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APPENDIX METHODS
Site Selection for the VA Demonstration Project

Among 35 sites applying/volunteering to participate, 8 sites were selected based on pre-set criteria.[1] All 8 sites selected were academic VA medical centers. While clinical champions and facility leadership at the sites supported the application to become a demonstration project site, individual clinics and clinicians did not necessarily volunteer to participate and were engaged much later in the process during the actual implementation of the demonstration project. Since all of the selected sites volunteered to participate, all can be considered "early adopters" of lung cancer screening. As noted in the main text discussion, early adopting sites participating in the demonstration project may demonstrate less variation in lung cancer screening decision making than would be typically seen across randomly selected sites. Thus, it would be expected that the demonstration project data would provide a lower estimate of the variation that likely exists in more diverse centers with both early and later adopters. However, it is important to note that a neutral shared decision process was emphasized during the demonstration project, aided by the use of a decision aid.[1] Participating clinics and clinicians were not incentivized in any way to achieve higher rates of screening. Also, the "early adopter" label probably only applies at the site level, and may not apply to all clinics and clinicians within a site.

Clinical Reminders

During the VA Lung Cancer Screening Demonstration Project, 3 clinical reminders were used as lung cancer screening decision support tools for VA clinicians. These clinical reminders capture patient information through health factors which are stored in the VA Corporate Data Warehouse. Health factor data from 2 of these reminders was utilized in the analysis, the Tobacco Pack-Year Reminder and Initial Lung Cancer Screen (Provider) Reminder.[1]

The Tobacco Pack-Year Reminder was only active for patients who were potentially eligible based on age (55–80 years old), a lack of permanent exclusions (e.g., history of lung cancer, health factor indicated life expectancy <6 months), and had not received a chest CT in the previous year. This reminder captured smoking status, how long patients smoked, and how many cigarettes per day patients smoked on average. These data points were used to calculate a patient's pack-year smoking history which is used to determine "potential LCS eligibility." Pack-year history is the number of average packs of cigarettes smoked per day times the number of years smoked (e.g., average of 1 pack of cigarettes smoked per day x 40 years smoked=40 pack-years). The Tobacco Pack-Year Reminder was completed by primary care staff in most cases.[1]

The Initial Lung Cancer Screen (Provider) Reminder was completed primarily by primary care clinicians (PCPs) (although it is possible for others such as screening coordinators to complete it and this did occur) and was active for "potentially LCS eligible" patients based on the completed Tobacco Pack-Year Reminder (i.e., patient is a current smoker or former smoker who quit <15 years ago, and has ≥30 pack-year smoking history). This reminder allowed PCP's to assess a patient's appropriateness for LCS and indicate if patients had any exclusions that would make them a poor LCS candidate (e.g., severe comorbidity; not willing or able to undergo curative lung cancer resection). For patients without exclusions, the reminder also captured a patient's decision to agree to LCS, defer screening for 1 year, or defer screening indefinitely. In addition to documenting LCS intentions, the clinical reminder could be used to refer patients to lung cancer screening coordinators for additional LCS discussion.[1]

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Variable Definitions in the VA's Corporate Data Warehouse (CDW)

Variable	CDW domain	Code/Definition
Years smoked	Health Factors	Health Factor type=LCS YEARS SMOKED
Packs smoked	Health Factors	Health Factor type=LCS PACKS/DAY
Quit time	Health Factors	Health Factor type=LCS YEAR QUIT SMOKING/LCS QUIT YEAR (ACTUAL)/LCS QUIT DATE
Smoking status	Health Factors	Health Factor type=LCS CURRENT SMOKER/LCS FORMER SMOKER
LCS exclusions	Health Factors	Health Factor type=LCS HAS EXCLUSIONS/LCS NO EXCLUSIONS
LC screening decision	Health Factors	Health Factor type=LCS AGREES TO BE SCREENED
LCS reminder location	Health Factors/Outpatient Visit	Sta6a facility code
LCS reminder provider	Health Factors/Staff table	LCS coordinators' names were known to project team
Age, gender, race	Patient	Included only self-identified race records
Charlson Comorbidity index	Inpatient and Outpatient Diagnosis	Published codes
ZIP code; latitude; longitude	Patient Address	N/A
Distance to central facility[a]	Calculated using SAS GeoDist function	N/A
CT screen	Outpatient	CPT Code 71250
Primary care provider	PCMM/RPCMM	Assigned PC provider at the time of the Pack Year Health factor completion

[a]Distance to the central medical facility was calculated using the latitude and longitude of patients' home address and the latitude and longitude of the VA medical facilities offering LCS (shortest geographic distance, not driving distance).

As noted in the main text, 72.6% of patients with a completed tobacco pack-year reminder and meeting age and smoking eligibility criteria were excluded from the study cohort due to missing an "appropriateness assessment." Having an appropriateness assessment simply means that a PCP considered lung cancer screening for a patient and documented whether the patient was an appropriate candidate or not, based on the patient's health status and clinical context.

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At the demonstration project sites, completing the pack-year reminders became a routine part of patient intake by non-PCP staff, identifying a large number of "potentially eligible" patients based on age and smoking history. However, the subsequent appropriateness assessment was only documented if the PCP (or screening coordinator) considered and had time to discuss LCS with the patient. Not having an appropriateness assessment can occur for several reasons: the patient did not get a subsequent appointment with their PCP; the PCP was not thinking about LCS during the visit or did not check the clinical reminder; or there was simply no time to discuss LCS during the visit due to competing demands. The lack of this assessment indicates that the patient was probably not aware they are potentially eligible for lung cancer screening.

While it was possible for PCPs to carry out LCS discussions and order screening CTs without using the clinical reminders that documented the decision-making, it was believed this was probably not a frequent occurrence. LCS was a new intervention that most PCPs were not familiar with or routinely offering prior to the demonstration project—and these sites initially had a limited and standardized roll-out of LCS during the demonstration project timeframe. Nonetheless, to the extent that this did happen, the focus on decision-making that was documented through the use of standardized clinical reminders would likely underestimate the true variation in decision-making, as discussed in the main text.

Clinical Exclusions
Patients were excluded from the cohort if there were clinical exclusions that would prevent them from being good candidates for lung cancer screening. Clinical exclusions include currently being treated for cancer, previous confirmed lung cancer, life expectancy <5 years, symptoms suggestive of lung cancer, or other conditions that would exclude them from surgical lung resection (i.e., severe COPD, heart problems, etc.). As previously mentioned, many of these exclusions were captured in the health factor generated from the Initial Lung Cancer Screen (Provider) Reminder.[1]

Lung Cancer Screening Coordinators
While each medical facility in the demonstration project was provided with the same resources and training, the utilization of these resources appeared to vary at a medical facility level. Some of the variation in LCS decision-making across medical facilities might be attributed to different practices or policies. For example, one facility initially had only the screening coordinator reach out to and discuss screening with patients with little-to-no involvement from PCPs, while other facilities had patients engage with screening coordinators only after a discussion with their PCP. In particular, the role of lung cancer screening coordinators could have impacted LCS decision making during the demonstration project. A descriptive assessment of the data showed that the facility with the highest rate of agreeing to and receiving LCS had the highest proportion of clinical reminders completed by a lung cancer screening coordinator (92% of all reminders). While the higher rate in agreeing to and receiving LCS was observed at this medical facility, there was no indication of a difference in screening appropriateness for those agreeing to and receiving LCS.

Model Outcomes
The two model outcomes evaluated are agreeing to LCS and receiving LCS. Agreeing to LCS was determined by a health factor generated from the Initial Lung Cancer Screen (LCS) Provider Reminder. Receiving LCS was defined as receiving at least 1 low-dose chest CT scan ordered

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without contrast within 3 months from the time the initial LCS provider reminder was completed. This approach was necessary because screening-specific CPT codes and Lung-RADS codes that can be used to specifically identify a *screening* CT were not created until after the period of the study.

To examine the best approach for determining receipt of a *screening* CT using the provider reminder (and exclude CTs ordered for diagnostic or surveillance purposes in symptomatic patients), a random chart review was performed of 74 patients who had a CPT code 71250 up to 12 months after the date that the initial LCS provider reminder was completed (30 patients in each time-period below were initially chosen however 74 remained after removing duplicates).

| Timeframe	No. with CPT code 71250 assessed by chart review	No. with CT confirmed as screening on chart review (%)
$\leq$3 months (90 days)	28	21 (75%)
>3months and $\leq$6 months	22	10 (45%)
>6 months and $\leq$12 months	24	11 (46%)

Most of the 71250 codes occurring within 3 months (i.e., $\leq$3 months from the date that the initial provider reminder was completed) were found to be screening CTs on chart review 21 out of 28 chart reviewed were confirmed to be screening exams). However, fewer (45%–46%) of 71250 codes occurring in the >3-month timeframes were found to be screening CTs. Thus, to minimize including non-screening CTs the study chose the $\leq$3-month timeframe as the most appropriate timeframe for the analyses, which examine factors associated with receipt of screening and variation in screening across PCPs and facilities. The approach will miss screening CTs ordered >3 months following the initial decision-making encounter. The results on screening utilization are thus specific to screening within 3 months of the likely screening discussion. The prior report by Kinsinger et al., which did chart reviews to confirm who did and did not have eventually screening (within the more limited population who were screened during demonstration project "as intended") examined rate of eventual screening, among those initially agreeing to screen, over a longer timeframe, although follow-up was limited to 3 months for some in their cohort. However, the multi-level analyses examining screening decision-making across a broader range of primary care providers and outlying clinics than were included in the Kinsinger et al. report is more appropriate for examining the extent of variation in screening decision-making. This is discussed further below.

Model Structure
A multilevel model structure was utilized to evaluate the impact of a patient's primary care provider (PCP) and medical facility on agreeing to and receiving LCS. Patients were nested within their PCP, and PCP was nested within medical facility, resulting in a 3-level model. The cohort included 5,551 patients, 363 PCPs, and 8 medical facilities. The 8 medical facilities were Ann Arbor, MI; Charleston, SC; Cincinnati, OH; Durham, NC; Minneapolis, MN; New York Harbor, NY; Portland, OR; & San Francisco, CA.

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Appendix Figure 1. Model nesting structure.
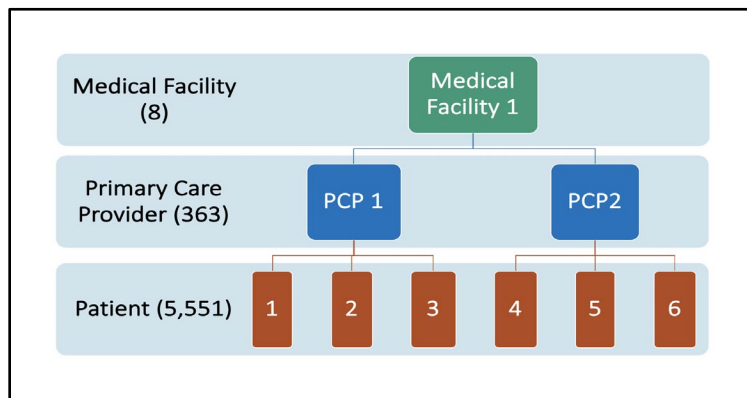
Comparison to an Earlier Report on the VA Demonstration Project (Kinsinger et al. 2017)[1]

The cohort was derived from the same 8 demonstration project sites and an overlapping timeframe and thus has some overlap with the prior Kinsinger et al. report on the VA LCS demonstration project. However, the timeframe for the analyses is slightly different, the study cohort included decision-making from a broader number of primary care providers and clinics than did the demonstration project, the method of identifying who agreed to screening may have differed in some cases, and the method of identifying who received screening differs.

Differences are detailed in the table below:

	Kinsinger et al. paper[1]	The study cohort
Time period	July 1, 2013 – June 30, 2015 (2 years)	October 1, 2013 – September 30, 2015 (2 years but later)
Number of study cohort with initial LCS provider reminder completed after June 30, 2015	0 (cohort inclusion for paper analyses ended June 30, 2015)	307
Number of primary care providers (PCPs) completing initial LCS provider reminder	Not reported but limited to smaller subset for the "as intended" demonstration project analyses by design	363
Number of patients in study cohort with decision-making documented outside the central facility (e.g., provider reminder completed at a community-based outpatient clinic)	Not reported but likely negligible (such patients should have been excluded as not being screening in the demonstration project "as intended")	1,476 (27% of full study cohort)
Method of identifying which eligible patients agreed to screening	Used initial LCS provider clinical reminder OR screening coordinator clinical reminder	Used initial LCS provider clinical reminder
Method of identifying which eligible patients had a low-dose CT screen	Used clinical reminder health factors and chart reviews to confirm screening*	Used clinical reminder data + CPT codes as described in the manuscript

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The differences above lead to different datasets. The numbers below are provided for additional context and discussed further in the text below.		
Total in study cohort	4,246	5,551
Agreed to screen	2,452 (57.7%)	3,720 (67.0%)
Had LCS…	Within 3-12 months: 2,106 (49.6%)[a]	Within 3 months: 2,398 (43.2%)

[a]In the Kinsinger report, patients had a minimum of 3 months of follow-up time, after being identified as a screening candidate, to determine screening utilization (median follow-up time from screening LDCT to June 30, 2015=236 days). Further, the Kinsinger main analyses only looked at screening CTs among those who agreed to screening whereas the analyses examined screening among any person in the full cohort. Finally, it was noted that in the Kinsinger report, the value "had LCS" is presented as the proportion of those agreeing to screen (2,106/2,452=85.9%) rather than proportion of the full cohort as presented in the table above.

The differences noted above led to different datasets even given the overlap in timeframe and facilities. In addition, unlike the Kinsinger et. al. analyses, there was no attempt to exclude patients who did not "go through the demonstration project 'as intended'" (or "had screening documentation as a result of a process outside of the demonstration project"). This allowed us to include a broader range of PCPs and outlying clinics outside the central VAMC offering LCS. For these reasons, the dataset is likely better suited to capturing the variation in screening decision-making across providers and different settings—a core goal of this study and of the multi-level analyses. At the same time, focusing on the demonstration project timeframe allowed us to leverage the unique use of clinical reminders documenting decision-making (via screening clinical reminders) across multiple sites during this timeframe.

The proportion of appropriate LCS candidates who agreed to screening is moderately higher (67%) in the cohort than that reported in the Kinsinger paper (57.7%). This may have been due to the fact that the study included decision-making documentation from a broader range of PCPs (and some outlying clinics) than that included in the demonstration project analyses. It is possible that these additional PCPs may have been more likely to be "early adopter" types, who more strongly encouraged screening to their patients. However, examining the reason for this difference is beyond the scope of this paper.

The results on screening utilization should be interpreted as examining predictors of getting screened *within 3 months*. The rate of screening utilization that is reported is somewhat lower than that reported in the demonstration project, and this is likely due to the fact that only screening in the 3 months following initial decision making about LCS was examined (i.e., screening within 3 months of completion of the initial LCS provider reminder). It is likely that some patients eventually had screening that occurred after this timeframe, and that the true rate of eventual screening utilization is higher than the 3-month rates reported in the paper.

Statistical Analyses
Variance inflation factors (VIF) was assessed, dispersion, and collinearity for each model. Neither model was overdispersed, and no factors had high VIF values. Sensitivity analyses were preformed to assess the nesting structure, data missingness, and the predictors included the model. No significant interaction between initial lung cancer risk and Charlson Comorbidity

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Index (CCI) in agreeing to and receiving LCS was found. However, no observed significant (though not likely to be clinically meaningful) interaction between initial lung cancer risk and age in receiving LCS. Detailed results are presented in tables below.

RESULTS

Appendix Table 1. Predictors of Agreeing to Lung Cancer Screening

	Estimate, log odds (95% CI)	**SE**	**p-value**
Intercept	**−0.97 (−1.92, −0.01)**	**0.49**	**0.047**
Age, centered	**−0.05 (−0.06, −0.03)**	**0.01**	**<0.001**
Female	**0.44 (0.00, 0.88)**	**0.22**	**0.048**
Black race	0.15 (−0.06, 0.35)	0.11	0.169
Other race	0.01 (−0.19, 0.21)	0.10	0.916
Risk score, log-transformed	−0.01 (−0.12, 0.10)	0.06	0.889
Charlson Index	0.01 (−0.05, 0.06)	0.03	0.830
Distance, log-transformed	0.06 (−0.01, 0.14)	0.04	0.114
Central decision making location	**2.61 (2.34, 2.87)**	**0.13**	**<0.001**

Appendix Table 2. Predictors of Receiving Lung Cancer Screening

	Estimate, log odds (95% CI)	**SE**	**p-value**
Intercept	**−1.10 (−2.06, −0.14)**	**0.49**	**0.024**
Age, centered	−0.01 (−0.02, 0.01)	0.01	0.311
Female	0.12 (−0.25, 0.50)	0.19	0.511
Black race	−0.12 (−0.31, 0.07)	0.10	0.211
Other race	−0.07 (−0.26, 0.11)	0.09	0.440
Risk score, log-transformed	−0.10 (−0.20, 0.00)	0.05	0.057
Charlson Index	0.02 (−0.03, 0.07)	0.02	0.415
Distance, log-transformed	−0.05 (−0.12, 0.01)	0.03	0.122
Central decision making location	**0.85 (0.62, 1.07)**	**0.12**	**<0.001**

Lung Cancer Risk Interaction With Age

Appendix Table 3. Predictors of Agreeing to LCS with Lung Cancer Risk*Age Interaction Term

	Estimate, log odds (95% CI)	**SE**	**p-value**
Intercept	−0.91 (−1.85, 0.04)	0.48	0.060
Age, centered	**−0.16 (−0.24, −0.09)**	**0.04**	**<0.001**
Female	**0.49 (0.06, 0.93)**	**0.22**	**0.027**
Black race	0.16 (−0.05, 0.37)	0.11	0.132
Other race	0.02 (−0.18, 0.22)	0.10	0.856
Risk score, log-transformed	−0.00 (−0.12, 0.11)	0.06	0.931
Charlson Index	0.01 (−0.05, 0.06)	0.03	0.837
Distance, log-transformed	0.06 (−0.02, 0.13)	0.04	0.130
Central decision making location	**2.61 (2.34, 2.87)**	**0.13**	**<0.001**
Risk score * Age interaction	**−0.02 (−0.04, −0.01)**	**0.01**	**0.002**

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Appendix Table 4. Predictors of Receiving LCS with Lung Cancer Risk*Age Interaction Term

	Estimate, log odds (95% CI)	SE	*p*-value
Intercept	**−1.07 (−2.03, −0.10)**	**0.49**	**0.030**
Age, centered	**−0.15 (−0.23, −0.08)**	**0.04**	**<0.001**
Female	0.19 (−0.18, 0.56)	0.19	0.322
Black race	−0.10 (−0.29, 0.09)	0.10	0.299
Other race	−0.06 (−0.25, 0.12)	0.09	0.497
Risk score, log-transformed	**−0.10 (−0.21, −0.00)**	**0.05**	**0.045**
Charlson Index	0.02 (−0.03, 0.07)	0.02	0.418
Distance, log-transformed	−0.06 (−0.13, 0.01)	0.03	0.100
Central decision making location	**0.85 (0.63, 1.08)**	**0.12**	**<0.001**
Risk score * Age interaction	**−0.03 (−0.04, −0.02)**	**0.01**	**<0.001**

Lung Cancer Risk Interaction With Comorbidity

Appendix Table 5. Predictors of Agreeing to LCS with Lung Cancer Risk*Charlson Index Interaction Term

	Estimate, log odds (95% CI)	SE	*p*-value
Intercept	−0.83 (−1.86, 0.20)	0.52	0.115
Age, centered	**−0.05 (−0.06, −0.03)**	**0.01**	**<0.001**
Female	**0.45 (0.01, 0.88)**	**0.22**	**0.046**
Black race	0.15 (−0.06, 0.35)	0.11	0.173
Other race	0.01 (−0.18, 0.21)	0.10	0.904
Risk score, log-transformed	0.02 (−0.12, 0.15)	0.07	0.782
Charlson Index	−0.12 (−0.48, 0.25)	0.19	0.535
Distance, log-transformed	0.06 (−0.02, 0.14)	0.04	0.118
Central decision making location	**2.60 (2.34, 2.87)**	**0.13**	**<0.001**
Risk score * Charlson interaction	−0.02 (−0.10, 0.05)	0.04	0.512

Appendix Table 6. Predictors of Receiving LCS with Lung Cancer Risk*Charlson Index Interaction Term

	Estimate, log odds (95% CI)	SE	*p*-value
Intercept	−1.00 (−2.03, 0.02)	0.52	0.056
Age, centered	−0.01 (−0.02, 0.01)	0.01	0.315
Female	0.13 (−0.25, 0.50)	0.19	0.506
Black race	−0.12 (−0.32, 0.07)	0.10	0.206
Other race	−0.07 (−0.26, 0.11)	0.09	0.444
Risk score, log-transformed	−0.08 (−0.20, 0.04)	0.06	0.210
Charlson Index	−0.07 (−0.41, 0.26)	0.17	0.669
Distance, log-transformed	−0.05 (−0.12, 0.01)	0.03	0.122
Central decision making location	**0.85 (0.62, 1.08)**	**0.12**	**<0.001**
Risk score * Charlson interaction	−0.02 (−0.08, 0.05)	0.03	0.583

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Charlson Comorbidity Index of Those With and Without Exclusions

While comorbidity as a significant predictor of screening decision making was not found, it could still play an important upstream role in determining whether a patient should even be considered a candidate for screening (appropriateness assessment by the provider). Indeed, it was found that patients deemed inappropriate for LCS (based on clinical exclusions) had a significantly higher Charlson score than those without documented clinical exclusions. Mean CCI of those without clinical exclusions was 1.12 while that mean CCI of those with document exclusions was 1.75 ($t = -10.24$, degrees of freedom=7,753, $p<0.001$). This indicates that during the appropriateness assessment, PCPs did exclude some patients from screening with a higher degree of comorbidity that may limit the benefits of screening.

Discussion of Patient-Level Associations With the Primary Outcomes

The finding that patients are less likely to agree to screening after conversations with PCPs in outlying clinics is consistent with qualitative findings from the academic detailing of PCPs in most of the clinics in the study cohort (unpublished), where the study observed that clinicians at outlying clinics tended to report stronger concerns about the effectiveness of screening, more difficultly identifying patients eligible for screening, and more challenges fitting in screening discussions amongst competing demands (compared to clinicians at the central VA facility).[25] Further, patients receiving regular care at an outlying clinic, where CT scanners are not available, may face additional real and perceived barriers to traveling to the central VA facility to actually receive CT screening.

Older patients were less likely to agree to screening. This could be due to older smokers' informed preferences. However, prior studies have often found that older patients often continue to have strong positive beliefs about the value of cancer screening.[2,3] This finding could instead be due to stronger personal biases among older smokers[4–6] or could also reflect the way that PCPs approach screening conversations with older patients and their concerns about the harms of screening for older patients.[7–9] While in many cases more caution in older persons is quite reasonable due to more limited life-expectancy, it is also true that LCS can be particularly advantageous for older persons who are otherwise healthy (e.g., Charlson score of 0), because age is such a strong risk factor for lung cancer.[10,11] The study also found that women were more likely to agree to screening and that further distance was associated with a decreased likelihood of receiving screening within 3 months of decision making.

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