The 10 Pillars of Lung Cancer Screening: Rationale and Logistics of a Lung Cancer Screening Program[1]

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Abbreviations: ACR = American College of Radiology, CMS = Centers for Medicare and Medicaid Services, LCS = lung cancer screening, Lung-RADS = Lung Imaging Reporting and Data System, NLST = National Lung Screening Trial, USPSTF = U.S. Preventive Services Task Force

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SA-CME LEARNING OBJECTIVES

After completing this journal-based SA-CME activity, participants will be able to:

- Assess the effect of low-dose chest CT for lung cancer screening.
- Describe Lung-RADS, the structured reporting system for the interpretation of lung cancer screening CT examinations.
- List the elements required to start a lung cancer screening program.

See www.rsna.org/education/search/RG.

On the basis of the National Lung Screening Trial data released in 2011, the U.S. Preventive Services Task Force made lung cancer screening (LCS) with low-dose computed tomography (CT) a public health recommendation in 2013. The Centers for Medicare and Medicaid Services (CMS) currently reimburse LCS for asymptomatic individuals aged 55–77 years who have a tobacco smoking history of at least 30 pack-years and who are either currently smoking or had quit less than 15 years earlier. Commercial insurers reimburse the cost of LCS for individuals aged 55–80 years with the same smoking history. Effective care for the millions of Americans who qualify for LCS requires an organized step-wise approach. The 10-pillar model reflects the elements required to support a successful LCS program: eligibility, education, examination ordering, image acquisition, image review, communication, referral network, quality improvement, reimbursement, and research frontiers. Examination ordering can be coupled with decision support to ensure that only eligible individuals undergo LCS. Communication of results revolves around the Lung Imaging Reporting and Data System (Lung-RADS) from the American College of Radiology. Lung-RADS is a structured decision-oriented reporting system designed to minimize the rate of false-positive screening examination results. With nodule size and morphology as discriminators, Lung-RADS links nodule management pathways to the variety of nodules present on LCS CT studies. Tracking of patient outcomes is facilitated by a CMS-approved national registry maintained by the American College of Radiology.

Online supplemental material is available for this article.

Introduction

Lung cancer accounts for more deaths than any other cancer in both men and women and caused an estimated 436 deaths per day in the United States in 2014 (1). When diagnosed after symptoms occur, lung cancer is typically advanced, resulting in a dismal 5-year survival rate of 17.4% (2). Although lung cancer is one of

TEACHING POINTS

- The NLST was the first randomized controlled trial to report a significant reduction in disease-specific lung cancer mortality due to screening.
- After a USPSTF grade B recommendation was issued in December 2013 and a positive coverage decision was granted by CMS in February 2015, millions of Americans at high risk became eligible for CT lung screening with no insurance co-payment.
- In February 2015, CMS decided to cover annual LCS with low-dose CT for asymptomatic individuals aged 55–77 years with a high-risk tobacco smoking history. Specifically, reimbursement covered those with a smoking history of at least 30 pack-years (1 pack-year equals smoking one pack [20 cigarettes] per day for 1 year) who are currently smoking or who had quit less than 15 years ago.
- Clear and concise communication of screening results is central to guiding providers toward the appropriate management pathway and to minimizing unnecessary workup.
- Lung-RADS is a structured reporting system that defines what constitutes a positive screening test and links accepted nodule care pathways to the variety of nodules present on LCS images.

the top four deadliest cancers and is curable when detected at an early stage, routine screening for lung cancer has not been performed until recently. Although multiple randomized trials had been conducted, no screening test had been shown to reduce lung cancer–specific mortality until the June 2011 release of data from the landmark National Lung Cancer Screening Trial (NLST) (Fig 1) (3,4).

The NLST was the first randomized controlled trial to report a significant reduction in disease-specific lung cancer mortality due to screening. Screening was performed in 53,454 individuals aged 55–74 years at high-risk for lung cancer; screening consisted of either a baseline plus two annual low-dose helical computed tomographic (CT) scans or chest radiographs. Data gathered at 33 medical centers in the United States showed that three rounds of low-dose CT screening resulted in a 20% relative reduction in the rate of death due to lung cancer (5). The investigators reported that 320 subjects needed to undergo screening to prevent one death due to lung cancer and that 96.4% of all positive results in the low-dose CT group were false-positive (5). Despite this high false-positive rate, the NLST data prompted dozens of national societies and stakeholder groups, including the U.S. Preventive Services Task Force (USPSTF), to make CT lung screening for individuals at high risk for lung cancer a public health recommendation (6). After a USPSTF grade B recommendation was issued in December 2013 and a positive coverage decision was granted by the Centers for Medicare and Medicaid Services (CMS) in February 2015, millions of Americans at high risk became eligible for CT lung screening with no insurance co-payment (7). Fueled by these developments, the number of lung cancer screening (LCS) programs continues to increase, and millions of Americans are expected to enroll in the next 3–5 years (8–11).

Successful LCS programs are expected to provide care similar to that of the centers that participated in the NLST for safe and effective care for millions of Americans at high risk for lung cancer. Starting a LCS program requires careful organization, from patient education to follow-up, using a step-wise approach. Practice parameters issued by the American College of Radiology (ACR) in collaboration with the Society of Thoracic Radiology, and a policy statement by the American College of Chest Physicians and the American Thoracic Society, provide a basic framework while others have described their daily operations in detail (12–14).

In this article, we will describe a 10-pillar model to illustrate the elements required to support an effective LCS program: eligibility, education, examination ordering, image acquisition, image review, communication, referral network, quality improvement, reimbursement, and research frontiers (Fig 2).

The rationale for each pillar will be explained. Of note, the order of presentation does not matter; we deem each pillar to be of equal importance, because an LCS program will not succeed unless all 10 pillars are in place.

Eligibility

In February 2015, CMS decided to cover annual LCS with low-dose CT for asymptomatic individuals aged 55–77 years with a high-risk tobacco smoking history. Specifically, reimbursement covered those with a smoking history of at least 30 pack-years (1 pack-year equals smoking one pack [20 cigarettes] per day for 1 year) who are currently smoking or who had quit less than 15 years ago (7). Age 77, the maximum age limit set by CMS is 3 years below the 80-year age limit recommended by the USPSTF in December 2013 and 3 years above the 74-year age limit for NLST participants. Various specialty societies have proposed alternative eligibility criteria for annual low-dose CT lung cancer screening in an effort to extend this service to all individuals deemed to be at risk for lung cancer (Table 1) (6,15–17). It is agreed that screening should be discontinued once a person develops a health problem that substantially limits life expectancy or the ability or willingness to undergo treatment (6).

Trial Name	Study Design	Number Recruited	Characteristics of Participants				Year Started	Report Date	LC Baseline Rate (LDCT)	Stage I Cancer at Baseline/Mortality Reduction
			Age	Sex	Smoker (Pack yrs)	Ex-Smoker (yrs)				
NLST	LDCT vs. CXR	53,454	55-74	M/F	≥30	<15	2002	2011	1%	63% / 20%
NELSON	LDCT vs. UC	15,822	50-75	M/F	≥15	<10	2003	2016	0.9%	63.9%
MILD	LDCT vs. UC	4,099	≥49	M/F	>20	<10	2005	2011	0.6%	63%
DANTE	LDCT vs. UC	2,811	60-74	M	≥20	<10	2001	2007	2.2%	57%
DEPISCAN	LDCT vs. CXR	765	50-75	M/F	≥15	<15	2002	2006	2.4%	0.9%
ITALUNG	LDCT vs. UC	3,206	55-69	M/F	≥20	<10	2004	N/A	1.5%	47.6%
DLCST	LDCT vs. UC	4,104	50-70	M/F	≥20	<10	2004	2016	0.8%	58.8%
LUSI	LDCT vs. CXR	4,052	50-69	M/F	>15	<10	2007	2012	1.1%	78.2%
UKLS	LDCT vs. UC	32,000 planned	50-75	M/F	N/A	N/A	2012	N/A	N/A	N/A

LDCT = Low-Dose Computed Tomography; CXR = Chest Radiograph; LC = Lung Cancer; UC = Usual Care

Figure 1. Chart shows results of *NLST* and major European LCS trials. *DANTE* = Detection and Screening of Early Lung Cancer by Novel Imaging Technology and Molecular Essays, *DEPISCAN* = French Randomized Pilot Trial of Lung Cancer Screening Comparing Low-Dose CT Scan and Chest X-Ray, *DLCST* = Danish Lung Cancer Screening Trial, *ITALUNG* = Italian Lung Trial, *LUSI* = Lung Cancer Screening Intervention, *MILD* = Multicentric Italian Lung Detection, *NELSON* = Dutch-Belgian Randomized Lung Cancer Screening Trial, *UKLS* = U.K. Lung Cancer Screening Trial.

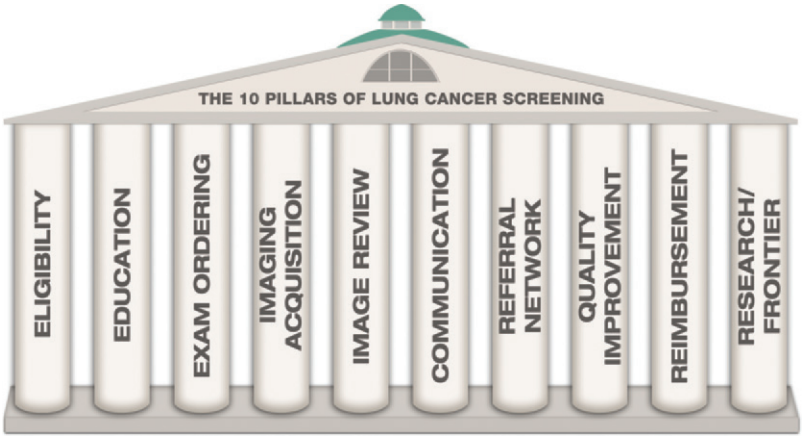


Figure 2. Diagram of the 10 pillars necessary for an effective LCS program.

Education

A successful LCS programs requires education of all stakeholders. Education of hospital leadership and administration is necessary to ensure allocation of sufficient space and financial resources for the program. Even with a low patient volume, expenses for hiring and training qualified support staff and equipping them with information technology resources to track enrolled patients through decades of screening evaluations have to be budgeted (14). Initially, the times when positron emission tomography (PET)/CT scanners are not in use could be used to perform the screening examinations without affecting the scheduling of other examinations (8). With increasing patient volume, the need for additional CT technologists, radiologists (possibly with interventional skills), and even an additional CT scanner must be evaluated (14). The workup of suspicious screening-detected pulmonary nodules

Table 1: Eligibility Criteria for Lung Cancer Screening According to CMS, USPSTF, and Various Specialty Societies

Organization	Patient Age (y), Symptoms	Smoking History (pack-years)	Other Factor(s)
CMS	55–77, asymptomatic	≥ 30	Less than 15 years since smoking cessation
USPSFT	55–80, asymptomatic	≥30	Less than15 years since smoking cessation
ACCP, ASCO, ATS, ACS, and ALS*	55–74, asymptomatic	≥30	Less than 15 years since smoking cessation
National Comprehensive Cancer Network	55–74, asymptomatic; or ≥50, asymptomatic	≥30 or ≥20	Less than 15 years since smoking cessation or one or more additional risk factor(s): pulmonary disease, family history of lung cancer, personal cancer history, radon exposure, professional exposure
American Association for Thoracic Surgery	55–79, asymptomatic; or 55–79; or 55–79, long-term cancer survivor	≥30 or ≥20 or aged 55–79 years and long-term cancer survivor	One comorbid condition producing cumulative cancer risk ≥ 5% over 5 years or aged 55–79 years and long-term cancer survivor

*ACCP = American College of Chest Physicians, ACS = American Cancer Society, ALA = American Lung Association, ASCO = American Society of Clinical Oncology, ATS = American Thoracic Society.

and incidentalomas will increase the number of patient visits for medical providers outside of the radiology department, predominantly pulmonologists and thoracic surgeons. At a national level, at least one workforce analysis predicted a possible shortage of thoracic surgeons given the expected increase in the number of operable lung cancers (18).

As far as the referral base is concerned, it is imperative to educate referring providers about the rationale and logistics of LCS through group meetings, grand rounds, and newsletters. Written resources are available online at no cost through ACR's Lung Cancer Screening Resources Web site (19). Providers at all levels need to be enabled to review and discuss the risks and benefits of LCS with their patients, because a visit centered around "counseling and shared decision making" is required by CMS before initiating lung cancer screening. An order is sufficient for follow-up examinations. In general, "shared decision making" is defined as a collaborative process during which the clinician offers options and describes the risks and benefits of each option, and the patient expresses his or her preferences and values. Each participant is "thus armed with a better understanding of the relevant factors and shares responsibility in the decision about how to proceed" (20). CMS requires that one or more decision aids similar to a tool developed by the National Cancer Institute be used to explain harms and benefits of lung cancer screening (21). Although CMS does not insist on a particular decision aid, the tool used should address the following harms: need for follow-up diagnostic testing, risk of overdiagnosis, and false-positive rate, as well as total radiation exposure. Furthermore, each patient should be counseled on the importance of adherence to annual low-dose CT screening for lung cancer and on the impact of comorbidities and ability or willingness to undergo diagnosis and treatment. CMS also requires providers to stress the importance of cigarette smoking abstinence for former smokers and of smoking cessation for current smokers and to provide tobacco cessation interventions (7).

During this visit, health care providers should ask patients to request copies of imaging studies previously performed at outside institutions so that they can be loaded onto the screening facility's picture archiving and communication system. Having prior studies available at the time of interpretation may well preclude further workup of nodules detected on CT images obtained for LCS.

To help providers navigate the above requirements of shared decision making and to facilitate referrals, it is crucial for any LCS program to create and maintain an online presence. The program Web site should provide a list of frequently asked questions for patients and health

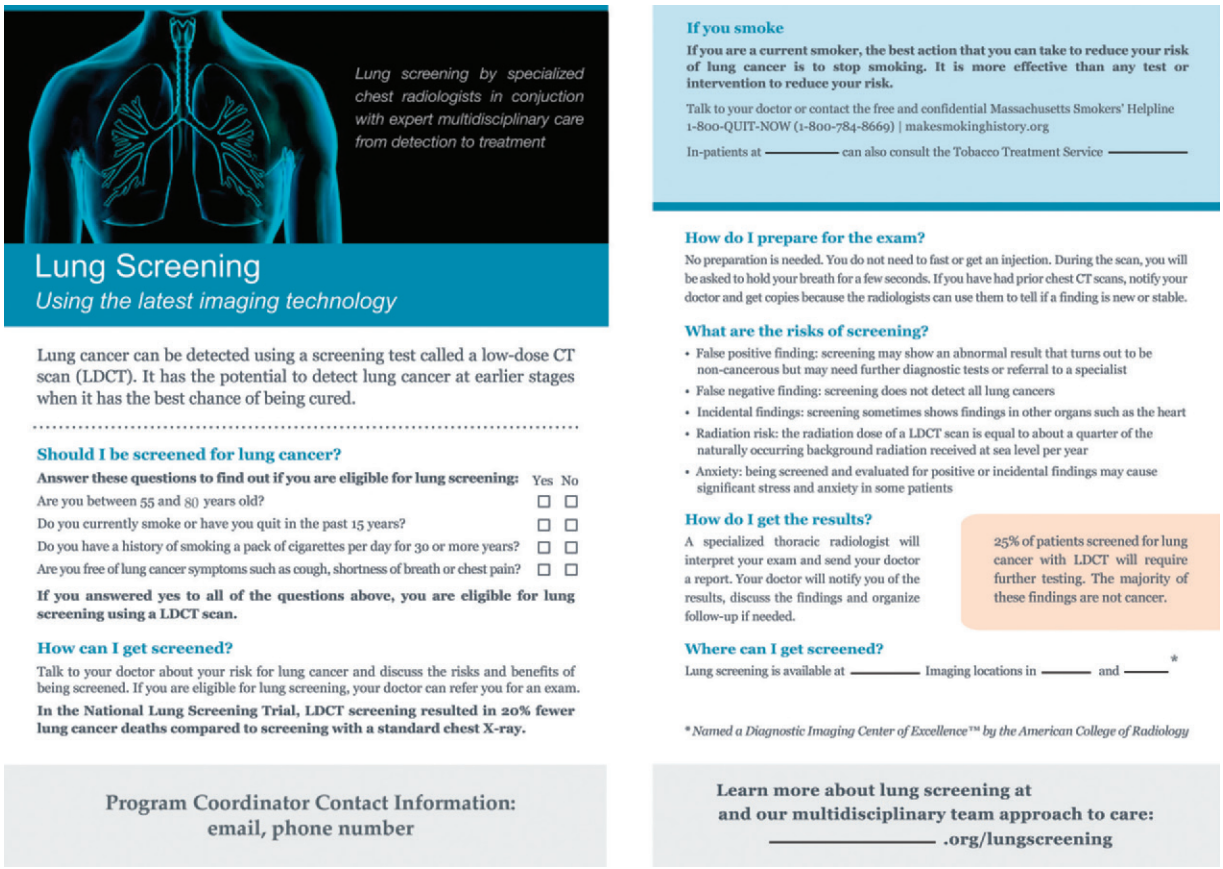


Figure 3. Part of a pamphlet designed to inform patients about LCS.

care providers, links to supporting literature and the contact information of a point person or program coordinator. In addition, educational materials need to be made available to patients. The National Comprehensive Cancer Network and the American Lung Association, among others, have excellent online resources available at no cost (22,23). Leaflets that contain information written with layperson's terminology about LCS are useful for distribution in waiting rooms, at health fairs, and at community outreach events. Such leaflets should include the following elements (Fig 3): *(a)* background information about lung cancer and lung cancer screening, *(b)* the importance of smoking cessation and resources to help quit smoking, *(c)* patient selection criteria for lung cancer screening, *(d)* the risks and benefits of lung cancer screening, *(e)* how to prepare for the examination and how often the test is performed, and *(f)* the method and timing of results communication.

Finally, radiologists need to be educated on how to interpret LCS findings and report them. In addition to publications in print, currently available continuing medical education materials include webinars from the American Roentgen Ray Society, recordings of live courses such as the "Essentials of Screening for Lung Cancer" from the Society of Thoracic Radiology and an interactive online tool created by the ACR (19).

Examination Ordering

CMS requires that the order for LCS with CT be furnished by a physician (as defined in section 1861(r)(1) of the Social Security Act) or qualified nonphysician practitioner (physician assistant, nurse practitioner, or clinical nurse specialist as defined in section 1861(aa)(5) of the Social Security Act) (7). To ensure that referring providers order LCS with CT appropriately, radiology departments can integrate eligibility criteria into the interface of their computerized provider order entry, or CPOE, system. Such decision support can take the form of a checklist detailing the eligibility criteria of either CMS (Table 2) or commercial insurance companies (Table 3), depending on a patient's insurance. Referring providers are not able to order LCS without answering all questions first. If the provided information for a given patient does not match eligibility criteria, LCS with CT cannot be ordered for that patient.

Of note, the ACR– Society of Thoracic Radiology practice parameters allow self-referred individuals at the discretion of the medical director of each facility but also emphasize that screening facilities that elect to accept self-referred patients

Table 2: Criteria for an LCS Computerized Provider Order Entry Interface for CMS Beneficiaries

Condition	Descriptor
True or false	Asymptomatic patient without signs or symptoms of lung cancer
True or false	Aged 55–77 years
True or false	Tobacco smoking history of ³30 pack-years
True or false	Currently smoking or quit within the past 15 years
True or false	Patient is willing to undergo curative treatment of lung cancer
True or false	Written order for low-dose CT from a qualified health care professional after LCS counseling and shared–decision-making visit

Table 3: Criteria for an LCS Computerized Provider Order Entry Interface Based on Commercial Insurance Company Eligibility Criteria

Condition	Descriptor
True or false	Asymptomatic patient without signs or symptoms of lung cancer
True or false	Age 55–80 years
True or false	Tobacco smoking history of ³30 pack-years
True or false	Currently smoking or quit within the past 15 years
True or false	Patient is willing to undergo curative treatment of lung cancer
True or false	Patient has experienced occupational or environmental exposure to lung carcinogens (eg, smoke, asbestos, radon)
True or false	Patient has a family history of lung cancer

Note.—Reimbursement may be possible if only one of the last two criteria is met.

must have procedures for referring them to a qualified health care provider if abnormal findings are present (12).

Image Acquisition

As detailed by the ACR–Society of Thoracic Radiology practice parameters, LCS with CT examinations should be acquired by using multidetector scanners with at least 16 detector rows, a helical technique, and with the patient in a suspended state of full inspiration (12). Intravenous contrast material is not indicated. The scan should cover from the lung apices to the costophrenic angles. Section thickness should be 2.5 mm or less, with less than 1 mm preferred, and gantry rotation should be 500 msec per rotation or faster. To maximize the risk-benefit ratio in favor of the screened individual, the radiation dose should be as low as reasonably achievable without compromising image quality. CMS has set the maximum dose threshold as a volumetric CT dose index of 3 mGy for a standard-sized patient (height, 5 feet 7 inches [170 cm]; weight, 155 pounds [69.75 kg]) with "appropriate dose reduction" for smaller patients and an appropriate increase for larger patients (7). Sample low-dose protocols for a variety of manufacturers are available online at no cost through a Web site maintained by the American Association of Physicists in Medicine (24).

Image Review

Only physicians with documented training in diagnostic radiology and radiation safety can review LCS CT examinations and claim reimbursement from CMS. Interpreting physicians need to be board certified or eligible for board certification by the American Board of Radiology or an equivalent organization. Additional criteria for reimbursement include participation in continuing medical education and involvement in the supervision or interpretation of at least 300 chest CT cases in the preceding 36 months (Table 4) (7).

Images should be reviewed on a picture archiving and communication system workstation. The goal is to detect signs of early lung cancer such as pulmonary nodules and to not miss potentially important incidental findings. Nodule detection is facilitated by using maximum intensity projection reconstructions (25). All nodules should be characterized on contiguous axial thin-section images as either solid, partly solid, ground glass, or calcified. It is imperative to compare all depicted nodules with the findings from the baseline screening examination and any

Table 4: Interpreting-Physician Criteria for CMS Reimbursement

Interpreting-Physician Criterion	Detailed Description
Board certification	Board certified or eligible with American Board of Radiology (or equivalent organization)
Training	Documented training in diagnostic radiology and radiation safety
Experience	Involved in supervision and interpretation of at least 300 chest CT studies in the past 3 years
Continuing education	Participation in continuing medical education according to ACR standards

CT scan of the chest WITHOUT intravenous contrast, using low dose lung cancer screening protocol.

COMPARISON: None

FINDINGS:
Lines/tubes: None.

Lungs and Airways: The lungs and airways are normal with no focal abnormality demonstrated.

Pleura: The pleural spaces are clear.

Base of neck, mediastinum and heart: The thyroid gland is normal. No mediastinal, hilar or axillary lymphadenopathy is seen. The heart and pericardium are within normal limits.

Soft tissues: Normal.

Abdomen: This study was performed without contrast and with lower than standard dose. These factors reduce the sensitivity for detection of small lesions in the upper abdomen. Given these technical limitations, no focal lesion is seen within the visualized liver, spleen, pancreas, kidneys and adrenal glands.

Bones: The visualized bony thorax is within normal limits.

IMPRESSION: No pulmonary nodules are identified.

Lung-RADS Category: 1 - Negative
Explanation of the Lung-RADS categories can be found at:
http://www.acr.org/~/media/ACR/Documents/PDF/QualitySafety/Resources/LungRADS/AssessmentCategories

RECOMMENDATION: Continue annual screening with low-dose Chest CT in 12 months

This report has been forwarded to an automated communication system that will electronically notify appropriate providers of potentially important findings.

Figure 4. Template for structured report of a Lung-RADS category 1 LCS CT examination.

preexisting imaging studies to assess change over time. Nodules should be measured in the axial plane with the use of lung window settings. Nodule diameter is calculated by taking the average of the longest and shortest diameter, rounded to the nearest whole number. If available, computer-assisted detection of nodules and volumetric assessment to determine growth should be used (12). When applied to LCS CT, computer-aided detection has been shown to decrease interreader variability in nodule detection and classification (26). Automated volume measurement is a means to assess the malignant potential of pulmonary nodules (27,28). In the Dutch-Belgian Randomized Lung Cancer Screening Trial, or NELSON, a volume increase of at least 25% after an interval of at least 3 months was found to be a reliable indicator of growth (29). Work is underway to address the known limitations of computer-aided detection with regard to the detection of nonsolid pulmonary nodules (30–32).

Any finding other than those that are suspicious for lung cancer and that requires clinical or imaging evaluation before the next scheduled LCS examination could be important. In the NLST, the overall rate of such nontarget clinically important findings was 7.5%, with a rate of 10.2% at baseline screening (5). Examples of nontarget clinically important findings include chronic obstructive pulmonary disease; atherosclerosis; aneurysm; osteopenia; and indeterminate breast, liver, kidney, and adrenal lesions (8).

Communication

Clear and concise communication of screening results is central to guiding providers toward the appropriate management pathway and to minimizing unnecessary workup. To this end, structured reporting has been recommended to inform the referring provider, the patient, and those physicians specialized in lung nodule management of findings from LCS examinations (12,13). Advantages of structured reporting include uniform reporting, facilitated comparison with previous studies, enhanced data-mining capability, triage of risk categories, and identification of patients with suspicious findings who require multidisciplinary team care (12). A structured report refers to predefined content organization. For the purpose of LCS, the report should contain the following items: technique, comparison date, description of findings, impression, Lung Imaging Reporting and Data System (Lung-RADS) category and specific management recommendation (Fig 4).

In the findings section, the following descriptors should be provided for each nodule: location (lobe, segment, with series or image number); size, determined on lung window images and reported as the average diameter rounded to the nearest whole number; attenuation (soft tissue, type of calcification, fat); morphology (solid, nonsolid [also known as ground glass] and part solid [containing both solid and nonsolid components]); margins (smooth, lobulated, spiculated) (8). Any interval change should be

a. b.

Figure 5. **(a)** Axial LCS chest CT image (lung window) in a 77-year-old man shows a solid nodule in the right lower lobe. The average of the longest and shortest axial diameters (*A* and *B,* respectively) is 20 mm. **(b)** Axial CT image (mediastinal window) shows fat (–77.5 HU) in the nodule, compatible with a hamartoma. Despite the large size of the nodule, its benign characteristics make this a Lung-RADS category 1 lesion. Appropriate management is to resume annual screening with low-dose CT in 12 months. *Dev* = deviation.

addressed in comparison with the findings from previous examinations, with particular attention to those from the baseline study. Lung-RADS defines growth as a greater than 1.5-mm increase in size to account for known interreader variability (33,34).

Lung-RADS is a structured reporting system that defines what constitutes a positive screening test and links accepted nodule care pathways to the variety of nodules present on LCS images (34). Inspired by the well-established Breast Imaging Reporting and Data System, Lung-RADS was designed as a decision-oriented reporting system that serves as a shorthand language that the multidisciplinary care team members can use to discuss the nature and downstream implications of imaging findings (14). The ACR released the current and first version in April 2014 (Fig E1 [online].

The Lung-RADS assessment category for each LCS examination is an alphanumeric score composed of two parts: category (part 1) plus modifier (part 2). Part 1 classifies nodules into categories 0–4 on the basis of morphology and size. Part 2 addresses findings other than nodules and uses the modifiers X, C, and S.

Category 0 indicates that information is incomplete owing to suboptimal technique or because one is awaiting prior studies for comparison. Category 1 is reserved for studies that show no nodules or definitely benign nodules with benign calcification patterns or fat. The probability of malignancy for category 1 nodules is less than 1%. From a management perspective, studies assigned to category 1 are deemed negative and trigger annual follow-up low-dose CT in 12 months (Fig 5).

Nodules that are not definitely benign are classified in categories 2, 3, 4A, or 4B, depending on their morphology (solid, partly solid, or nonsolid) and size. Nodule morphology allows prediction of the likelihood of malignancy because pure ground-glass nodules are known to be less likely to represent malignancy than are solid nodules of the same size (35). Endobronchial nodules are classified as category 4A regardless of their size. The NLST investigators registered any nodule larger than 4 mm as a positive screening result and documented a very high rate of false-positives. To reduce the rate of false-positives and the associated unnecessary workup, Lung-RADS was designed with a variable size threshold that is dependent on nodule morphology (36). It does not matter whether a nodule is perifissural or not.

Category 2 nodules have a benign appearance or behavior. The probability of malignancy for category 2 nodules is less than 1%. For example, a solid nodule measuring up to 6 mm and a nonsolid nodule measuring up to 20 mm identified on baseline screening low-dose CT images are classified in category 2 (Figs 6, 7). From a management perspective, examinations in category 2 trigger annual follow-up low-dose CT in 12 months. Presence of a category 2 nodule does not exclude lung cancer, however (Fig 8).

Category 3 indicates that a nodule is probably benign, with a 1%–2% probability that it will become clinically active cancer. From a management perspective, an assignment to category 3 triggers follow-up low-dose CT in 6 months.

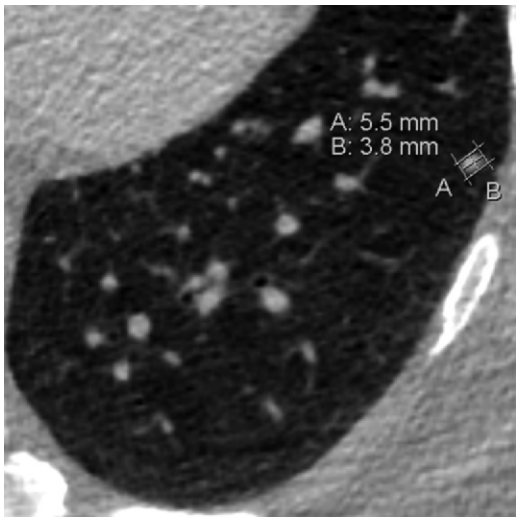


Figure 6. Axial LCS chest CT image (lung window) in a 59-year-old man shows a solid nodule in the left lower lobe. The average of the longest and shortest axial diameters (*A* and *B*) rounded to the nearest whole number is 5 mm. This is a Lung-RADS category 2 lesion. Appropriate management is to continue annual screening with low-dose CT in 12 months.

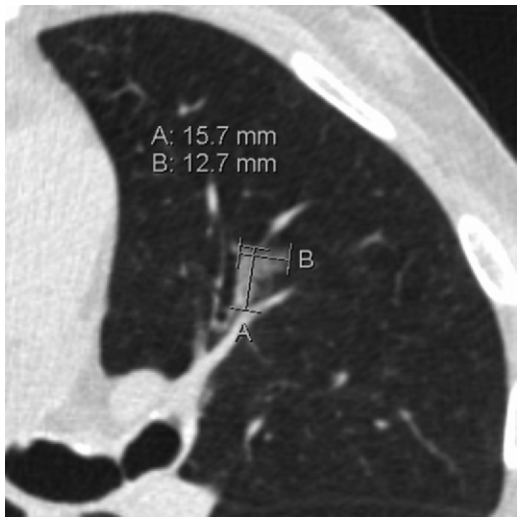
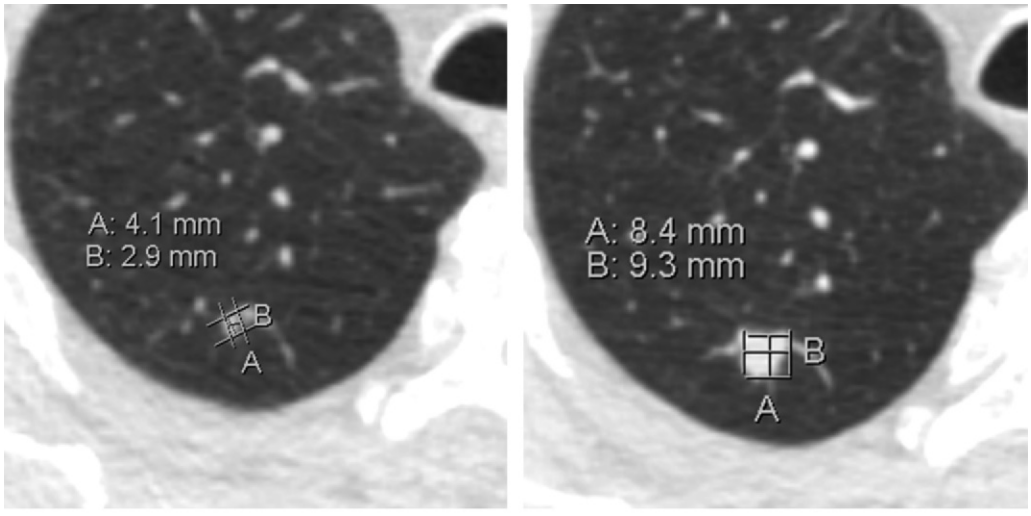


Figure 7. Axial LCS chest CT image (lung window) in a 61-year-old man shows a lingular nonsolid (ground-glass) nodule. The average of the longest and shortest axial diameters (*A* and *B*) rounded to the nearest whole number is 14 mm. This is a Lung-RADS category 2 lesion. Appropriate management is to continue annual screening with low-dose CT in 12 months.



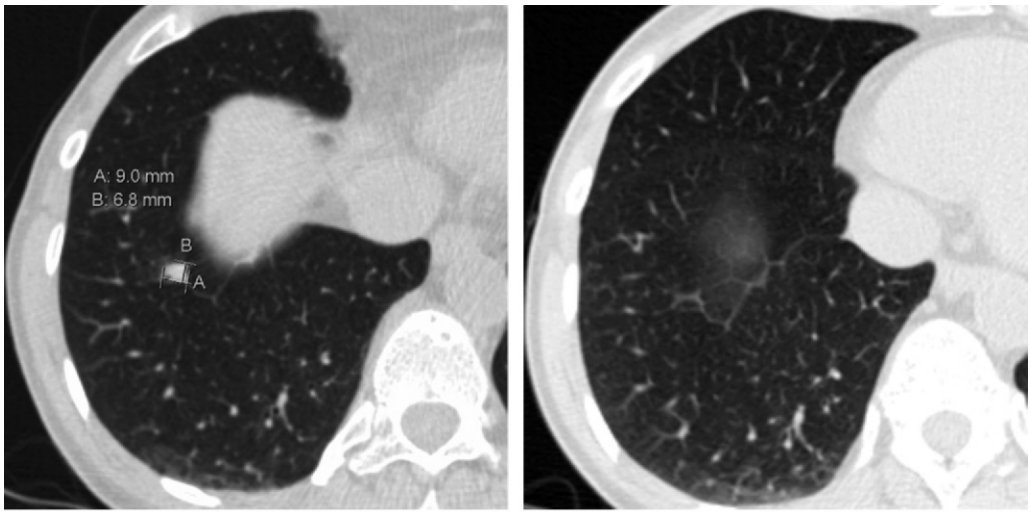
a. **b.**

Figure 8. Axial LCS chest CT images in a 66-year-old man. **(a)** Lung window image shows a solid nodule in the right upper lobe. The average of the longest and shortest axial diameters (*A* and *B*) rounded to the nearest whole number is 4 mm. This is a Lung-RADS category 2 lesion. Appropriate management is to follow-up in 12 months with low-dose CT. **(b)** At 12-month follow-up low-dose CT, the nodule had grown to 9 mm. Because of the interval growth, this lesion was reclassified as a Lung-RADS category 4B lesion. Resection revealed adenocarcinoma.

Category 4 indicates that a nodule is suspicious for malignancy. Increases in the probability of malignancy are expressed by assigning either subcategory, 4A (5%–15%) or 4B (>15%). Management includes additional diagnostic testing with low-dose CT in 3 months, contrast material–enhanced CT, PET/CT, and/or tissue sampling (Fig 9).

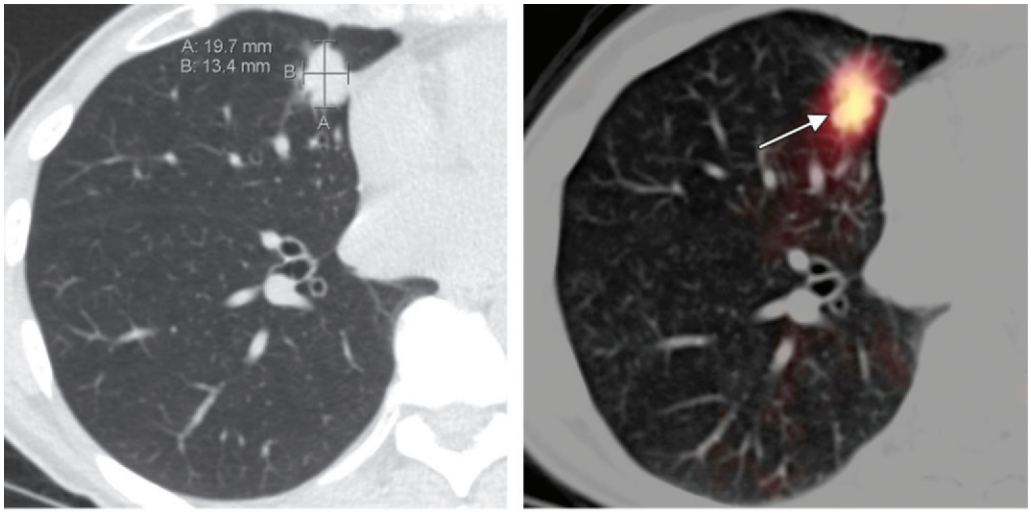
The three modifiers—X, C, and S—can be added to the category if findings other than nodules are present. The category number plus the modifier generates the overall Lung-RADS assessment score.

The X modifier indicates that additional findings or imaging features such as spiculation, a rapidly enlarging ground-glass nodule with a doubling time of less than 1 year, or enlarged lymph nodes increase the suspicion that a nodule in category 3 or 4 represents a lung cancer (Fig 10). Addition of the X modifier changes the assessment score to

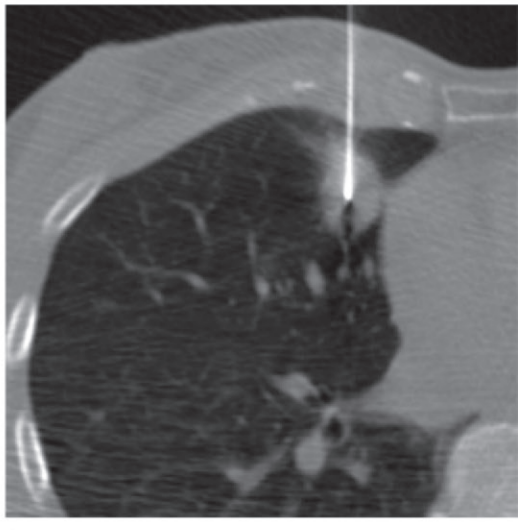


a. b.

Figure 9. **(a)** Axial LCS chest CT image (lung window) in a 65-year-old woman demonstrates a solid nodule in the right lower lobe. The average of longest *(A)* and shortest *(B)* axial diameters rounded to the nearest whole number is 8 mm, which makes this a Lung-RADS category 4A lesion. Spiculated margins increase the suspicion for lung cancer and changes the Lung-RADS category to 4X. Follow-up with CT in 3 months was recommended. **(b)** At follow-up, the nodule had resolved and was therefore inflammatory. The next appropriate step is to resume annual low-dose CT screening in 12 months.



a. b.



c.

Figure 10. **(a)** Axial LCS chest CT image (lung window)in a 57-year-old woman shows a solid spiculated nodule in the right middle lobe. The average of the longest *(A)* and shortest *(B)* axial diameters rounded to the nearest whole number is 17 mm, which makes this a Lung-RADS category 4B lesion. Spiculation further increases the probability of malignancy and changes the Lung-RADS category to 4X. **(b)** Axial PET/CT image demonstrated FDG avidity (arrow), and **(c)** CT-guided percutaneous tissue sampling revealed squamous cell carcinoma.

Figure 11. Axial LCS chest CT image in a 68-year-old man shows an incompletely imaged abdominal aortic aneurysm (arrow) measuring up to 4 cm in diameter. In the absence of additional findings, this is a negative LCS result, with an S modifier: Lung-RADS category 1S. Appropriate management is evaluation with contrast-enhanced CT or magnetic resonance imaging of the abdomen, depending on renal function and local expertise. Annual lung screening with low-dose CT should resume in 12 months.

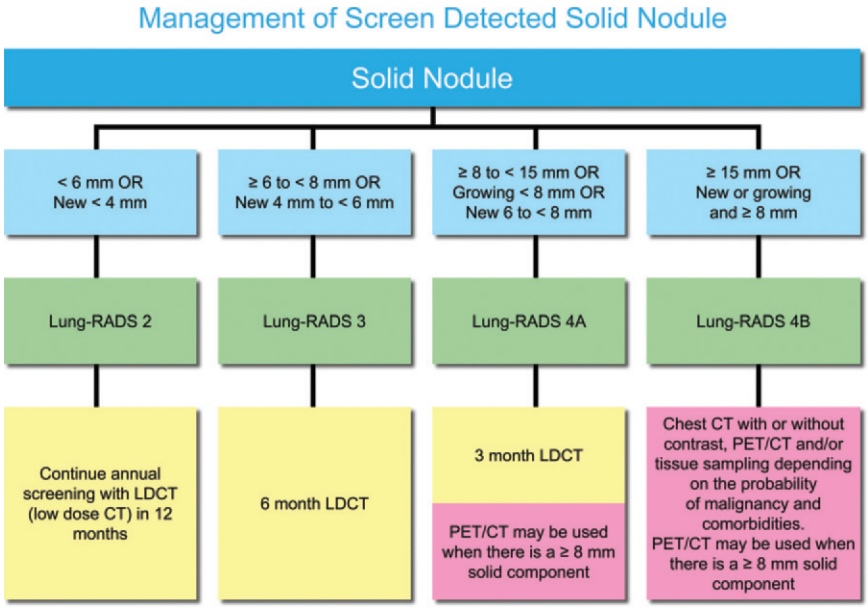


Figure 12. Flowchart outlines the management of solid pulmonary nodules detected at screening, per Lung-RADS version 1.0. *LDCT* = low-dose CT. (Refer to the Lung-RADS Web site at *http://www.acr.org/QualitySafety/Resources/LungRADS* for the most current information.)

4X, which indicates a probability of malignancy higher than 15%. Management is the same as that for category 4B lesions: additional diagnostic testing with contrast-enhanced CT, PET/CT, and/or tissue sampling.

The modifier C indicates that a patient has had lung cancer in the past; it can be added to any category. Modifier S indicates that potentially important findings other than lung cancer are present on the examination images and can be added to any category (Fig 11).

The most suspicious nodule determines the classification of each LCS examination and the specific management recommendation, which need to be stated at the end of each report (Fig 4). Flowcharts derived from the Lung-RADS assessment categories facilitate retrieval of the specific management recommendation for solid (Fig 12), part-solid (Fig 13), and nonsolid (Fig 14) nodules of various sizes.

Some recommend a conversation with the patient after each examination to review the findings (37). We notify the referring provider by sending an e-mail once the report is finalized and available in the patient's electronic medical record (Fig 4). Category 4 and some category 3 nodules trigger direct physician-to-physician communication. Our institution allows patients to access their reports via an electronic patient portal after a 2-week delay, if they so desire. In addition, we send a letter to each patient to make him or her aware of follow-up and treatment recommendations (Fig 15). A number of commercially available software tools are available to help generate result notification letters, among other functions.

Referral Network

The referral network of a facility engaged in LCS needs to provide smoking cessation support, as well as access to clinicians with expertise in the management of lung nodules and the treatment of lung cancer.

Smoking cessation support to all current smokers confers a substantial lung cancer risk reduction and increases the cost-effectiveness of screening by 20%–45% (38). Integrating smoking cessation interventions into the daily

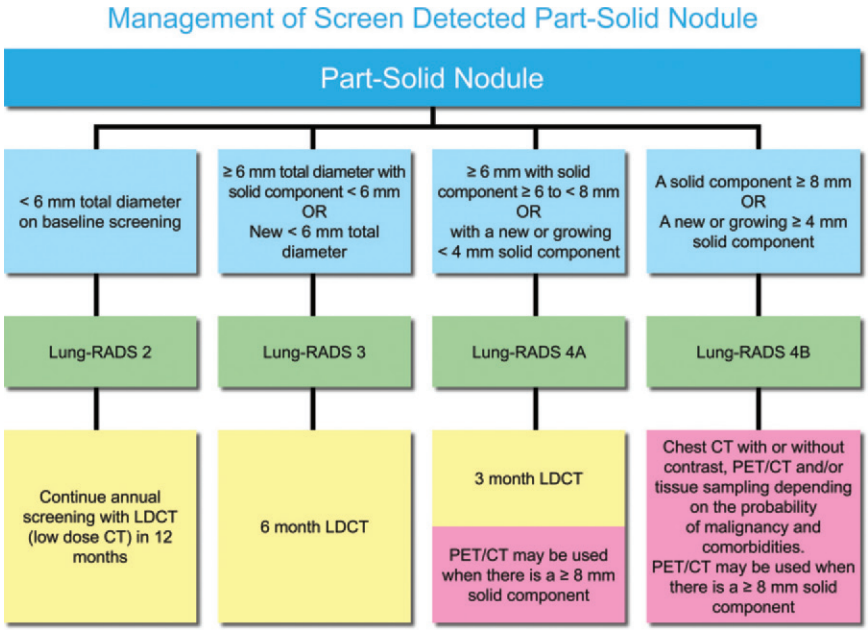


Figure 13. Flowchart outlines the management of part-solid pulmonary nodules detected at screening, per Lung-RADS version 1.0. *LDCT* = low-dose CT. (Refer to the Lung-RADS Web site at *http://www.acr.org/QualitySafety/Resources/LungRADS* for the most current information.)

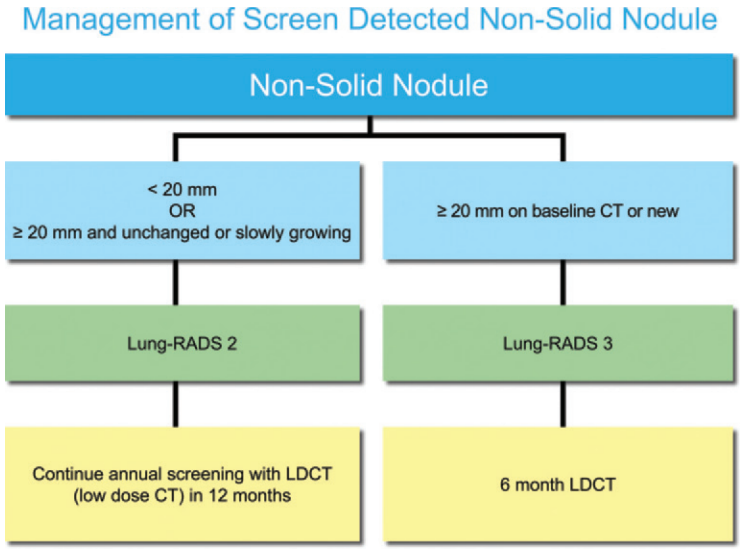


Figure 14. Flowchart outlines the management of nonsolid pulmonary nodules detected at screening, per Lung-RADS version 1.0. *LDCT* = low-dose CT. (Refer to the Lung-RADS Web site at *http://www.acr.org/QualitySafety/Resources/LungRADS* for the most current information.)

operations of an LCS program creates numerous opportunities for program staff (scheduler, technologist, physician) to deliver and reinforce the message throughout the course of screening (14). Local smoking cessation resources can be supplemented with material available on Web sites maintained by the Centers for Disease Control and Prevention, American Cancer Society, American Lung Association, and National Comprehensive Cancer Network (39–42).

A "patient navigator" is a critical link between patients, referring providers, and clinicians with expertise in the management of lung nodules (Fig 16). The patient navigator could be a midlevel provider such as a physician assistant or nurse practitioner working under the supervision of a physician in the department of radiology, radiation oncology, medicine, or surgery. The role of the navigator is to ensure that referring providers adhere to the follow-up recommendations stated in the radiology report and that patients connect with the clinical management team, if needed. By guiding referring providers and patients toward the appropriate nodule-management pathway, unnecessary diagnostic testing and procedures, as well as procedure-related complications, can be prevented. A robust tracking system should be implemented

[TODAY]

[PATIENT_ADDRESS]

Exam date: [EXAM_DATE]

RE: Your low-dose screening chest CT scan done on:

Interpreted by:

Report sent to:

Dear [PATIENT_SALUTATION],

We are pleased to inform you that the results of your recent low dose chest CT showed no signs of lung cancer.

Your full report, including any minor observations, has been sent to your health care provider. Your exam report and images will be kept on file as part of your permanent record and are available for your continuing care.

As you know, early detection of cancer is very important. Although low dose chest CT is very effective at finding lung cancers early, it cannot find all lung cancers. Any new symptoms such as shortness of breath or chest pain should always be reported to your health care provider regardless of your chest CT findings.

Please keep in mind that good health involves quitting smoking, an annual physical exam and continued screening with low dose chest CT. Current American Cancer Society Guidelines recommend screening Chest CT for high risk patients between 55 to 80 years and in fairly good health, have a smoking history equivalent to a pack a day for 30 years, and currently smoke or have quit within the past 15 years

The date of your next low dose-screening exam should be in [month/year].

If you have any questions or have difficulty in contacting your health care provider please call____

Sincerely,

[SITE_NAME_ONLY]

Figure 15. Template for a patient notification letter.

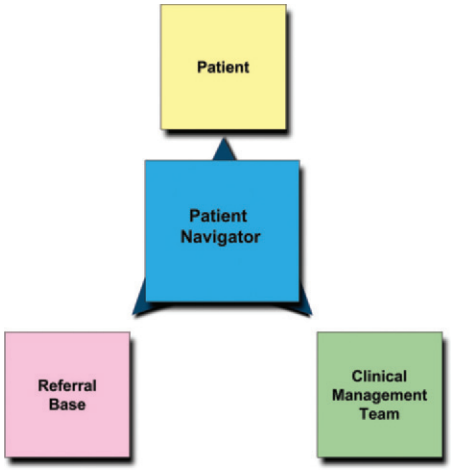


Figure 16. Illustration shows the central role of the patient navigator in the management of imaging findings from screening.

to facilitate this task. McKee et al (14) describe how a relational database with access to the radiology information system greatly facilitates the task of following thousands of patients for years and how notification letters are sent to patients and providers in case of noncompliance. There are a number of commercially available software tools to help manage patient flow.

The decision regarding when to involve physicians experienced in the management of pulmonary nodules depends on personal preference. One approach would be to refer patients with Lung-RADS category 4 nodules to a multidisciplinary group of experts for evaluation and decision making. Having such "actionable nodules" managed jointly by pulmonologists, thoracic surgeons, medical oncologists, and radiation oncologists would create conditions similar to the care provided at the mainly academic and tertiary care centers that participated in the NLST. Our institution operates a multidisciplinary Pulmonary Nodule Clinic that establishes a comprehensive management plan in a single visit. Before the clinic visit, a thoracic radiologist reviews all imaging studies together with a multidisciplinary group that includes representatives from interventional radiology, pulmonology, thoracic surgery, medical oncology, and radiation oncology. The group formulates a management plan with input from all subspecialties, and this plan is discussed with the patient during the same visit.

Quality Improvement

CMS requires that outcomes of screened patients be followed locally and nationally to generate data for benchmarking (7). Among other parameters, smoking history, radiation dose, and downstream care, including interventions and their complications, will need to be tracked. To this end, the ACR has developed the Lung Cancer Screening Registry, which has already been approved by CMS. The registry opened for registration in May 2015 and data may be submitted retroactively on examinations performed on or after January 1, 2015 (43). The ACR recommends that facilities

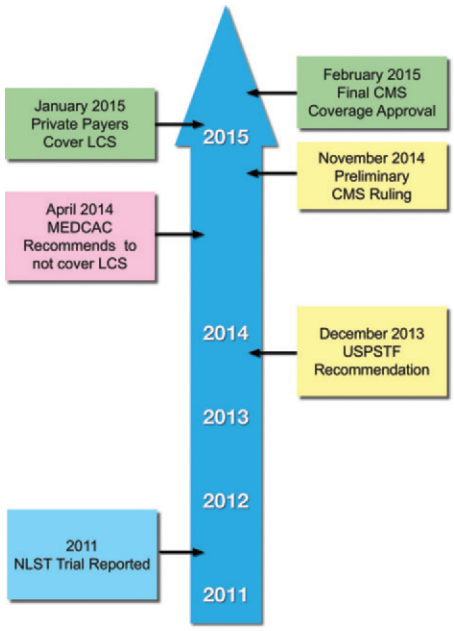


Figure 17. Timeline of milestones leading up to CMS approval for LCS reimbursement. *MEDCAC* = Medicare Evidence Development and Coverage Advisory Committee.

inquire with the electronic health record vendor and the reporting vendor to determine if they can support data submission to the ACR Lung Cancer Screening Registry.

Although not currently required by CMS for reimbursement, any facility engaged in LCS should consider becoming accredited by ACR as a Designated Lung Cancer Screening Center (44). Accreditation criteria include the need for imaging equipment to meet ACR practice parameters and technical standards but overall are less stringent than CMS reimbursement criteria. More information and the application form are available through ACR (45).

Reimbursement

With a level B recommendation by the USPSTF in place since December 2013, commercial payers are required to cover LCS for patients meeting the USPSTF eligibility criteria (see Table 1) without cost sharing (deductible, copay, or coinsurance) starting January 2015 under section 2713 of the Patient Protection and Affordable Care Act (46). CMS ruled to cover LCS for a subset of its beneficiaries on February 5, 2015, despite a recommendation of its advisory committee to the contrary (Fig 17) (47).

CMS reimbursement hinges on a set of criteria that have been outlined throughout this manuscript and are summarized in the following three tables according to conditions radiologists (Table 4), patients (Table 5), and facilities (Table 6) need to meet.

Table 5: Patient Criteria for CMS Reimbursement

Patient Criterion	Detailed Description
Age (y)	55–77
Clinical symptoms	No signs or symptoms of lung cancer
Smoking history (pack-years)	At least 30
Smoking status	Current smoker or quit within last 15 years
LCS order	Written order for low-dose CT LCS obtained during an LCS counseling and shared–decision-making visit

Table 6: Imaging Facility Criteria for CMS Reimbursement

Facility Criterion	Description
Radiation dose	$CTDI_{vol} \leq 3$ mGy for standard-sized patient and appropriate reduction in $CTDI_{vol}$ for smaller patients and appropriate increase in $CTDI_{vol}$ for larger patients*
Reporting	Uses standardized lung nodule identification, classification, and reporting system
Smoking cessation	Smoking cessation interventions available for current smokers
National registry	Collect and submit specific data elements to CMS-approved national registry for each low-dose CT LCS examination provided

*$CTDI_{vol}$ = volumetric CT dose index.

Additional options are to offer LCS without charge (ie, for free). The choice will depend on which business model works best for a given facility, as has been discussed by others (8).

Research Frontiers

In PubMed, the search term "lung cancer screening" returned 8141 entries for 2013 and 6396 entries for 2014 (48). Despite this apparent decrease in LCS-related publications, many questions remain unanswered and continued research is needed.

The optimal interval between screening examinations, the duration of screening, and optimal nodule-management algorithms remain subjects of ongoing investigation. Nonsolid (ground-glass nodules), in particular, seem to represent indolent cancers subject to overdiagnosis (49). The size thresholds used in Lung-RADS version 1.0 continue to undergo evaluation with the goal to

further reduce the rate of false-positives while maintaining sensitivity (36,50). Risk stratification of screening-detected pulmonary nodules by using imaging features such as upper lobe location and spiculation in addition to nodule size and morphology has been described by McWilliams et al (35). Their model. referred to as *PLCO (M2012)* because it was validated on the basis of the Prostate, Lung, Colorectal, and Ovarian—or PLCO—cancer screening trial, appeared to decrease false-positives and increase sensitivity when applied to NLST data (51). Risk stratification is also being attempted by using serum biomarkers. In particular, circulating tumor cells, exosomal microRNA, free circulating DNA, and telomerase have shown promising results (52,53). Advances in the areas of computer-assisted detection of nodules and volumetric nodule measurement to assess for interval growth show the potential of this technology to greatly increase throughput and accuracy of LCS programs (27). Radiation dose reduction is important to minimize patient risk from cumulative radiation exposure, and submillisievert techniques are in development (54). In addition, educational programs are needed for radiologists to ensure that patients receive the same standard of care wherever they choose to be screened.

Conclusion

Interest in LCS continues to increase, stimulated by the substantial reduction in disease-specific mortality demonstrated by NLST. Successful implementation of an LCS program requires careful organization, collaboration with all stakeholders, adherence to societal guidelines, and continuous quality control to ensure proper patient care and follow-up as outlined by the 10 pillars.

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