Lung Screening (OaSiS) trial tested a radiology facility-level intervention and demonstrated a reduction in tobacco use over 6 months, but found no difference between the intervention and usual care arms.[67] Two other randomized controlled trials tested more vs less intensive patient-level tobacco counseling, pharmacotherapy interventions, or both and found no significant different in short-term or long-term smoking abstinence.[68,69] Although the optimal strategy of tobacco treatment within the SDM context remains uncertain, these studies continue to emphasize the importance of tobacco dependence treatment in LCS.

TABLE 4] High-Quality LCS Components Summary

High-Quality Component	Program Component
Component 1: LCS target population	LCS programs should define their LCS target population, prioritizing individuals likely to have a net benefit from screening, such as those identified by USPSTF 2021 and CMS. Individual programs may consider the expanded populations identified by the ACS, CHEST, or NCCN. Target population determination should consider lung cancer mortality risk, health status, insurance coverage, and health equity.
Component 2: LCS uptake and adherence	LCS programs should develop strategies to increase LCS uptake, adherence, and appropriate follow-up for individuals—including individuals in underserved populations—that maximizes the net benefit of screening.
Component 3: shared decision-making, including tobacco treatment	LCS programs should support effective SDM, elements of which include confirmation of screen eligibility and overall health, a discussion of the benefits and harms of LCS, the use of a decision aid, exploration of patient values and preferences, and tobacco dependence treatment for individuals who currently smoke.
Component 4: performing LDCT imaging	LCS programs should have protocols in place to minimize radiation dose associated with annual LCS. Multiple aspects of LCS can be optimized to meet this goal, including adherence with ACR and STR technical standards for dose index volume of ≤ 3 mGy and ensuring appropriate evaluation of LCS-detected nodules and nonnodule findings to reduce unneeded imaging.
Component 5: identify and report LDCT imaging-detected lung nodules	LCS programs should develop and adhere to a systematic approach to lung nodule identification that defines and classifies positive results, facilitates structured reporting such as the ACR Lung-RADS, and guides further evaluation.
Component 6: managing screen-detected lung nodules	LCS programs should develop an approach to screen-detected lung nodule management that includes guideline-based follow-up of low-risk nodules and a multidisciplinary or specialist referral strategy for management of higher-risk nodules.
Component 7: reporting and evaluating nonnodule LDCT imaging findings	LCS programs should develop an approach to evaluate nonnodule findings identified during LCS that includes consistent reporting of clinically significant findings and a structured approach to their evaluation to ensure that nonnodule findings are communicated appropriately and evaluated.
Component 8: quality improvement measures	LCS programs should monitor valid, feasible, and clinically relevant quality measures related to screening process, structure, and outcomes to drive quality improvement initiatives. Quality metrics should include whether an LCS-appropriate target population is completing screening, measures of LCS uptake and adherence, timeliness of cancer diagnosis, and benign biopsy results and resection rates.

ACR = American College of Radiology; ACS = American Cancer Society; CHEST = American College of Chest Physicians; CMS = Centers for Medicare and Medicaid Services; LCS = lung cancer screening; LDCT = low-dose CT; NCCN = National Comprehensive Cancer Network; SDM = shared decision-making; STR = Society of Thoracic Radiology; USPSTF = US Preventive Services Task Force.

Program Component: LCS programs should support effective SDM, whose elements include confirmation of screen eligibility and overall health, a discussion of the benefits and harms of LCS, the use of a decision aid, exploration of patient values and preferences, and tobacco dependence treatment for individuals who currently smoke.

Component 4: Performing LDCT Imaging

2015 Component: How the CT Scan Is Performed:

Evidence Update: Individuals embarking on LCS undergo LDCT imaging at least annually for up to 30 years or as long as they remain in the target population. The American College of Radiology (ACR) and the Society of Thoracic Radiology Practice Parameter outlines technical standards for performing LDCT imaging, as well as the recommended personnel qualifications and examination specifications providing standard guidance for radiology facilities to minimize radiation-related harms.[70] For example, the ACR and Society of Thoracic Radiology guidelines recommend that LDCT imaging should be performed with a technique that yields a dose index volume of ≤ 3 mGy for standard-sized patients; of note, this dose threshold is equivalent to that of approximately 10 posterior-anterior chest radiographs.[70] Other radiation

exposure factors such as gantry rotation time of ≤ 0.75 seconds, milliamperes, and peak kilovoltage should be specified in an LDCT imaging protocol, with the objective of obtaining diagnostic quality images with the lowest possible patient radiation exposure.[70] By submitting equipment and examination data to the ACR Dose Index Registry and ACR LCS Registry, facilities can participate in regional and national benchmarking of facility-level performance. Radiation dose varies among institutions and may vary with facility-level factors, for example, with lower radiation doses when lead radiologists and medical physicists develop LDCT imaging protocols.[71] One multicenter analysis found that institutions where any radiologists could establish protocols showed a 44% higher mean volume CT scan dose index and 27% higher mean effective dose compared with institutions that limited who established protocols to those with specific expertise.[71] The high prevalence of screen-detected lung nodules and non-nodule findings also contributes to cumulative radiation exposure through short-interval LDCT imaging and other downstream imaging. Guideline-concordant management of these findings is an important part of minimizing radiation harms.

Program Component: LCS programs should have protocols in place to minimize ionizing radiation dose associated with annual LCS. Multiple aspects of LCS can be optimized to meet this goal, including adherence with ACR and Society of Thoracic Radiology technical standards for dose index volume of ≤ 3 mGy and ensuring appropriate evaluation of LCS-detected nodules and nonnodule findings to reduce unneeded imaging.

Component 5: Identify and Report Low-Dose CT Scan-Detected Lung Nodules

2015 Components: Lung Nodule Identification; Structured Reporting: Evidence Update: Lung-RADS remains the gold standard to report and recommend follow-up for nodules found through LCS. The lung nodule size threshold for positive screening results was increased from 4 mm in the NLST to 6 mm on baseline LDCT imaging with the original Lung-RADS published in 2014.[7] Although nodule diameter is used more frequently in the United States, NELSON and other LCS trials in Europe have used nodule volume (> 500 mm^3) or volume-doubling time (< 400 days) criteria for positive results, with high discriminatory power between nonmalignant nodules and lung cancer.[8,72,73]

Structured reporting of lung nodules identified on LDCT imaging facilitates lung cancer risk assessment by promoting consistent clinical management and patient tracking. The updated Lung-RADS version 2022 provides definitions and structured reporting parameters for classification of screen-detected lung nodules based on diameter, attenuation, location, and growth.[74] Analyses of the ACR Lung Cancer Screening Registry (LCSR) and other cohorts demonstrated high rates of Lung-RADS use and confirmed the association of Lung-RADS category with lung cancer prevalence rates (cancer detection rate in the LCSR increased from 0.4% for Lung-RADS category 3 to 11%-13% for Lung-RADS category 4B and 19.9% for Lung-RADS category 4X).[35,75]

Lung RADS version 2022 provides new categories for specific nodule subtypes including atypical pulmonary cysts, juxtapleural nodules, suspected inflammatory or infectious findings, and airway nodules.[76] Separating low-risk juxtapleural nodules, for example, may reduce short-term follow-up scans and false-positive results.[77] Lung-RADS version 2022 also provides guidance for measuring mean diameter and volume, along with new recommendations for slow-growing pure ground-glass, part-solid, and solid lung nodules.[76]

Growth of screening program numbers and locations requires increased efficiency and broader expertise in the interpretation of imaging findings. Artificial intelligence-based imaging tools applied to lung nodule identification and characterization may improve the efficiency of interpretation while maintaining accuracy.[78]

Program Component: LCS programs should develop and adhere to a systematic approach to lung nodule identification that defines and classifies positive results, facilitates structured reporting such as the ACR Lung-RADS, and guides further evaluation.

Component 6: Managing Screen-Detected Lung Nodules

2015 Components: Lung Nodule Identification; Lung Nodule Management Algorithms: Evidence Update: The ACR provides recommendations for management of screen-detected lung nodules based on the Lung-RADS classification, with Lung-RADS categories 3, 4A, 4B, and 4X considered positive results of screening examinations.[74] Most examinations identify no lung nodules or small nodules that likely are benign.[35] A contemporary analysis of 1 million people who

underwent LCS in the United States identified 83% of baseline screening studies as showing Lung-RADS category 1 or 2 findings, 10% as showing Lung-RADS category 3 findings, and 7% as showing Lung-RADS category 4A, 4B, or 4X findings.[35] The likelihood of lung cancer diagnosis increased with Lung-RADS category, demonstrating the clinical validity of a standardized classification.

Lung-RADS version 2022 recommends surveillance imaging at 6 months for category 3 findings and return to annual screening for category 1 or 2 findings, based on the low probability of an aggressive malignancy and the limited ability of LDCT scans to detect growth in small malignant nodules over short intervals. Lung-RADS version 2022 also introduced stepped-down management for lung nodules that are stable or becoming smaller on follow-up scans.[76] The evidence supporting follow-up intervals is evolving. Categories 4A, 4B, and 4X require a clinician to decide among multiple strategies including subspecialty referral, surveillance with chest CT imaging, or further testing with PET-CT imaging or tissue sampling. Management of these nodules often benefits from multidisciplinary discussion, such as a lung nodule conference or tumor board, to determine a management strategy that aligns with clinical practice guidelines and incorporates individualized lung cancer risk, procedure-related risks, procedure expertise and availability, and patient preferences.[79,80-82] Lung cancer risk models tailored to screen-detected findings can be used to refine lung cancer probability estimates.[41,83]

Technical advances in image-guided bronchoscopy, including electromagnetic navigation and robotic-assisted bronchoscopy, have improved the feasibility of bronchoscopic biopsy of small peripheral lung nodules, whereas endobronchial ultrasound-guided staging of the hila and mediastinum is standard of care for larger (eg, ≥ 2-3 cm) or centrally located nodules.[84,85] Although dependent on procedural availability and expertise, these improvements facilitate accurate diagnosis and staging for lung cancer identified by LCS, a critical step in the era of neoadjuvant and perioperative immunotherapy for locally advanced disease. Many unanswered questions remain in the advanced diagnostic bronchoscopy literature. Further research designed to clarify the diagnostic yield of bronchoscopic technologies as they evolve and compare them with percutaneous biopsy will help to guide the use of these tools.[86,87]

Future nodule management strategies may integrate radiomic algorithms with clinical and molecular characteristics to determine the probability of clinically active lung cancer.[88] It will be a priority for future applications of these and other research findings to distill large amounts of data—potentially leveraging artificial intelligence and machine learning—into a streamlined result that can be understood and applied by clinicians performing LCS. More research is needed to determine the natural history of screen-detected pure ground-glass, part-solid, and cystic lesions. Some of these nodules may have a more indolent growth pattern, altering the balance of harms and benefits of management decisions. Additionally, the clinical impact of stepped management and extended monitoring of pure ground-glass opacities beyond 5 years is unknown, and the potential tradeoffs of closer monitoring for earlier diagnosis with an increased number of LDCT scans warrants further investigation.

Program Component: LCS programs should develop an approach to screen-detected lung nodule management that includes guideline-based follow-up of low-risk nodules and a multidisciplinary or specialist referral strategy for management of higher-risk nodules.

Component 7: Reporting and Evaluating Nonnodule LDCT Scan Findings

2015 Component: Structured Reporting: Evidence Update: The current ACR Lung-RADS classification provides limited guidance for when to use an S modifier for a significant or potentially significant finding unrelated to lung cancer,[74] and no consensus exists on the specific non-nodule findings warranting an S modifier. The CHEST Screening for Lung Cancer guidelines include a table that classifies common incidental findings into not clinically relevant, possible clinically relevant, and clinically concerning categories.[6] Inconsistent use of the S modifier is reported widely, between radiologists within a single institution or health care system and among multiple LDCT scans from a single patient.[89] A significant non-nodule finding was reported in 33.8% of NLST participants, and an S modifier was reported in 18.8% of screening studies in the ACR LCSR cohort.[89,90] Among LDCT scans with significant findings, the most frequent non-nodule findings include emphysema (43% in the NLST) and coronary artery calcifications (62% in the ACR LCSR).[90,91]

It is important for LCS programs to develop a consistent workflow for managing non-nodule findings, including who will be responsible for directing the evaluation: the

primary care or ordering clinician or the staff within the LCS program. The ACR Quick Guide provides recommendations for the most common LDCT scan findings.[89] The suggested evaluations are based on the ACR white papers for abnormalities within the field of view of LDCT scan examinations.[89]

Evidence exists to suggest that LDCT imaging can improve the early detection and diagnosis of non-lung cancer thoracic disease. For example, LDCT scan-detected coronary artery calcifications can predict cardiovascular mortality in the LCS population.[92,93] Similarly, LDCT imaging-detected emphysema is associated with greater lung cancer incidence and mortality. [94,95] The 2024 report from the Global Initiative for Chronic Obstructive Lung Disease recommends spirometry when imaging findings consistent with COPD are detected on LDCT imaging.[96] More research is needed to determine the benefit from management of LDCT imaging-detected coronary artery calcifications, emphysema, and other findings.

Program Component: LCS programs should develop an approach to evaluate non-nodule findings identified during LCS that includes consistent reporting of clinically significant findings and a structured approach to their evaluation to ensure that non-nodule findings are communicated and evaluated appropriately.

Component 8: Quality Improvement Measures

2015 Component: Data Collection: Evidence Update: As the LCS target population evolves and as LCS uptake increases across the United States and worldwide, the balance of harms and benefits must be reevaluated continuously. Rigorous measurement of clinically relevant and reliable quality measures will assist in identifying implementation strategies that maximize the net benefit to the target population. The National Lung Cancer Roundtable identified 6 LCS quality indicators through surveys of multidisciplinary experts.[43] The indicators that achieved consensus included screening an appropriate target population; offering tobacco treatment to LCS recipients; adherence to recommended LDCT imaging follow-up, including continued annual surveillance and workup of screen-detected findings; and timely diagnosis of lung cancer in category 4 lung nodules.[43] Additional quality indicators and outcome metrics that could be considered include nonmalignant surgical resection rate, cancer detection rate, and noninvasive and invasive procedure complication rates. A multidisciplinary steering committee that supports an LCS program can facilitate monitoring quality and performance through measurement of agreed-on indicators and outcomes.

Although the electronic health record has the capacity to store and harmonize a large volume of patient-level data, extracting LCS-specific information in an accurate, clinically meaningful fashion to monitor performance on quality indicators remains unrealized.[97] Barriers exist across the entire LCS process, including case ascertainment and risk factor documentation (incomplete or erroneous smoking history and tobacco treatment records), visit documentation (variations in SDM and inconsistent ordering or use of LDCT imaging screening Current Procedural Terminology codes), and patient tracking (challenges in determining and measuring expected vs actual time frames for patient return).[98] Tracking software can assist with managing patients and communication by automating reminder messages, as well as submission of data to national registries and to demonstrate financial contribution margins for programmatic growth. However, many of these systems are external to the primary electronic health record and require staff effort to maintain. Programs may benchmark some outcomes against national data collected in the ACR Lung Cancer Screening Registry since 2015 through CMS-mandated facility-level data submission, although this is no longer required.[34,35]

Future research should identify tools and strategies for characterizing LCS outcomes, focusing on identifying measurable, clinically relevant indicators. Upcoming Healthcare Effectiveness Data and Information Set (HEDIS) measures from the National Committee on Quality Assurance focused on tobacco use documentation and LCS uptake in the target population will put pressure on health care systems to improve methods for data entry and extraction. Additionally, a statement of proposed quality metrics for measuring LCS outcomes is anticipated from the International Association for the Study of Lung Cancer in 2025. Development of multicenter consortia will be critical to understanding the multilevel challenges in improving LCS outcomes.[99,100]

Program Component: LCS programs should monitor valid, feasible, and clinically relevant quality measures related to screening process, structure, and outcomes to drive quality improvement initiatives. Quality metrics should include whether an LCS-appropriate target population is completing screening, measures of LCS

uptake and adherence, timeliness of cancer diagnosis, and benign biopsy and resection rates.

Conclusions

The current era of LCS is characterized by evolution of approaches to improving uptake and adherence to screening, identifying the target population, conducting effective and efficient SDM, supporting tobacco cessation efforts, reporting results from LDCT imaging, and managing LDCT imaging findings. Although cutting-edge developments in the areas of molecular biomarkers, artificial intelligence, and implementation science will drive further progress in the field, it is important to evaluate new research findings critically before integrating them into the LCS paradigm. Based on current knowledge, the 8 components described herein are necessary for delivery of high-quality screening that optimizes the balance of benefits and harms (Table 4).

Although resource availability and the exact approach to each component may vary among health systems and institutions, programs should have an overarching objective of developing high-quality LCS programs anchored by the components described. Health equity and interdisciplinary collaboration among disciplines including primary care, thoracic radiology, pulmonary medicine, thoracic surgery, radiation oncology, and medical oncology should remain important themes as the field advances. Because the next decade of innovation surely will drive further LCS uptake, application of these components will be critical to scaling high-quality LCS programs and further reducing lung cancer mortality.

The authors have reported to *CHEST* that no funding was received for this study.

Financial/Nonfinancial Disclosures

The authors have reported to *CHEST* the following: J. A. B. reports research grants from the Prevent Cancer Foundation, the Genentech Health Equity Innovations Fund, and Astra Zeneca UK; consulting paid to her institution from Delfi Diagnostics, Inc.; and advisory board membership for Guardant Health, Freenome, and Nucleix. D. A. reports a one-eighth Veterans Affairs (VA) appointment, unpaid institutional representation on the NCCN tobacco dependence treatment panel, and salary support paid to his institution from Roche. L. B. reports speaker or advisory panel membership, or both for Genentech/Roche, Bristol Myers Squibb, and Astra Zeneca. M. K. G. reports nonemployee compensation from the American Thoracic Society to serve as deputy editor of *Annals of the American Thoracic Society* and royalties from UpToDate. V. S. N. reports grant support from Roche and Biodesix; advisor to Roche, Biodesix, and Freenome; and consulting for Eurofins Viracor and Verathon, Inc. M. P. reports receiving consulting fees from Center for Business Models in Healthcare, CARES (Chicago Association for Research and Education in Science), and Prevent Cancer Foundation Scientific Review Panel (grant reviews), as well as funding from Coleman Foundation and American Lung Association. C. A. P. reports consulting for Daiichi Sankyo, Astra Zeneca, BioNTech, Pfizer, Merus, Seagen, and Duality. K. S. reports medical advisory board membership and financial interest in RevealDx. G. S. reports grant funding from and scientific advisory board roles for Delfi Diagnostics, Nucleix, and Freenome, as well as research funding from Qure.ai. M. T. reports serving on the NCCN guideline clinical practice guideline panel for smoking cessation (unpaid) and on an advisory board for GO2 Foundation for Lung Cancer (paid), as well as grant funding paid to his institution from the National Institutes of Health, BMS Foundation, American Thoracic Society, Lungevity foundation, CHEST foundation, and American Lung Association. A. V. reports grants or contracts from Precyte, Inc., Optellum, Ltd., NCCN, MagArray, Gordon and Betty Moore Foundation, Lungevity Foundation, and Delfi Diagnostics; consulting fees paid to self from Johnson and Johnson; and participation in a data safety and monitoring board or advisory board for Intuitive Surgical with payment to self and Delfi Diagnostics (unpaid). R. S. W. reports serving in unpaid roles on committees, policy statements, or guidelines related to lung cancer screening for CHEST, the American Thoracic Society, the American College of Radiology, and the National Lung Cancer Round Table. She receives salary support for her role as Deputy Chief Consultant for the VA's National Center for Lung Cancer Screening and for her role as associate documents editor for the American Thoracic Society. She receives (or received within the past 5 years) grant funding paid to her institution from VA Office of Research & Development, the Department of Defense, the National Institutes of Health, and Patient-Centered Outcomes Research Institute. P. J. M. reports receiving grants paid to his institution from the Patient-Centered Outcomes Research Institute, Moore Foundation, Mandel Accelerator, Adela, Biodesix, DELFI, Exact Sciences, MagArray, Nucleix, PrognomiQ,

and Veracyte paid to his institution; and serving as editor-in-chief of *CHEST*. None declared (F. D.).

References

1. Tammemägi MC, Darling GE, Schmidt H, et al. Risk-based lung cancer screening performance in a universal healthcare setting. *Nat Med*. 2024;30(4):1054-1064.
2. Crosbie PAJ, Gabe R, Simmonds I, et al. Participation in community-based lung cancer screening: the Yorkshire Lung Screening Trial. *Eur Respir J*. 2022;60(5):2200483.
3. Sakoda LC, Rivera MP, Zhang J, et al. Patterns and factors associated with adherence to lung cancer screening in diverse practice settings. *JAMA Network Open*. 2021;4(4). e218559-e218559.
4. Kim RY, Rendle KA, Mitra N, et al. Racial disparities in adherence to annual lung cancer screening and recommended follow-up care: a multicenter cohort study. *Ann Am Thorac Soc*. 2022;19(9):1561-1569.
5. Mazzone P, Powell CA, Arenberg D, et al. Components necessary for high-quality lung cancer screening: American College of Chest Physicians and American Thoracic Society policy statement. *Chest*. 2015;147(2):295-303.
6. Mazzone PJ, Silvestri GA, Souter LH, et al. Screening for lung cancer: CHEST guideline and expert panel report. *Chest*. 2021;160(5):1959-1980.
7. Aberle DR, Adams AM, Berg CD, et al. Reduced lung-cancer mortality with low-dose computed tomographic screening. *N Engl J Med*. 2011;365(5):395-409.
8. de Koning HJ, van der Aalst CM, de Jong PA, et al. Reduced lung-cancer mortality with volume CT screening in a randomized trial. *N Engl J Med*. 2020;382:503-513.
9. Núñez ER, Zhang S, Glickman ME, et al. What goes into patient selection for lung cancer screening? Factors associated with clinician judgments of suitability for screening. *Am J Respir Crit Care Med*. 2023;209(2):197-205.
10. Rendle KA, Saia CA, Vachani A, et al. Rates of downstream procedures and complications associated with lung cancer screening in routine clinical practice. *Ann Intern Med*. 2024;177(1):18-28.
11. US Preventive Services Task Force. Screening for lung cancer: US Preventive Services Task Force recommendation statement. *JAMA*. 2021;325(10):962-970.
12. Wolf AMD, Oeffinger KC, Shih TY-C, et al. Screening for lung cancer: 2023 guideline update from the American Cancer Society. *CA Cancer J Clin*. 2024;74(1):50-81.
13. National Comprehensive Cancer Network (NCCN). NCCN clinical practice guidelines in oncology (NCCN guidelines®) for lung cancer screening V2.2024. National Comprehensive Cancer Network website. Accessed December 1, 2024. https://www.nccn.org/guidelines/guidelines-detail?category=2&id=1441
14. Tammemägi MC, Ruparel M, Tremblay A, et al. USPSTF2013 versus PLCOm2012 lung cancer screening eligibility criteria (International Lung Screening Trial): interim analysis of a prospective cohort study. *Lancet Oncol*. 2022;23(1):138-148.
15. Pasquinelli MM, Tammemägi MC, Kovitz KL, et al. Risk prediction model versus United States Preventive Services Task Force lung cancer screening eligibility criteria: reducing race disparities. *J Thorac Oncol*. 2020;15(11):1738-1747.
16. Choi E, Ding VY, Luo SJ, et al. Risk model–based lung cancer screening and racial and ethnic disparities in the US. *JAMA Oncol*. 2023;9(12):1640-1648.
17. Pu CY, Lusk CM, Neslund-Dudas C, Gadgeel S, Soubani AO, Schwartz AG. Comparison between the 2021 USPSTF lung cancer screening criteria and other lung cancer screening criteria for racial disparity in eligibility. *JAMA Oncol*. 2022;8(3):374-382.
18. Landy R, Gomez I, Caverly TJ, et al. Methods for using race and ethnicity in prediction models for lung cancer screening eligibility. *JAMA Network Open*. 2023;6(9):e2331155-e2331155.
19. Landy R, Young CD, Skarzynski M, et al. Using prediction models to reduce persistent racial and ethnic disparities in the draft 2020 USPSTF lung cancer screening guidelines. *J Natl Cancer Inst*. 2021;113(11):1590-1594.
20. Aredo JV, Choi E, Ding VY, et al. Racial and ethnic disparities in lung cancer screening by the 2021 USPSTF guidelines vs. risk-based criteria: the Multiethnic Cohort Study. *JNCI Cancer Spectr*. 2022;6(3):pkac033.
21. Yang JJ, Wen W, Zahed H, et al. Lung cancer risk prediction models for Asian ever-smokers. *J Thorac Oncol*. 2024;19(3):451-464.
22. Kearney LE, Belancourt P, Katki HA, et al. The development and performance of alternative criteria for lung cancer screening. *Ann Internal Med*. 2024;177(9):1222-1232.
23. Potter AL, Xu NN, Senthil P, et al. Pack-year smoking history: an inadequate and biased measure to determine lung cancer screening eligibility. *J Clin Oncol*. 2024;42(17):2026-2037.
24. Rivera MP, Tanner NT, Silvestri GA, et al. Incorporating coexisting chronic illness into decisions about patient selection for lung cancer screening. An official American Thoracic Society research statement. *Am J Respir Crit Care Med*. 2018;198(2):e3-e13.
25. Centers for Medicare & Medicaid Services (CMS). National Coverage Analysis (NCA) Decision Memo. Screening for lung cancer with low-dose computed tomography (LDCT). CAG-00439R. February 10, 2022. CMS website. Accessed December 1, 2024. https://www.cms.gov/medicare-coverage-database/view/ncacal-decision-memo.aspx?proposed=N&ncaid=304
26. Mazzone PJ, Sears CR, Arenberg DA, et al. Evaluating molecular biomarkers for the early detection of lung cancer: when is a biomarker ready for clinical use? An official American Thoracic Society policy statement. *Am J Respir Crit Care Med*. 2017;196(7):e15-e29.
27. Mazzone PJ, Bach PB, Carey J, et al. Clinical validation of a cell-free DNA fragmentome assay for augmentation of lung cancer early detection. *Cancer Discov*. 2024;14(11):2224-2242.
28. Gaga M, Chorostowska-Wynimko J, Horváth I, et al. Validation of Lung EpiCheck, a novel methylation-based blood assay, for the detection of lung cancer in European and Chinese high-risk individuals. *Eur Respir J*. 2021;57(1):2002682.
29. Etzioni R, Gulati R, Weiss NS. Multicancer early detection: learning from the past to meet the future. *J Natl Cancer Inst*. 2022;114(3):349-352.
30. Barta JA, Mazzone PJ, Nair VS. Multi-cancer and single-cancer early detection testing: opportunities and challenges. *Chest*. 2024;166(3):425-428.
31. Bandi P, Star J, Ashad-Bishop K, Kratzer T, Smith R, Jemal A. Lung cancer screening in the US, 2022. *JAMA Internal Med*. 2024;184(8):882-891.
32. Sabatino SA, Thompson TD, White MC, et al. Up-to-date breast, cervical, and colorectal cancer screening test use in the United States, 2021. *Prev Chronic Dis*. 2023;20:E94.
33. Shusted CS, Evans NR, Kane GC, Juon H-S, Barta JA. Analysis of lung cancer screening by race after USPSTF expansion of screening eligibility in 2021. *JAMA Network Open*. 2022;5(6):e2217578-e2217578.
34. Silvestri GA, Goldman L, Burleson J, et al. Characteristics of persons screened for lung cancer in the United States. *Ann Internal Med*. 2022;175(11):1501-1505.
35. Silvestri GA, Goldman L, Tanner NT, et al. Outcomes from more than 1 million people screened for lung cancer with low-dose CT imaging. *Chest*. 2023;164(1):241-251.
36. Rivera MP, Katki HA, Tanner NT, et al. Addressing disparities in lung cancer screening eligibility and healthcare access. An official American Thoracic Society statement. *Am J Respir Crit Care Med*. 2020;202(7):e95-e112.
37. Sahar L, Douangchai Wills VL, Liu KK, et al. Geographic access to lung cancer screening among eligible adults living in rural and urban environments in the United States. *Cancer*. 2022;128(8):1584-1594.

38. Sahar L, Douangchai Wills VL, Liu KK, Kazerooni EA, Dyer DS, Smith RA. Using geospatial analysis to evaluate access to lung cancer screening in the United States. *Chest*. 2020;159(2):833-844.

39. Núñez ER, Caverly TJ, Zhang S, et al. Adherence to follow-up testing recommendations in US veterans screened for lung cancer, 2015-2019. *JAMA Netw Open*. 2021;4(7):e2116233-e2116233.

40. Schabath MB, Massion PP, Thompson ZJ, et al. Differences in patient outcomes of prevalence, interval, and screen-detected lung cancers in the CT arm of the National Lung Screening Trial. *PloS One*. 2016;11(8):e0159880.

41. Tammemägi MC, ten Haaf K, Toumazis I, et al. Development and validation of a multivariable lung cancer risk prediction model that includes low-dose computed tomography screening results: a secondary analysis of data from the National Lung Screening Trial. *JAMA Netw Open*. 2019;2(3):e190204-e190204.

42. Han SS, Erdogan SA, Toumazis I, Leung A, Plevritis SK. Evaluating the impact of varied compliance to lung cancer screening recommendations using a microsimulation model. *Cancer Causes Control*. 2017;28(9):947-958.

43. Mazzone PJ, White CS, Kazerooni EA, Smith RA, Thomson CC. Proposed quality metrics for lung cancer screening programs: a national lung cancer roundtable project. *Chest*. 2021;160(1):368-378.

44. Barta JA, Shusted CS, Ruane B, et al. Racial differences in lung cancer screening beliefs and screening adherence. *Clin Lung Cancer*. 2021;22(6):570-578.

45. Kim RY, Rendle KA, Mitra N, et al. Socioeconomic status as a mediator of racial disparity in annual lung cancer screening adherence. *Am J Respir Crit Care Med*. 2022;207(6):777-780.

46. Lopez-Olivo MA, Maki KG, Choi NJ, et al. Patient adherence to screening for lung cancer in the US: a systematic review and meta-analysis. *JAMA Netw Open*. 2020;3(11):e2025102-e2025102.

47. Caverly TJ, Wiener RS, Kumbier K, Lowery J, Fagerlin A. Prediction-augmented shared decision-making and lung cancer screening uptake. *JAMA Netw Open*. 2024;7(7):e2419624-e2419624.

48. DiCarlo M, Myers P, Daskalakis C, et al. Outreach to primary care patients in lung cancer screening: a randomized controlled trial. *Prev Med*. 2022;159:107069.

49. Triplette M, Snidarich M, Heffner JL, et al. A community-engaged research study to inform tailored programming for smoking cessation and lung cancer screening among at-risk LGBTQ+ Elders. *Health Promot Prac*. 2025;26(5):956-968.

50. Volk RJ, Lowenstein LM, Leal VB, et al. Effect of a Patient decision aid on lung cancer screening decision-making by persons who smoke: a randomized clinical trial. *JAMA Netw Open*. 2020;3(1):e1920362-e1920362.

51. Williams LB, Shelton BJ, Gomez ML, Al-Mrayat YD, Studts JL. Using implementation science to disseminate a lung cancer screening education intervention through community health workers. *J Community Health*. 2021;46(1):165-173.

52. Carter-Bawa L, Slaven JE Jr, Monahan PO, et al. Unpacking the relationship between shared decision-making and decisional quality, decision to screen, and screening completion in lung cancer screening. *Patient Educ Couns*. 2024;122:108143.

53. Nishi SPE, Lowenstein LM, Mendoza TR, et al. Shared decision-making for lung cancer screening: how well are we "sharing". *Chest*. 2021;160(1):330-340.

54. Shusted CS, Juon H-S, Ruane B, et al. Individual- and neighborhood-level characteristics of lung cancer screening participants undergoing telemedicine shared decision making. *BMC Health Serv Res*. 2023;23(1):1179.

55. Mazzone PJ, Tenenbaum A, Seeley M, et al. Impact of a lung cancer screening counseling and shared decision-making visit. *Chest*. 2017;151(3):572-578.

56. Núñez ER, Caverly TJ, Zhang S, et al. Factors associated with declining lung cancer screening after discussion with a clinician in a cohort of US veterans. *JAMA Netw Open*. 2022;5(8):e2227126-e2227126.

57. Daskalakis C, Shimada A, Myers RE, et al. Decision preferences in shared decision-making for lung cancer screening among White and African American individuals. *Ann Am Thorac Soc*. 2023;20(5):756-758.

58. Kukhareva PV, Li H, Caverly TJ, et al. Implementation of lung cancer screening in primary care and pulmonary clinics: pragmatic clinical trial of electronic health record-integrated everyday shared decision-making tool and clinician-facing prompts. *Chest*. 2023;164(5):1325-1338.

59. Walsh JME, Karliner L, Smith A, et al. LungCARE: encouraging shared decision-making in lung cancer screening—a randomized trial. *J Gen Intern Med*. 2023;38(14):3115-3122.

60. Schapira MM, Hubbard RA, Whittle J, et al. Lung cancer screening decision aid designed for a primary care setting: a randomized clinical trial. *JAMA Netw Open*. 2023;6(8):e2330452-e2330452.

61. Wiener RS, Barker AM, Carter-Harris L, et al. Stakeholder research priorities to promote implementation of shared decision-making for lung cancer screening: an American Thoracic Society and Veterans Affairs Health Services research and development statement. *Am J Respir Crit Care Med*. 2022;205(6):619-630.

62. Tanner NT, Kanodra NM, Gebregziabher M, et al. The association between smoking abstinence and mortality in the National Lung Screening Trial. *Am J Respir Crit Care Med*. 2015;193(5):534-541.

63. Cadham CJ, Cao P, Jayasekera J, et al. Cost-effectiveness of smoking cessation interventions in the lung cancer screening setting: a simulation study. *J Natl Cancer Inst*. 2021;113(8):1065-1073.

64. Shen J, Crothers K, Kross EK, Petersen K, Melzer AC, Triplette M. Provision of smoking cessation resources in the context of in-person shared decision-making for lung cancer screening. *Chest*. 2021;160(2):765-775.

65. Joseph AM, Rothman AJ, Almirall D, et al. Lung cancer screening and smoking cessation clinical trials. SCALE (Smoking Cessation within the Context of Lung Cancer Screening) Collaboration. *Am J Respir Crit Care Med*. 2018;197(2):172-182.

66. Lang AE. Update on the National Cancer Institute's Smoking Cessation at Lung Examination Collaboration Trials. *Chest*. 2024;165(6):1302-1306.

67. Foley KL, Dressler EV, Weaver KE, et al. The Optimizing Lung Screening Trial (WF-20817CD): multicenter randomized effectiveness implementation trial to increase tobacco use cessation for individuals undergoing lung screening. *Chest*. 2023;164(2):531-543.

68. Fu SS, Rothman AJ, Vock DM, et al. Optimizing longitudinal tobacco cessation treatment in lung cancer screening: a sequential, multiple assignment, randomized trial. *JAMA Netw Open*. 2023;6(8):e2329903-e2329903.

69. Taylor KL, Williams RM, Li T, et al. A randomized trial of telephone-based smoking cessation treatment in the lung cancer screening setting. *J Natl Cancer Inst*. 2022;114(10):1410-1419.

70. American College of Radiology. ACR–STR practice parameter for the performance and reporting of lung cancer screening thoracic computed tomography (CT). American College of Radiology website. 2019. Accessed July 19, 2024. https://www.acr.org/-/media/ACR/Files/Practice-Parameters/CT-LungCaScr.pdf

71. Demb J, Chu P, Yu S, et al. Analysis of computed tomography radiation doses used for lung cancer screening scans. *JAMA Internal Med*. 2019;179(12):1650-1657.

72. Horeweg N, van der Aalst CM, Vliegenthart R, et al. Volumetric computed tomography screening for lung cancer: three rounds of the NELSON trial. *Eur Respir J*. 2013;42(6):1659.

73. Bankier AA, MacMahon H, Goo JM, Rubin GD, Schaefer-Prokop CM, Naidich DP. Recommendations for measuring pulmonary nodules at CT: a statement from the Fleischner Society. *Radiology*. 2017;285(2):584-600.

74. American College of Radiology. Lung CT screening reporting and data system (Lung-RADS) version 2022. American College of Radiology website. 2022. https://www.acr.org/-/media/ACR/Files/RADS/Lung-RADS/Lung-RADS-2022.pdf

75. Hwang AR, Mesfin N, Kogut M, et al. Percutaneous lung biopsy prevalence and use of Lung-RADS in the Veterans Health Administration Lung Cancer Screening Program. *Chest*. 2024;166(5):1254-1257.

76. Christensen J, Prosper AE, Wu CC, et al. ACR Lung-RADS v2022: assessment categories and management recommendations. *J Am Coll Radiol*. 2024;21(3):473-488.

77. Chelala L, Hossain R, Jeudy J, Nader Z, Kastner J, White C. Lung–Reporting and Data System 2.0: impact of the updated approach to juxtapleural nodules during lung cancer screening using the National Lung Cancer Screening Trial data set. *J Thorac Imaging*. 2024;39(4):241-246.

78. Liu JA, Yang IY, Tsai EB. Artificial intelligence (AI) for lung nodules, from the AJR Special Series on AI Applications. *AJR Am J Roentgenol*. 2022;219(5):703-712.

79. Madariaga ML, Lennes IT, Best T, et al. Multidisciplinary selection of pulmonary nodules for surgical resection: diagnostic results and long-term outcomes. *J Thorac Cardiovasc Surg*. 2020;159(4):1558-1566.e3.

80. Till BM, Grenda T, Tidwell T, et al. Brief report: nonmalignant surgical resection among individuals with screening-detected versus incidental lung nodules. *Clin Lung Cancer*. 2024;25(3):e129-e132.e4.

81. Verdial FC, Madtes DK, Cheng G-S, et al. Multidisciplinary team-based management of incidentally detected lung nodules. *Chest*. 2020;157(4):985-993.

82. Gould MK, Donington J, Lynch WR, et al. Evaluation of individuals with pulmonary nodules: when is it lung cancer? Diagnosis and Management of Lung Cancer, 3rd ed: American College of Chest Physicians evidence-based clinical practice guidelines. *Chest*. 2013;143(5 suppl):e93S-e120S.

83. McWilliams A, Tammemagi MC, Mayo JR, et al. Probability of cancer in pulmonary nodules detected on first screening CT. *N Engl J Med*. 2013;369(10):910-919.

84. Ost DE, Ernst A, Lei X, et al. Diagnostic yield and complications of bronchoscopy for peripheral lung lesions. Results of the AQuIRE Registry. *Am J Respir Crit Care Med*. 2015;193(1):68-77.

85. Nadig TR, Thomas N, Nietert PJ, et al. Guided bronchoscopy for the evaluation of pulmonary lesions: an updated meta-analysis. *Chest*. 2023;163(6):1589-1598.

86. Vachani A, Maldonado F, Laxmanan B, Kalsekar I, Murgu S. The impact of alternative approaches to diagnostic yield calculation in studies of bronchoscopy. *Chest*. 2022;161(5):1426-1428.

87. Gonzalez AV, Silvestri GA, Korevaar DA, et al. Assessment of advanced diagnostic bronchoscopy outcomes for peripheral lung lesions: a Delphi consensus definition of diagnostic yield and recommendations for patient-centered study designs. An official American Thoracic Society/American College of Chest Physicians research statement. *Am J Respir Crit Care Med*. 2024;209(6):634-646.

88. Kammer MN, Lakhani DA, Balar AB, et al. Integrated biomarkers for the management of indeterminate pulmonary nodules. *Am J Respir Crit Care Med*. 2021;204(11):1306-1316.

89. Dyer DS, White C, Conley Thomson C, et al. A quick reference guide for incidental findings on lung cancer screening CT examinations. *J Am Coll Radiol*. 2023;20(2):162-172.

90. Gareen IF, Gutman R, Sicks J, et al. Significant incidental findings in the National Lung Screening Trial. *JAMA Internal Med*. 2023;183(7):677-684.

91. Morgan L, Choi H, Reid M, Khawaja A, Mazzone PJ. Frequency of incidental findings and subsequent evaluation in low-dose computed tomographic scans for lung cancer screening. *Ann Am Thorac Soc*. 2017;14(9):1450-1456.

92. Takx RA, Išgum I, Willemink MJ, et al. Quantification of coronary artery calcium in nongated CT to predict cardiovascular events in male lung cancer screening participants: results of the NELSON study. *J Cardiovasc Comput Tomogr*. 2015;9(1):50-57.

93. Chiles C, Duan F, Gladish GW, et al. Association of coronary artery calcification and mortality in the National Lung Screening Trial: a comparison of three scoring methods. *Radiology*. 2015;276(1):82-90.

94. Labaki WW, Xia M, Murray S, et al. Quantitative emphysema on low-dose CT imaging of the chest and risk of lung cancer and airflow obstruction: an analysis of the National Lung Screening Trial. *Chest*. 2021;159(5):1812-1820.

95. Ruparel M, Quaife SL, Dickson JL, et al. Prevalence, symptom burden, and underdiagnosis of chronic obstructive pulmonary disease in a lung cancer screening cohort. *Ann Am Thorac Soc*. 2020;17(7):869-878.

96. Global Initiative for Chronic Obstructive Lung Disease. Global strategy for prevention, diagnosis and management of COPD: 2024 report. 2024. Global Initiative for Chronic Obstructive Lung Disease website. Accessed February 9, 2024. https://goldcopd.org/2024-gold-report

97. Fathi JT, White CS, Greenberg GM, Mazzone PJ, Smith RA, Thomson CC. The integral role of the electronic health record and tracking software in the implementation of lung cancer screening; a call to action to developers: a white paper from the National Lung Cancer Roundtable. *Chest*. 2020;157(6):1674-1679.

98. Kukhareva PV, Caverly TJ, Li H, et al. Inaccuracies in electronic health records smoking data and a potential approach to address resulting underestimation in determining lung cancer screening eligibility. *J Am Med Inform Assoc*. 2022;29(5):779-788.

99. Barta JA, Erkmen CP, Shusted CS, et al. The Philadelphia Lung Cancer Learning Community: a multi–health-system, citywide approach to lung cancer screening. *JNCI Cancer Spectr*. 2023;7(5):pkad071.

100. Rendle KA, Burnett-Hartman AN, Neslund-Dudas C, et al. Evaluating lung cancer screening across diverse healthcare systems: a process model from the Lung PROSPR Consortium. *Cancer Prev Res*. 2020;13(2):129-136.