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Components Necessary for High Quality Lung Cancer Screening: American College of Chest Physicians and American Thoracic Society Policy Statement

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Abstract

Lung cancer screening with a low dose chest CT scan can result in more benefit than harm when performed in settings committed to developing and maintaining high quality programs. This project aimed to identify the components of screening that should be a part of all lung cancer screening programs. To do so, committees with expertise in lung cancer screening were assembled by the Thoracic Oncology Network of the ACCP and the Thoracic Oncology Assembly of the ATS. Lung cancer program components were derived from evidence-based reviews of lung cancer screening, and supplemented by expert opinion. This statement was developed and modified based on iterative feedback of the committees. Nine essential components of a lung cancer screening program were identified. Within these components twenty one Policy Statements were developed and translated into criteria that could be used to assess the qualification of a program as a screening facility. Two additional Policy Statements related to the need for multi-society governance of lung cancer screening were developed. High quality lung cancer screening programs can be developed within the presented framework of nine essential program components outlined by our committees. This document has been formally endorsed by several professional organizations (ACCP, ATS, American Association of Thoracic Surgery, American Cancer Society, American Society of Preventive Oncology).

Introduction

We believe that, when performed in an appropriate patient population in settings committed to quality, lung cancer screening with low dose CT (LDCT) will result in more benefit than harm. The benefits and harms of lung cancer screening depend on a complex interplay of multiple factors. Lung cancer screening is not solely an imaging test, it is a process that should take place within an organized program. In the text that follows we outline the components of lung cancer screening programs that can influence the balance of benefit and harms. We briefly review the evidence base and considerations for each program component, list Policy Statements for each component, and provide criteria that could be applied to qualify a program as a lung cancer screening facility. Within each component reducing harm may impact the potential benefit and vice versa. The purpose of this document is to provide guidance for policy development by relevant stakeholders who will play an important role in lung cancer screening implementation. There remain opportunities for continued study in order to optimize the outcomes of lung cancer screening.

Methods

Committees with expertise in lung cancer screening were assembled by the Thoracic Oncology Network of the ACCP and the Thoracic Oncology Assembly of the ATS. Participants included Pulmonolgists, Thoracic Surgeons, a Chest Radiologist, and Health Services Policy experts with expertise in lung cancer CT screening as identified by their publications and involvement in professional societies. The committees reviewed evidence-based guidelines related to lung cancer screening including a combined review from the ACCP, ATS, and ASCO (1), a separate review from the ACCP (2), and the statement from the USPSTF (3). Particular focus was given to the areas of these documents discussing implementation challenges. This review was supplemented by the experience of the committee members to develop a list of components of a lung cancer screening program that are capable of influencing the balance of benefit to harm.

The evidence related to each component was summarized and Policy Statements were developed based on the evidence. Consensus about the component descriptions and Policy Statements was achieved through incorporation of the iterative written and verbal feedback of the committees. Two quality metrics were developed based on our expert committee's consensus that the metrics are valid, feasible, and relevant. The statement was developed, reviewed and formally approved by the leadership of the ACCP, and ATS. It was subsequently endorsed by the American Association of Thoracic Surgery, American Cancer Society, and the American Society of Preventive Oncology. All elements of the final draft were unanimously accepted by all authors and endorsed by all sponsoring Societies.

Results

Component 1: Who is offered lung cancer screening

The principal question is how do lung cancer screening programs identify a group at high enough risk of developing lung cancer to benefit more than they are harmed. The balance with this choice is that more lives can be saved by screening at lower thresholds of risk, but the relative harms of screening increase as the threshold is lowered. It is difficult to determine the ideal balance of benefit and harm as the value of the benefit and harms is not equal, and varies with patient preferences.

The only group in which lung cancer screening has direct evidence of a proven benefit is the National Lung Screening Trial (NLST) cohort (4). Based on the results of computer models of screening performed by CISNET for the AHRQ (5), the USPSTF extended the age limit for screening from 74 to 80 in its recommendations (3). Even within the NLST cohort, there is a wide range of risk for developing lung cancer, and thus a wide range of the benefit to harm balance that can be expected (6) (Table 1).

Multiple models exist to help estimate the risk of developing lung cancer (7-11) (Table 2). One model, PLCO 2012, was validated in comparison to the NLST criteria, showing marginally improved sensitivity with similar specificity for identifying patients with lung cancer (9). At this time, it is not clear that obtaining an equal risk through different risk factors equates to equal benefit from lung cancer screening.

Over the next several years, ongoing randomized controlled trials of different study design could inform us about the potential balance of benefit and harm in populations with lower and higher risk than those included in the NLST.

USPSTF Recommendation[3]:
Screening for lung cancer with low-dose computed tomography (LDCT) in adults aged 55 to 80 years who have a 30 pack-year smoking history and currently smoke or have quit within the past 15 years. Screening may not be appropriate for patients with substantial comorbid conditions, particularly those who are in the upper end of the screening age range.

Policy Statement:

1. Lung cancer screening programs should collect data on all enrolled subjects related to the risk of developing lung cancer.

For Qualification as a Lung Cancer Screening Facility:

1. The lung cancer screening program must confirm that there is a policy about who will be offered screening that is in keeping with the USPSTF recommendation.

2. At least 90% of all screened subjects must match the program's stated policy, excluding those enrolled in clinical trials.gov registered NIH, CDC, AHRQ, CMS, DOD, VA, and PCORI funded screening research protocols.

Future Research: The role of currently available, or newly developed, clinical predictors of the risk of developing and/or dying from lung cancer requires further study. The role of molecular biomarkers of risk and/or early detection requires further study.

Component 2: How often, and for how long, to screen

The principal question is whether the benefit seen in the NLST would be modified by screening for longer periods or at different intervals than were used in the NLST. The tradeoff with this choice is that the reduction in harm will lead to a reduction in the number of lung cancer deaths avoided.

Due to the expense and impracticality of performing a controlled trial lasting throughout the period of high risk (20-25 years) this question may never have direct evidence to inform its' answer. The NLST showed an equal number of stage I lung cancers during each incidence screening round, and a slight narrowing of the cumulative incidence gap during the observation period (4). This suggests that additional years of screening could have added to the benefit. Other controlled trials of variable design have found similar portions of early and late stage cancers regardless of design (12). The modeling performed for the USPSTF found maximal benefit, and the greatest efficiency, in the models that incorporated annual screening (to age 80) (5) (Figure 1).

USPSTF Recommendation[3]:

1. Annual screening until age 80.
2. Screening should be discontinued once a person has not smoked for 15 years or develops a health problem that substantially limits life expectancy or the ability or willingness to have curative lung surgery.

For Qualification as a Lung Cancer Screening Facility:

1. The lung cancer screening program must confirm that there is a policy about the frequency and duration of screening that is in keeping with the USPSTF recommendation.

Future Research: Tools should be developed to assess life expectancy based on age and comorbidities, to provide a quantifiable reason to exclude patients who are unlikely to benefit from lung cancer screening because they are at too high a risk of dying of another cause.

Component 3: How the CT is performed

This component refers to a program's ability to ensure performance of the CT with reduced dose techniques similar to those used in the NLST. The American College of Radiology (ACR) and Society of Thoracic Radiology (STR) have developed technical specifications for the performance of a LDCT (13) (Table 1S).

Policy Statements:

1. A low dose lung cancer screening CT should be performed based on the ACR-STR technical specifications.

2. A lung cancer screening program should collect data to ensure the mean radiation dose is in compliance with ACR-STR recommendations.

For Qualification as a Lung Cancer Screening Facility:

1. The lung cancer screening program must confirm that there is a policy about the technical specifications for performing low dose CT screening that is in keeping with the ACR-STR technical specifications and credentialing criteria.

Future Research: Evaluation of new CT scanner algorithms and ultra-low dose imaging techniques to assess the impact of reducing harm from radiation exposure on nodule detection rates.

Component 4: Lung nodule identification

The principal question is what nodule size threshold should be used to label the screen as positive. The balance with this choice is that a lower threshold will lead to fewer lung cancers being missed but will increase the false positive rate.

The NLST and other screening trials have shown that the majority of the nodules identified are solid and 5 mm in diameter or smaller. These very small nodules have a very low probability of being malignant (14,15). Based on current nodule management guidelines, most of these nodules can be safely monitored at the time of the annual screening CT. In the NLST, raising the size threshold from 4 to 7 mm would have decreased the number of nodules identified by more than 50% and would have resulted in approximately 7% of the cancer diagnoses being delayed (14,15) (Table 3).

In well-supported controlled trials of CT screening there are subjects who are not adherent with their annual screen or are lost to follow-up (Table 4). The COSMOS trial reported 21% loss to follow-up over 5 years (16). This number is likely to be larger in clinical practice. As the size threshold for nodule identification is increased, the issue of non-adherence becomes a greater concern. Having a nodule may improve adherence with follow-up, though this has not been directly studied.

Patient distress has been reported around the identification of a lung nodule (17). Rates of smoking abstinence may be related to the identification of a nodule (18). There is no direct evidence linking the nodule size threshold that is used to label the screen as positive to oncologic (e.g. stage of cancer at diagnosis) or patient centered outcomes.

Policy Statements:

1. A lung cancer screening program should have a policy about the size and characteristics of a nodule to be used to label the test as positive.
2. A lung cancer screening program should collect data about the number, size, and characteristics of lung nodules from positive tests.

For Qualification as a Lung Cancer Screening Facility:

1. The lung cancer screening program should describe their policy about the size of a lung nodule that is used to label the test as positive.
2. The lung cancer screening program should provide data that describes the number and size of nodules that are being detected.

Future Research: Evaluation of oncologic and patient centered outcomes based on the lung nodule size threshold used to label the screening test positive should occur.

Component 5: Structured reporting

Screening programs should consider the format that they will use to report the results of the LDCT screen. A structured report must communicate the pertinent findings to the ordering provider, define what constitutes a positive finding on the LDCT, recommend nodule management strategies based on the algorithm accepted by the program, and be used to populate quality control and evidence development registries.

The ACR has developed a structured reporting system called LungRADS, based on the breast cancer screening structured reporting system BiRADS, designed to be a communication tool, to define what constitutes a positive finding on the LDCT, and to be a lung nodule management strategy for low risk nodules (19) (Table 2S). The lung nodule management strategy is not identical to other available evidence-based guideline recommendations.

Policy Statements:

1. A lung cancer screening program should use a structured reporting system, such as LungRADS.
2. A lung cancer screening program should collect data about compliance with the use of the structured reporting system.

For Qualification as a Lung Cancer Screening Facility:

1. The lung cancer screening program is using LungRADS as their structured reporting system, or uses a structured reporting system with similar elements (communication tool, identification of positive findings, lung nodule management recommendations).
2. The selected structured reporting system is being used for at least 90% of the CT screen reports.

Future Research: The impact of structured reporting systems on oncologic and patient centered outcomes, compliance with follow-up, and radiologist work-flow should be studied.

Component 6: Lung nodule management algorithms

Lung nodules should be managed based on the probability that they are malignant. Management algorithms, based on risk of malignancy, are available for solid subcentimeter nodules, solid larger nodules (1-3 cm), and for sub-solid nodules (19-22). The appropriate management of screen detected lung nodules will minimize additional imaging, minimize the number of invasive procedures performed for benign nodules, and will facilitate the timely treatment of malignant nodules.

Solid subcentimeter nodules have a very low probability of being malignant (14) and are difficult to characterize by additional imaging or non-surgical biopsies. Thus, surveillance imaging is the most appropriate management strategy. The interval of surveillance is based on the size of the nodule. There are guidelines available about how frequently surveillance should occur (19-21) (Table 5). Evidence to support one of the guideline strategies over the other is not available.

Solid nodules larger than 1 cm have a higher probability of malignancy. Additional imaging and non-surgical biopsies are more helpful for characterizing these nodules as benign or malignant. Management of nodules in this category begins with a review of prior imaging and is followed by an estimation of risk based on clinical and imaging variables. Very low risk nodules can enter a surveillance strategy, low to moderate risk nodules can be further characterized with PET imaging and/or a non-surgical biopsy, while high risk nodules may proceed directly to resection. In addition to the risk of malignancy the choice of testing includes patient factors such as their comorbidities, general health, and values (20) (Figure 1S).

Sub-solid nodules, including pure ground glass nodules and part-solid nodules, have a higher baseline risk of malignancy than solid nodules of equal size, but are generally more indolent in their behavior when malignant. The majority of overdiagnosed screen detected lung cancers will present as sub-solid nodules (23). The higher probability of malignancy and less aggressive behavior inform the management algorithm for sub-solid nodules (19,20,21) (Figure 2S).

The few patient centered outcomes that have been reported in lung cancer screening trials reflect on the impact of finding a nodule on the patient's quality of life (24). There is a growing body of evidence suggesting many patients lack an understanding of the meaning of a nodule and overestimate the risk of malignancy (25,26).

<u>Policy Statements</u>: A lung cancer screening program must:

1. Include clinicians with expertise in the management of lung nodules and the treatment of lung cancer,
2. Have developed lung nodule care pathways,
3. Have the ability to characterize concerning nodules through PET imaging, non-surgical and minimally invasive surgical approaches,
4. Have an approach to communication with the ordering provider and/or patient,
5. Have a means to track nodule management, and
6. Collect data related to the use of, and outcomes from, surveillance and diagnostic imaging, surgical and non-surgical biopsies for the management of screen detected lung nodules.

<u>For Qualification as a Lung Cancer Screening Facility</u>:

1. The lung cancer screening program has designated clinicians with expertise in lung nodule management, the performance of non-surgical biopsies and minimally invasive surgical biopsies, and lung cancer treatment. The following specialties should be represented:
    a. Radiology (Diagnostic, Interventional)
    b. Pulmonary Medicine
    c. Thoracic Surgery
    d. Medical Oncology
    e. Radiation Oncology
2. The lung cancer screening program has designated an acceptable lung nodule management strategy, such as the use of available published evidence-based algorithms and/or care pathways.
3. The lung cancer screening program can describe the lung nodule communication and nodule management tracking system being used by their program.
4. The lung cancer screening program must be capable of reporting on:
    a. the number of surveillance and diagnostic imaging tests,
    b. non-surgical and surgical biopsies that are performed for malignant and benign screen detected nodules,
    c. the number of cancer diagnoses, and
    d. the number of procedure related adverse events (e.g. hospitalization, death)

Future Research: The impact of nodule management algorithms and communication tools on oncologic and patient centered outcomes should be studied. The clinical utility of validated lung nodule molecular biomarkers should be studied. Means to characterize T1a lung cancers, and tools to estimate life expectancy, should be studied in order to better understand and minimize overdiagnosis.

Component 7: Smoking cessation

The mortality reduction that could be achieved by smoking cessation exceeds that from lung cancer screening (27). The impact of lung cancer screening on smoking cessation rates is poorly defined. Limited evidence suggests LDCT screening itself does not influence smoking behavior, however the reporting of positive results may be associated with increased smoking abstinence (18). The cost-effectiveness of screening improves with increasing rates of smoking cessation (28). Table 3S lists smoking cessation resources.

Policy Statements:

1. A lung cancer screening program must be integrated with a smoking cessation program.
2. A lung cancer screening program should collect data related to the smoking cessation interventions that are offered to active smokers enrolled in the screening program.

For Qualification as a Lung Cancer Screening Facility:

1. The lung cancer screening program has integrated smoking cessation services for patients enrolled in their program.
2. The lung cancer screening program will report on the portion of active smokers who are offered, and who participate in, a smoking cessation intervention.

Future Research: The impact of participation in a screening program, the results of screening, and the elements of a screening program, on smoking cessation rates should be studied.

Component 8: Patient and provider education

Providers must understand the components of screening well enough that they can identify patients in the appropriate risk group, know how to interpret and manage the screening results, and be capable of helping their patients make value-based decisions about being screened. The lung cancer screening program is the source of education for the provider and should supplement the patient's education. Table 4S lists patient educational material resources.

Policy Statements:

1. A lung cancer screening program should educate providers so that they can adequately discuss the benefits and harms of screening with their patients. Examples may include grand round presentations, face to face meetings, electronic and paper descriptions of the key components of the program.
2. A lung cancer screening program should develop or use available standardized education materials to assist with the education of providers and patients.
3. A lung cancer screening program is responsible for the oversight and supplementation of provider-based patient education.

For Qualification as a Lung Cancer Screening Facility:

1. The lung cancer screening program will list the educational strategies used to educate ordering providers about the key components of lung cancer screening.
2. The lung cancer screening program demonstrates the availability of standardized patient and provider educational material.

Future Research: The impact of provider education methods on compliance with screening metrics, and the impact of patient education methods on their understanding of the benefits and harms of lung cancer screening should be studied.

Component 9: Data collection

In order to ensure that a lung cancer screening program is maintaining quality standards, data collection and periodic review must occur. Data collection can also serve to advance our understanding of the science of screening. Ideally, a core set of data elements would be collected by all programs, and a means would be available to share data across programs, such as through a centralized lung cancer screening registry.

Policy Statements:

1. A lung cancer screening program must collect data on all enrolled patients related to the quality of the program, including those enrolled in registered clinical research trials. Data collection should include elements related to each of the other 8 components of a lung cancer screening program (as above). In addition, data collection should include the outcomes of testing (complications, cancer diagnoses), and a description of the cancers diagnosed (histology, stage, treatment, survival).
2. A review of the data and subsequent quality improvement plan should be performed at least annually.
3. An annual summary of the data collected should be reported to an oversight body with the authority to credential screening programs. Standards set forth in the above policy statements should be used by the oversight body to judge areas of compliance and deficiency.

For Qualification as a Lung Cancer Screening Facility:

1. The lung cancer screening program must collect data related to each component of a lung cancer screening program, the outcomes of testing, as well as the cancers diagnosed, and report this data annually to an oversight body.
2. The lung cancer screening program should respond to concerns from the oversight body in order to maintain accreditation.

Future Research: Programs and IT infrastructure that facilitates automatic data collection through linkage with electronic health records and PACs systems should be further developed.

Multi-Society, Multi-Disciplinary Governance

There are recognized implications of the content of this policy statement. The components of lung cancer screening programs outlined above demonstrate the multi-disciplinary nature of the expertise required to develop and maintain a high quality screening program. In addition, we have stressed that most of the components of a successful screening program will be optimized over time by incorporating knowledge gained through research. Finally, a credentialing system based on the qualifying elements suggested in each of the above components would have a broader mandate than that currently available.

Policy Statements:

1. A multi-society, multi-disciplinary governance structure should be developed and supported in order to advance quality standards based on evolving evidence, administer an expanded credentialing system, and suggest research priorities.
2. At a minimum, the multi-society governance should oversee the evolution of structured reporting; nodule management algorithms; the structure, maintenance, and integrity of a lung cancer screening registry; the research conducted on the registry; and research that would help to define the criteria for screening eligibility.

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5-Year Risk of Lung Cancer Death (%)	FP per Prevented Lung Cancer Death	Number Needed to Screen
All	108	302
0.15-0.55	1648	5276
0.56-0.84	181	531
0.85-1.23	147	415
1.24-2.00	64	171
>2.00	65	161

Table 1: Variation in benefit (number needed to screen to prevent one death from lung cancer) to harm (false positives per prevented lung cancer death) based on the quintile of risk within the NLST (6). FP= false positive (benign nodule detected on screening CT)

First Author	Bach	Spitz	Cassidy	Tammemegi	Hoggart
Source	Caret	MDA	LLP	PLCO	EPIC
Subjects	18,172 10-60 cpd 25-55 years	3,852 N/F/C smokers	1,736 N/F/C smokers	115,185 Healthy population	169,035 F/C smokers
Age (years)	50-75	20-80	20-80	55-74	35-65
Variables	Age Asbestos Sex Smoking	Age Dust Emphysema Family history Sex Smoking	Age Asbestos Family history Pneumonia Prior cancer Sex Smoking	Age BMI Chest x-ray COPD Education Family history Smoking	Age Smoking

Table 2: Available clinical lung cancer risk prediction models (7-11). Caret = Carotene and Retinol Efficacy Trial, MDA = MD Anderson, LLP = Liverpool Lung Project, PLCO = Prostate, Lung, Colorectal, Ovarian screening trial, EPIC = European Prospective Investigation into Cancer and Nutrition, cpd = cigarettes per day, N = never, F = former, C = current, BMI = body mass index, COPD = chronic obstructive pulmonary disease

Threshold (mm)	Nodules (%)	Cancer (%)	Cancers (#)
4	26.7	3.8	267
7	12.6	7.4	249
11	4.6	17.3	214
21	1.1	33.9	103
30	0.4	41.3	45

Table 3: Consequences of potential nodule thresholds within the NLST (14).

	NLST (4)	**NELSON** (12)	**ITALUNG** (29)	**COSMOS** (16)

Round 1	26309	7557	1406	5203
Round 2	24715	7295	1356	4822
Round 3	24102	6922	1308	4583
Round 4	NP	NR	1263	4385
Round 5	NP	NP	NP	4123

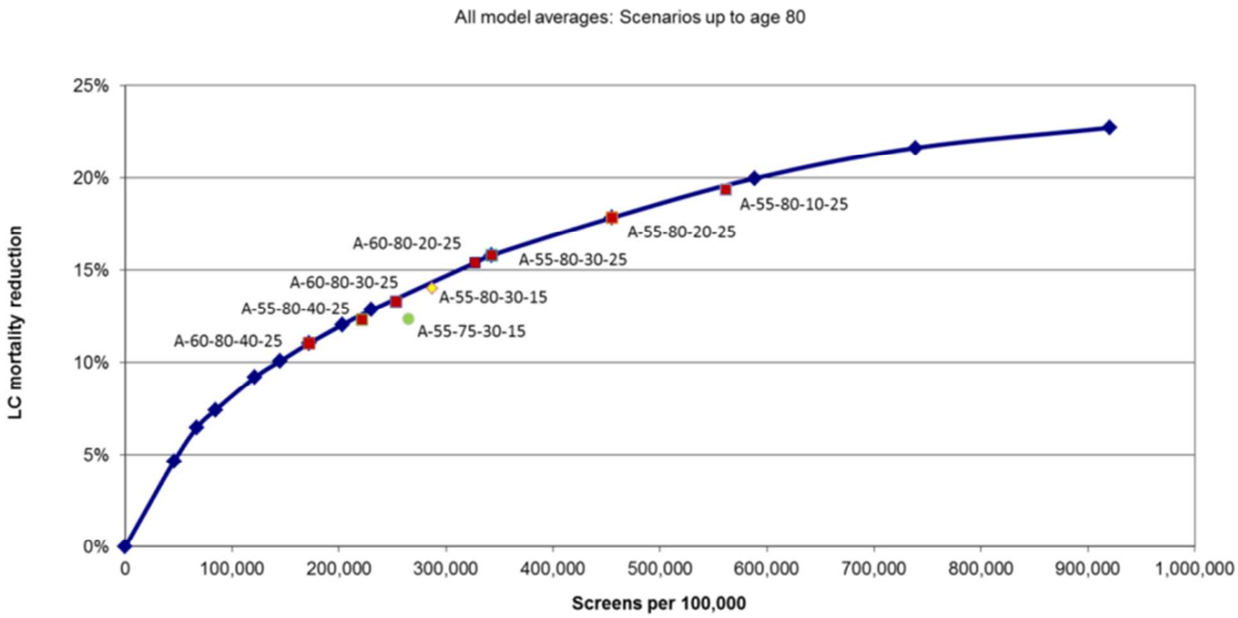
Table 4: Compliance with annual screening in controlled trials. NP = not performed, NR = not reported, NLST = National Lung Screening Trial, NELSON = Nederlands Leuvens Longkanker Screenings Onderzoek, Italung = Italian Lung, COSMOS = Continuous Observation of Smoking Subjects

Nodule Type	**Size (mm)**	**Recommended Follow-up in Months**		
		Fleischner/ACCP* (20-22)	**NCCN**	**Lung-RADS** (19)
Solid	<6	6-12, 18-24	RTAS	RTAS
	≥6 - <8	3-6, 9-12, 24	3, 6, RTAS	6, RTAS
	≥8 - ≤10	3-6, 9-12, 24	PET and/or biopsy or resect	3, RTAS
Pure GGN	≤5	None	RTAS	RTAS
	>5	3, 12, 24, 36	6, RTAS	RTAS up to 20mm
Part-solid	≤5	3, then annual x 3	RTAS	RTAS (uses 6mm)
	>5	3, then bx or resect	As for solid	Based on size of solid component

Table 5: Available society guidelines for smaller and low risk nodules. (Adapted from table developed by Michael Gould) RTAS=return to annual screening; bx=biopsy; GGN= ground glass nodule

Figure 1: Most efficient strategies based on modeling performed for the USPSTF (A=annual) all used an annual strategy (5). Estimated Lung Cancer Mortality Reduction (Average of Five Models) From Annual Computed Tomography Screening in the 1950 Birth Cohort for Programs With Eligible Ages of 55 to 80 Years and Different Smoking Eligibility Cutoffs.

Figure 1


All model averages: Scenarios up to age 80
LC mortality reduction
Screens per 100,000
25%
20%
15%
10%
5%
0%
0
100,000
200,000
300,000
400,000
500,000
600,000
700,000
800,000
900,000
1,000,000
A-55-80-10-25
A-55-80-20-25
A-60-80-20-25
A-55-80-30-25
A-60-80-30-25
A-55-80-30-15
A-55-80-40-25
A-55-75-30-15
A-60-80-40-25

ADULT LUNG CANCER SCREENING TECHNICAL SPECIFICATIONS		
Adult Chest for Lung Cancer Screening		
Technique Parameters (Items in bold are designation requirements. Failure to meet these requirements will result in deferral of Designation)		
Scan Parameter	**Parameter Specification**	**Comments**
Scanner type	**multidetector helical (spiral) detector rows ≥ 4**	non helical and single detector scanners are not appropriate for lung cancer screening CT
Required Series		No IV or oral contrast should be used
kV	100 to 140 acceptable for standard sized patient	Should be set in combination with mAs to meet CTDIvol specifications
mAs	Should be set in combination with kVp to meet CTDIvol specifications.	The mAs selected should result in diagnostic-quality images of the lungs Should take into account the patient's body habitus and age, slice width, kVp, and unique attributes of the scanner and acquisition mode
Max.Tube Rotation Time	≤ 0.5 seconds	0.75 second is acceptable if a single breath hold ≤15 seconds can be achieved for scanners that cannot perform 0.5 second rotation time
Pitch (IEC Definition)	Between 0.7 and 1.5	Should be set with other technical parameters to achieve single breath hold scan and CTDIvol specifications
Respiration	**single breath hold full inspiration**	
Scan duration/ Acquisition time	≤ 15 seconds	Time to acquire the scan though entire lungs within a single breath
Reconstructed image width (nominal width of reconstructed image along z-axis)	**≤ 2.5 mm**	≤ 1 mm preferred
Reconstructed image spacing (Distance between two reconstructed images)	≤ slice width	Overlapping reconstructions are not necessary but are acceptable

Table 1S: ACR-STR lung cancer screening LDCT recommendations (13).

Category	Category Descriptor	Category	Findings	Management	Probability of Malignancy	Estimated Population Prevalence
Incomplete	-	0	prior chest CT examination(s) being located for comparison part or all of lungs cannot be evaluated	Additional lung cancer screening CT images and/or comparison to prior chest CT examinations is needed	n/a	1%
Negative	No nodules and definitely benign nodules	1	no lung nodules nodule(s) with specific calcifications: complete, central, popcorn, concentric rings and fat containing nodules	Continue annual screening with LDCT in 12 months	< 1%	90%
Benign Appearance or Behavior	Nodules with a very low likelihood of becoming a clinically active cancer due to size or lack of growth	2	solid nodule(s): < 6 mm new < 4 mm part solid nodule(s): < 6 mm total diameter on baseline screening non solid nodule(s) (GGN): < 20 mm OR ≥ 20 mm and unchanged or slowly growing category 3 or 4 nodules unchanged for ≥ 3 months			
Probably Benign	Probably benign finding(s) - short term follow up suggested; includes nodules with a low likelihood of becoming a clinically active cancer	3	solid nodule(s): ≥ 6 to < 8 mm at baseline OR new 4 mm to < 6 mm part solid nodule(s) ≥ 6 mm total diameter with solid component < 6 mm OR new < 6 mm total diameter non solid nodule(s) (GGN) ≥ 20 mm on baseline CT or new	6 month LDCT	1-2%	5%
Suspicious	Findings for which additional diagnostic testing and/or tissue sampling is recommended	4A	solid nodule(s): ≥ 8 to < 15 mm at baseline OR growing < 8 mm OR new 6 to < 8 mm part solid nodule(s: ≥ 6 mm with solid component ≥ 6 mm to < 8 mm OR with a new or growing < 4 mm solid component endobronchial nodule	3 month LDCT; PET/CT may be used when there is a ≥ 8 mm solid component	5-15%	2%
		4B	solid nodule(s) ≥ 15 mm OR new or growing, and ≥ 8 mm part solid nodule(s) with: a solid component ≥ 8 mm OR a new or growing ≥ 4 mm solid component	chest CT with or without contrast, PET/CT and/or tissue sampling depending on the *probability of malignancy and comorbidities. PET/CT may be used when there is a ≥ 8 mm solid component.	> 15%	2%
		4X	Category 3 or 4 nodules with additional features or imaging findings that increases the suspicion of malignancy			
Other	Clinically Significant or Potentially Clinically Significant Findings (non lung cancer)	S	modifier - may add on to category 0-4 coding	As appropriate to the specific finding	n/a	10%
Prior Lung Cancer	Modifier for patients with a prior diagnosis of lung cancer who return to screening	C	modifier - may add on to category 0-4 coding	-	-	-

Table 2S: LungRADS (19)

Table 3S: Smoking cessation resources

http://tobaccodependence.chestnet.org/
http://www.uspreventiveservicestaskforce.org/uspstf09/tobacco/tobaccors2.htm
http://www.surgeongeneral.gov/initiatives/tobacco/resources.html
http://www.cdc.gov/tobacco/campaign/tips/quit-smoking/guide/
http://annals.org/article.aspx?articleid=744446

Table 4S: Education material resources

http://www.lung.org/lung-disease/lung-cancer/lung-cancer-screening-guidelines/lung-cancer-one-pager.pdf
http://jama.jamanetwork.com/article.aspx?articleid=1685860
http://www.uspreventiveservicestaskforce.org/uspstf13/lungcan/lungcanguide.pdf
http://www.uspreventiveservicestaskforce.org/uspstf13/lungcan/lungcanfact.pdf
http://www.cancer.gov/newscenter/qa/2002/NLSTstudyGuidePatientsPhysicians

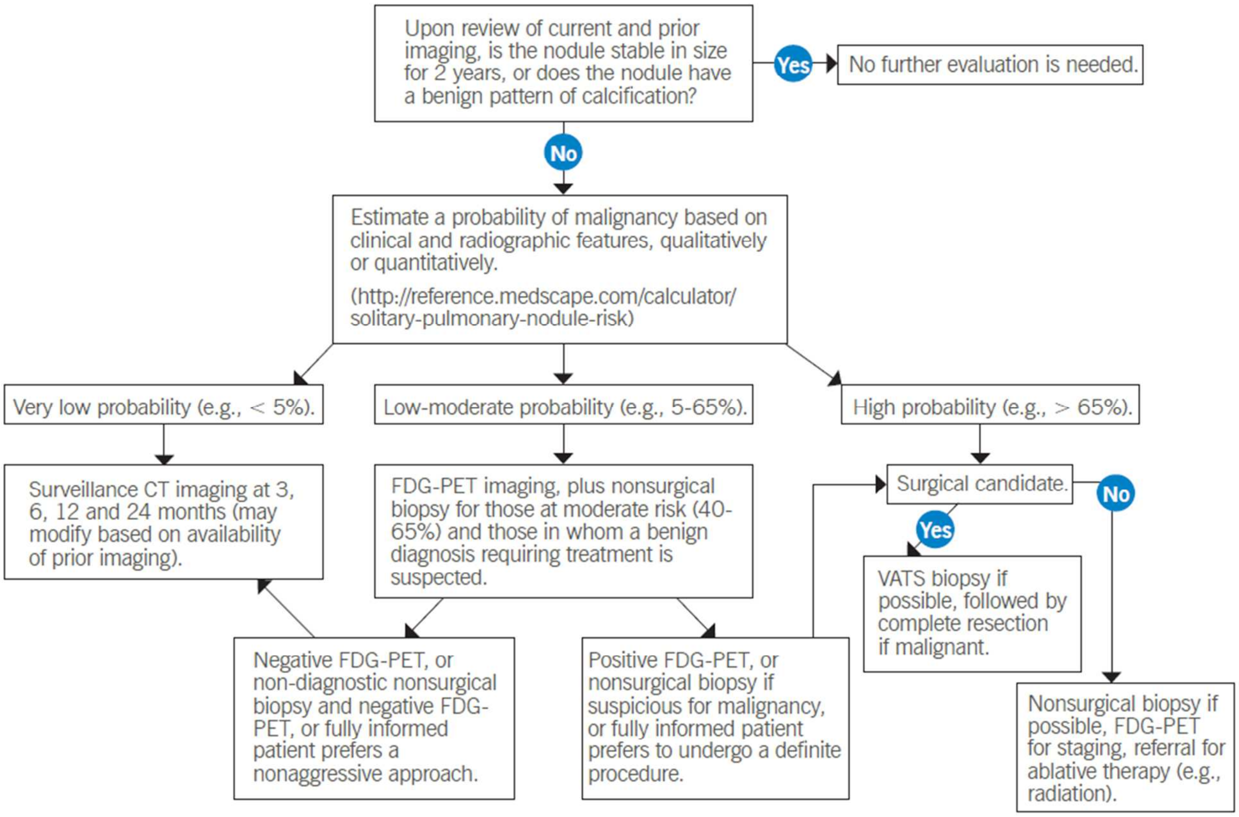


Figure 1S: Example of management algorithm for solid nodules 1 cm or greater in diameter.

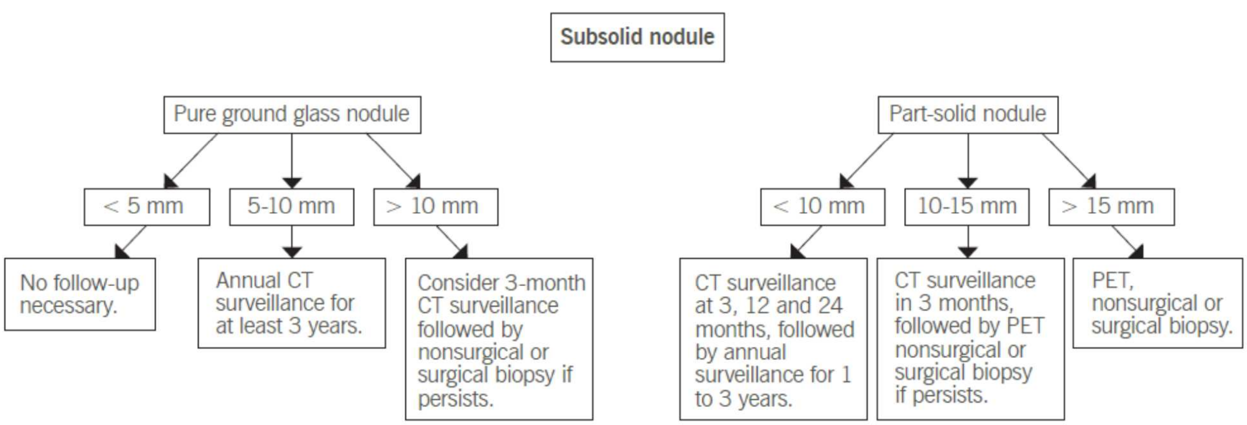


Figure 2S: Example of management algorithm for subsolid nodules (20).