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Cost-Effectiveness of Smoking Cessation Interventions Integrated Into Lung Cancer Screening

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Abstract

IMPORTANCE National-level data are limited on the long-term costs and outcomes of integrating smoking cessation interventions into lung cancer screening (LCS) programs in the US.

OBJECTIVE To evaluate the cost-effectiveness of smoking cessation interventions in LCS using data from 4 randomized clinical trials implemented within the National Cancer Institute's Smoking Cessation at Lung Examination (SCALE) Collaboration.

DESIGN, SETTING, AND PARTICIPANTS In this economic evaluation, data were pooled from individuals enrolled across 23 arms in 4 SCALE trials from October 2016 to April 2023. Included participants were eligible for LCS and currently smoked. Data were analyzed from May 2025 to June 2026.

EXPOSURES LCS with and without cessation interventions. The 23 arms were classified into 8 composite treatment classes based on low, moderate, and high intensities of pharmacotherapy and counseling.

MAIN OUTCOMES AND MEASURES From a societal perspective, cost per quit was estimated during trial follow-up periods and incremental cost-effectiveness ratios over a lifetime horizon. Intervention costs were micro-costed at steady state. Trial data were extended to a lifetime horizon using an established lung cancer microsimulation model. Costs and quality-adjusted life-years (QALYs) were discounted at 3%. Sensitivity analyses tested the estimated effects of varying quit rates, costs, background cessation rates, relapse, and screening uptake and adherence.

RESULTS Of 2520 participants (mean [SD] age, 63.8 [5.8] years), 1278 (50.7%) were male. Mean (range) treatment class costs varied from $38.96 ($2.43-$57.45) to $803.10 ($563.18-$1212.73) per participant, with self-reported quit rates ranging from a mean (range) of 10.1% (8.0%-13.0%) to 27.3% (19.5%-31.4%). The lowest-intensity treatment class had the lowest cost per quit at $329.85, whereas the highest-intensity treatment class had the highest at $2945.35. Model projections suggested that the high-intensity pharmacotherapy and low-intensity counseling treatment class yielded the lowest lifetime costs ($1.54 billion per 100 000 screen-eligible population) and the second-highest QALYs (2.26 billion years per 100 000 screen-eligible population). The highest-intensity treatment class achieved the highest QALYs, at an incremental cost-effectiveness ratio of $991.15 per QALY. Compared with screening alone, joint cessation and screening programs were cost-saving. Results were robust across sensitivity analysis scenarios.

(continued)

Key Points

Question What is the cost-effectiveness of integrating smoking cessation interventions with varying intensity into lung cancer screening programs in the US?

Findings In this economic evaluation of 2520 individuals enrolled in 4 randomized clinical trials, trial data were projected over a lifetime horizon using an established microsimulation model. All cessation interventions combined with lung cancer screening were cost-saving vs screening alone, and high-intensity pharmacotherapy and counseling were associated with the greatest health gains, with an incremental cost-effectiveness ratio of $991 per quality-adjusted life-year.

Meaning The findings of this study suggest that integrating evidence-based smoking cessation interventions into lung cancer screening programs may represent a highly cost-effective use of health care resources.

+ Supplemental content

Author affiliations and article information are listed at the end of this article.

Abstract (continued)

CONCLUSIONS AND RELEVANCE In this economic evaluation of integrating smoking cessation interventions in LCS, joint cessation and screening programs were associated with substantial health benefits and favorable cost-effectiveness. These findings may be useful for health systems to guide decisions, while considering budget and capacity, on the modality and intensity of cessation interventions to adopt.

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Introduction

Lung cancer remains the second-most commonly diagnosed cancer and the leading cause of cancer-related mortality in the US.[1] Cigarette smoking accounts for more than 80% of lung cancer cases.[2] The US Preventive Services Task Force (USPSTF) first recommended annual low-dose computed tomography (LDCT) screening in 2013 for adults with a substantial smoking history[3] and later expanded eligibility in 2021 to adults aged 50 to 80 years with a 20 pack-year or more history who currently smoke or who have quit within 15 years.[4] It is estimated that over 13 million US adults are eligible for LDCT screening under the 2021 USPSTF criteria, and nearly half currently smoke.[5,6] The number of US screen-eligible adults who smoke presents an important opportunity to enhance the clinical benefits of lung cancer screening by delivering concurrent smoking cessation interventions. Consistent with this goal, since 2015, the Centers for Medicare & Medicaid Services has required the shared decision-making visit preceding the first LDCT screening to include counseling on the importance of smoking cessation for individuals who smoke.[7,8] Additionally, the USPSTF recommended that clinicians advise all adults who use tobacco to quit and provide a combination of Food and Drug Administration–approved pharmacotherapy and behavioral counseling.[9] These policies and clinical recommendations reinforce the strong consensus that integrating evidence-based cessation support with LDCT screening is essential to further reduce smoking-related morbidity and mortality.

However, there is uncertainty regarding which cessation approaches are most efficacious, cost-effective, and feasible to implement, considering the differences in availability of health care resources, staffing, and clinical workflows within US health care systems. To address this evidence gap, the National Cancer Institute launched the Smoking Cessation at Lung Examination (SCALE) Collaboration in 2016 to evaluate the effectiveness of different cessation interventions delivered in LDCT screening settings.[10] Most SCALE trials are now published, providing rich data on intervention quit rates, costs, feasibility, and implementation outcomes across a wide range of counseling and pharmacotherapy intensities.[11-18]

Although SCALE trials provide high-quality evidence on short-term cessation outcomes and implementation, not all were designed to assess long-term health and economic consequences, which are critical for informing program implementation decisions. Hence, we established a collaboration between the SCALE and the Cancer Intervention and Surveillance Modeling Network (CISNET), which combines empirical trial data with established lung cancer microsimulation models to project long-term population health and economic outcomes. Leveraging this collaboration, our team evaluated the cost-effectiveness of 5 hypothetical cessation interventions using intervention efficacies and costs from the published literature and the simulation modeling approach before any SCALE trial results were available.[19] Team members subsequently conducted a trial-based cost-effectiveness analysis using data from a completed SCALE trial.[20]

Building on this prior work, we used data from 4 completed SCALE trials, encompassing 23 intervention arms, with varying intensities of counseling and/or pharmacotherapy interventions, to evaluate short-term cost per quit and long-term cost-effectiveness of different intensities of smoking cessation interventions implemented within LDCT settings.

Methods

SCALE Trials

This study included 4 randomized clinical trials completed at Georgetown University (Lung Screening, Tobacco, and Health [LSTH]),[13] the University of Minnesota (Program for Lung Cancer Screening and Tobacco Cessation [PLUTO]),[14] Memorial Sloan-Kettering (Cessation and Screening to Save Lives [CASTL]),[21,22] and the Medical University of South Carolina Hollings Cancer Center (Lung Cancer Screening Patients Utilizing Nicotine Replacement Therapy [NRT] and Gain-Framed Messages [LUNG]).[15,23,24] In total, these trials included 23 intervention arms and individuals who smoked at the time of enrollment and met the USPSTF eligibility criteria for lung cancer screening. Participants were enrolled and followed up between October 2016 to April 2023. All parent trials received institutional review board approval at their respective institutions, and written informed consent was obtained from all participants. Purdue University determined that the present study, which involved secondary analyses of aggregated trial data, did not constitute human participant research. This economic evaluation was reported in accordance with the Consolidated Health Economic Evaluation Reporting Standards (CHEERS) 2022 reporting guideline.[26]

All interventions offered some form of counseling—delivered in person, by telephone, or via video messages—and pharmacotherapy in the form of NRT and/or prescription medications (varenicline and bupropion). To facilitate cross-trial comparisons, intervention intensity was classified based on counseling and pharmacotherapy using standardized criteria and expert opinion (B.A.T., J.O., S.S.F., and K.L.T.).[25] Pharmacotherapy intensity (medication [MED]) was categorized as low (0-3 weeks [Low]), moderate (4-8 weeks [Mod]), and high (>8 weeks [High]). Counseling intensity (CSL) was categorized as low (<60 minutes or provision of only educational materials), moderate (60-82 minutes), and high (>82 minutes). These classifications yielded 8 composite treatment classes ([Low/Mod/High]MED + [Low/Mod/High]CSL) because no intervention combined low-intensity pharmacotherapy with high-intensity counseling. To ensure comparability across trials, we used self-reported 7-day point prevalence abstinence at the primary cessation assessment time point, defined as 6 months after randomization for the CASTL, LSTH, and LUNG trials and 12 months after randomization for the PLUTO trial, as PLUTO interventions were delivered over a 12-month period. The unique trial design and calculation of arm-specific quit rates for the PLUTO trial are described in eMethods 1, eTable 1, and the eFigure in Supplement 1). Arm-specific characteristics, counseling, and pharmacotherapy intensity and the final classification of each arm for the 4 trials are summarized in **Table 1**. In the 4 trials, participants' race categories included Black, White, and other (which had varying definitions across the trials and was reported as "All other"). For the 4 trials, race was ascertained by self-report.

CISNET Simulation Model

We used an established CISNET microsimulation model—Lung Cancer Interventions Decision Simulation (LuCID-Sim) (previously known as the Michigan Lung Cancer Natural History and Screening model or the British Columbia Cancer Research Institute Lung Cancer Natural History and Screening model)[27,28]—and the CISNET Smoking History Generator.[29,30] We used LuCID-Sim to project lung cancer onset, diagnosis, and survival and other-cause mortality based on individual age, sex, and smoking history for individuals who underwent lung cancer screening with and without each of the 8 composite treatment classes. Smoking histories for 1 million men and 1 million women from the 1960 US birth cohort were simulated using the Smoking History Generator and followed up from ages 45 to 90 years under 2021 USPSTF screening eligibility criteria. We modeled a 1-time cessation intervention at the time of the first screening. Its efficacy was based on the observed quit rate for each of the 8 composite treatment classes. Because the included trials did not include a no-intervention control group, background quit rates were obtained from the 2018 to 2019 Tobacco Use Supplement to the Current Population Survey.[31] For each composite treatment class, the relative risk of quitting was calculated as the ratio of the observed quit rate to the background quit rate, and

this ratio was then applied to the age-specific cessation probabilities in the Smoking History Generator. Lung cancer outcomes and other-cause mortality risks were then reevaluated based on the modified smoking history. Additional details of smoking cessation modeling have been described previously.[19,20,32] Moreover, we assumed 100% screening uptake and adherence and 100% cessation program participation to focus solely on the association of different cessation intervention intensities with lung cancer outcomes. However, we varied screening uptake and intervention adherence in sensitivity analyses.

Costs

We collected data from all 4 SCALE trials based on care-delivery costs at steady state, defined as the per-participant costs expected once the intervention was fully implemented under routine clinical

Table 1. Classification of Smoking Cessation Intervention Arms Across SCALE Trials by Pharmacotherapy Duration and Counseling Intensity

Trial	Study arm	Intervention characteristics	Pharmacotherapy (summed across types), total wk[a]	Total duration of counseling, min	Intensity category of pharmacotherapy[b]	Intensity category of counseling[c]	Composite treatment class
LSTH	Minimal	3 Sessions of 20-min counseling and a 2-wk supply of NRT patches	2	60.0	Low	Moderate	LowMED + ModCSL
	Intensive	8 Sessions of 20-min counseling and an 8-wk supply of NRT patches	8	160.0	Moderate	High	ModMED + HighCSL
PLUTO	TLC	Intensive telephone coaching with 1-y supply of NRT patches	20[d]	130.5[d]	High	High	HighMED + HighCSL
	TLC and MTM	TLC with pharmacist referral for prescription medications	18[d]	133.0[d]	High	High	HighMED + HighCSL
	TLC quarterly	A quarterly version of TLC with reduced contact frequency	23[d]	131.5[d]	High	High	HighMED + HighCSL
LUNG	Gain- framed video and NRT combo	2-wk Starter pack of dual NRT plus gain-framed resources	4	2.5	Moderate	Low	ModMED + LowCSL
	Control	Unframed resources with no NRT	0	0	Low	Low	LowMED + LowCSL
CASTL	16 Arms representing all combinations of MI (yes or no), NRT-L (yes or no), NRT-P (yes or no), and MF (loss or gain)	MI, no NRT, MF-L	0	72.0	Low	Moderate	LowMED + ModCSL
		MI, no NRT, MF-G	0	72.0	Low	Moderate	LowMED + ModCSL
		MI, NRT-P, MF-L	6	82.0	Moderate	Moderate	ModMED + ModCSL
		MI, NRT-P, MF-G	6	82.0	Moderate	Moderate	ModMED + ModCSL
		MI, NRT-L, MF-L	6	79.0	Moderate	Moderate	ModMED + ModCSL
		MI, NRT-L, MF-G	6	79.0	Moderate	Moderate	ModMED + ModCSL
		MI, NRT-P, NRT-L, MF-L	12	82.0	High	Moderate	HighMED + ModCSL
		MI, NRT-P, NRT-L, MF-G	12	82.0	High	Moderate	HighMED + ModCSL
		no MI, no NRT, MF-L	0	26.0	Low	Low	LowMED + LowCSL
		no MI, no NRT, MF-G	0	26.0	Low	Low	LowMED + LowCSL
		no MI, NRT-P, MF-L	6	36.0	Moderate	Low	ModMED + LowCSL
		no MI, NRT-P, MF-G	6	36.0	Moderate	Low	ModMED + LowCSL
		no MI, NRT-L, MF-L	6	33.0	Moderate	Low	ModMED + LowCSL
		no MI, NRT-L, MF-G	6	33.0	Moderate	Low	ModMED + LowCSL
		no MI, NRT-P, NRT-L, MF-L	12	36.0	High	Low	HighMED + LowCSL
		no MI, NRT-P, NRT-L, MF-G	12	36.0	High	Low	HighMED + LowCSL

Abbreviations: CASTL, Cessation and Screening to Save Lives; CSL, counseling intensity; HighCSL, high CSL (>82 minutes); HighMED, high MED (>8 weeks); LowCSL, low CSL (<60 minutes); LowMED, low MED (0-3 weeks); LSTH, Lung Screening, Tobacco, and Health; LUNG, Lung Cancer Screening Patients Utilizing Nicotine Replacement Therapy (NRT) and Gain-Framed Messages; MED, medication (pharmacotherapy) intensity; MF, message framing; MF-G, MF gain frame; MF-L, MF loss frame; MI, motivational interview; ModCSL, moderate CSL (60-82 minutes); ModMED, moderate MED (4-8 weeks); MTM, medication therapy management; NRT-L, NRT lozenges; NRT-P, NRT patches; PLUTO, Program for Lung Cancer Screening and Tobacco Cessation; SCALE, Smoking Cessation at Lung Examination; TLC, tobacco longitudinal care.

[a] Total weeks of pharmacotherapy were calculated as the sum of weeks across all pharmacotherapy types received, including NRT lozenges, NRT patches, and prescription medications; weeks from concurrent therapies were summed (eg, 6 weeks of patch + 6 weeks of lozenge = 12 weeks).

[b] Pharmacotherapy intensity categories: low (0-3 weeks of NRT and/or prescription drugs), moderate (4-8 weeks of NRT and/or prescription drugs), and high (>8 weeks of NRT and/or prescription drugs).

[c] Counseling intensity categories: low (<60 minutes), moderate (60-82 minutes), and high (>82 minutes).

[d] Participants in the PLUTO trial were offered up to 52 weeks of pharmacotherapy; however, the reported duration reflects the median pharmacotherapy requested and received by participants (18-23 weeks across study arms). Reported counseling duration similarly reflects the median duration completed by participants.

practice. Research and development costs were excluded, including trial-specific activities such as protocol development, regulatory oversight, research staff time for data collection, and other activities conducted solely for study purposes and not required for ongoing program delivery. Costs were grouped as fixed (eg, office space), variable (eg, staff time delivering cessation counseling and patient time in counseling), and wholesale costs of pharmacotherapy per patient.[33] Costs were estimated on an as-used basis using the median (IQR) or mean (SD) time that practitioners and participants spent in the cessation intervention and the percentage of participants who received the intervention. Time costs were valued based on median US wage rates of practitioners and patients from the US Bureau of Labor Statistics.[34] Costs were reported from the societal perspective. Detailed costing methods and trial-specific cost estimates are provided in eMethods 2 and eTables 3 to 6 in Supplement 1.

Lung cancer screening and diagnostic costs were sourced from the Centers for Medicare & Medicaid Services by using *Current Procedural Terminology* codes.[35-37] Lung cancer treatment costs by age, stage, histology, and phase of care (initial, continuing, and terminal) were based on Surveillance, Epidemiology, and End Results-Medicare data.[38] We used Medicare costs for all individuals with lung cancer; we did not consider costs of care for other tobacco-related diseases or patient time costs for screening and diagnosis. All costs were inflated to 2025 US dollars using the consumer price index.[39]

Utility Values and Quality-Adjusted Life-Years (QALYs) Calculation

The baseline age-specific and sex-specific utilities (ie, quality of life) were obtained from Hanmer et al,[40] which provided nationally representative US health-related quality-of-life estimates. Among those who developed lung cancer, we applied lung cancer-specific utilities based on histology (small cell vs non–small cell) and stage (limited and extended for small cell and I, II, III, and IV for non–small cell).[41] During the terminal phase of lung cancer, a terminal utility value was applied.[42] These values were converted to lung cancer–specific disutilities and applied to the age-specific and sex-specific baseline utilities to account for quality-of-life decrements associated with lung cancer, consistent with previous studies.[19,20,35-37]

Individual outputs from the LuCID-Sim model were summarized into person-years lived by age, sex, lung cancer status, histology, stage, and phase. QALYs were calculated by multiplying utility values by person-years lived in each health state and summing across the lifetime horizon.

Statistical Analysis

We calculated the cost per quit based on self-reported 7-day point prevalence abstinence. The CISNET simulation model was used to project the lifetime association of the composite treatment classes and screening with costs and effectiveness. Total lifetime costs included the cost of the cessation intervention, screening, diagnostic follow-up, and lung cancer–related costs (treatment, continuing care, and palliative care). We compared lung cancer screening with and without each composite treatment class, using incremental cost-effectiveness ratios (ICERs). We also calculated the incremental net monetary benefit for screening plus cessation strategies relative to screening alone using willingness-to-pay thresholds of $50 000 and $100 000 per QALY. Costs and QALYs were discounted at 3%. Data were analyzed between May 2025 and June 2026.

In sensitivity analyses, we varied (1) quit rates across the highest and lowest arm-specific quit rates within a given composite treatment class, (2) intervention costs across the highest and lowest arm-specific costs within each composite treatment class, and (3) combinations of costs and efficacy (ie, highest efficacy and lowest costs; lowest efficacy and highest costs). Additionally, we varied the background quit rates (ie, with no intervention) obtained from the Tobacco Use Supplement to the Current Population Survey over its 95% CI (3.97% [95% CI, 3.47%-4.55%]).[20,31] Furthermore, we varied the probability of receiving screening for each screen-eligible individual from 100% to 20%, reflecting the current uptake and adherence of lung cancer screening.[43] Consequently, cessation intervention uptake would also drop from 100% to 20%. To assess the potential association of

smoking relapse after quitting with the intervention, we reduced the quit rates by 50% for all composite treatment classes, approximating a 50% relapse rate within 1 year among individuals who initially achieved smoking cessation. Statistical analyses were performed using R, version 4.5.6 (R Project for Statistical Computing), with 2-sided $P < .05$ as the threshold for statistical significance.

Results

Of the 2520 participants included across the 4 SCALE trials (mean [SD] age, 63.8 [5.8] years), 1242 (49.3%) were female, and 1278 (50.7%) were male. The study included 323 Black participants (12.8%), 2061 White participants (81.8%), and 131 participants of other race (5.2%). Trial-specific intervention and participant characteristics are provided in eTable 2 in Supplement 1. The 8 composite treatment classes represented a range of pharmacotherapy and counseling intensities, from LowMED + LowCSL (0-3 weeks of NRT and/or prescription drugs and <60 minutes of counseling) to HighMED + HighCSL (>8 weeks of NRT and/or prescription drugs and >82 minutes of total counseling time) (Table 1).

Short-Term Composite Treatment Class Cost and Cost Per Quit

Mean costs and quit rates per treatment class are presented in **Table 2**. The mean (range) costs per patient ranged from $38.96 ($2.43-$57.45) for the LowMED + LowCSL treatment class to $803.10 ($563.18-$1212.73) for the HighMED + HighCSL treatment class, whereas the mean (range) self-reported quit rate varied from 10.1% (8.0%-13.0%) for the LowMED + ModCSL class to 27.3% (19.5%-31.4%) for the HighMED + HighCSL class, corresponding to relative risk of quitting between 2.55 and 6.87. The cost per quit ranged from $329.85 for LowMED + LowCSL to $2945.35 for HighMED + HighCSL.

Long-Term Cost-Effectiveness

QALYs and total costs over a lifetime horizon are shown in **Figure 1** and **Table 3**. Total lifetime costs ranged from $1.54 billion per 100 000 screen-eligible population for the HighMED + LowCSL

Table 2. Short-Term Costs Per Self-Reported Quit Rate for the 8 Composite Treatment Classes in the Context of Lung Cancer Screening

Composite treatment class	No. of intervention arms in each class	Quit rates, mean (range), %[a,b]	Composite treatment class cost per person, mean (range), $[b]	Cost per quit, $
LowMED+LowCSL	3	11.8 (11.0-13.0)	38.96 (2.43-57.45)	329.85
LowMED + ModCSL	3	10.1 (8.0-13.0)	108.22 (78.01-165.86)	1067.91
ModMED + LowCSL	5	12.8 (8.0-16.8)	193.16 (170.81-223.44)	1512.92
ModMED + ModCSL	4	12.5 (8.0-15.0)	218.30 (190.49-247.44)	1746.43
ModMED + HighCSL	1	10.3[c]	292.75[c]	2842.22
HighMED + LowCSL	2	22.5 (15.0-30.0)	320.46 (319.33-321.58)	1424.25
HighMED + ModCSL	2	15.0 (11.0-19.0)	341.01 (340.71-341.31)	2273.40
HighMED + HighCSL	3	27.3 (19.5-31.4)	803.10 (563.18-1212.73)	2945.35
Treatment outcomes	NA	15.3[c]	289.49[c]	1894.01

Abbreviations: CSL, counseling intensity; HighCSL, high CSL (>82 minutes); HighMED, high MED (>8 weeks of nicotine replacement therapy [NRT] and/or prescription drugs); LowCSL, low CSL (<60 minutes); LowMED, low MED (0-3 weeks of NRT); ModCSL, moderate CSL (60-82 minutes); MED, medication (pharmacotherapy) intensity; ModMED, moderate MED (4-8 weeks of NRT); NA, not applicable.

[a] Quit rates are based on self-reported 7-day point prevalence abstinence at 6 months after randomization for all trials except the PLUTO [Program for Lung Cancer Screening and Tobacco Cessation] trial, in which a 7-day point prevalence abstinence at 12 months after randomization was used.

[b] Composite treatment class quit rates and costs were calculated as unweighted means of arm-specific estimates. Values in parentheses indicate the range (minimum and maximum) across intervention arms within each class.

[c] No range is reported for treatment classes represented by a single arm.

treatment class to $1.63 billion per 100 000 screen-eligible population for the screening-alone scenario. All screening plus cessation strategies achieved higher QALYs at lower costs compared with screening alone. The HighMED + HighCSL treatment class had the highest QALYs at the second-lowest costs ($1.55 billion per 100 000 screen-eligible population), associated with an ICER of $991.15 per QALY compared with the HighMED + LowCSL treatment class with the second-highest QALYs (2.26 billion years per 100 000 screen-eligible population) and lowest costs ($1.54 billion per 100 000 screen-eligible population). The other 6 cessation plus screening strategies were dominated as they showed lower QALYs and higher costs. At a willingness-to-pay threshold of $50 000 or $100 000 per QALY, all screening plus cessation strategies had positive incremental net monetary benefits relative to screening alone, with the HighMED + HighCSL treatment class having the highest net monetary benefit ($3.22 billion at $100 000 per QALY), followed by the HighMED + LowCSL treatment class ($2.58 billion at $100 000 per QALY).

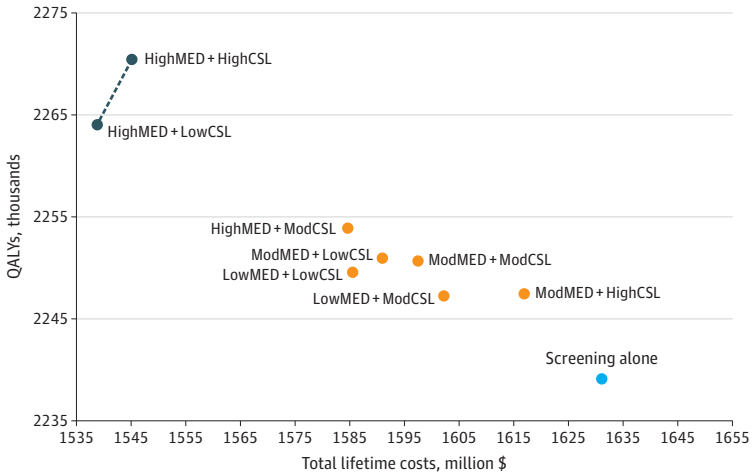
Sensitivity Analysis

In 1-way and 2-way sensitivity analyses, the ICERs of HighMED + HighCSL compared with HighMED + LowCSL ranged from −$1723 (cost saving) to $12 075 (**Figure 2**). Across most sensitivity analyses, the relative ranking of the 8 composite treatment classes remained similar to the base-case analysis. However, under assumptions of lower intervention costs or a lower background cessation rate, the HighMED + HighCSL treatment class became both the least costly and most effective strategy. Under assumptions of lower quit rates, with or without simultaneously increasing intervention costs, the LowMED + LowCSL treatment class became the least costly strategy, whereas the HighMED + HighCSL treatment class remained the most cost-effective. Additionally, lowering the cessation intervention and screening uptake and adherence from 100% to 20% doubled the ICER of HighMED + HighCSL to $2407 per QALY; assuming a 50% smoking relapse rate increased the ICER to $6362 per QALY. Across all sensitivity scenarios, the screening-alone strategy consistently yielded the highest total costs and the lowest QALYs. Detailed results are provided in eTables 7 to 12 in Supplement 1.

Discussion

This economic evaluation used data from 4 SCALE randomized clinical trials to evaluate the short-term and long-term cost-effectiveness of 8 composite cessation treatment classes implemented in

Figure 1. Dot Plot of Total Quality-Adjusted Life Years (QALYs) vs Total Lifetime Costs Per 100 000 of the Screen-Eligible Population for 8 Screening Plus Composite Treatment Class Scenarios and 1 Screening-Alone Scenario



CSL indicates counseling intensity; HighCSL, high CSL (>82 minutes); HighMED, high MED (>8 weeks); LowCSL, low CSL (<60 minutes); LowMED, low MED (0-3 weeks); MED, medication (pharmacotherapy) intensity; ModCSL, moderate CSL (60-82 minutes); ModMED, moderate MED (4-8 weeks). Dark blue circles indicate efficient strategies, with dashed line indicating efficiency frontier; orange circles, dominated strategies; light blue circle, screening-alone strategy.

the lung cancer screening setting. In the short-term, the LowMED + LowCSL treatment class (0-3 weeks of NRT and/or prescription and <60 minutes of counseling) had the lowest cost per quit at $330, while HighMED + HighCSL (ie, >8 weeks of NRT and/or prescription drugs and >82 minutes of counseling) had the highest at $2945. In the long term, HighMED + LowCSL (ie, >8 weeks of NRT and/or prescription drugs and <60 minutes of counseling) and HighMED + HighCSL were among the most efficient composite treatment classes across the base-case analysis and most of the sensitivity analyses. Compared with HighMED + LowCSL, the ICER of HighMED + HighCSL was $991 per QALY (ranging from cost saving to $12 075). Screening alone had consistently higher costs and lower QALYs than all screening plus cessation strategies.

The cost savings of screening plus cessation strategies resulted from reductions in LDCT screenings and diagnostic procedures as more individuals became ineligible after quitting for more than 15 years and from lower lung cancer treatment costs due to reduced lung cancer incidence (eTable 13 in Supplement 1). Our results are consistent with our team's previous cost-effectiveness analysis using observed data from the Georgetown University LSTH trial.[20] In contrast, our team's previous modeling study of hypothetical smoking cessation interventions using published data did not find screening plus cessation interventions to be cost-saving.[19] The previous results were driven by substantially higher intervention costs ($405-$957), higher use of prescribed medications (varenicline and bupropion), longer treatment durations, and lower relative quit rates (relative risk, 1.93-2.40) reported in the literature, which reflected older individuals receiving cessation interventions outside of screening settings.[19] In our current analysis, we used observed data from 4 SCALE trials, which had markedly higher efficacies (relative risk, 2.55-6.87) and had lower

Table 3. Model-Projected Lifetime Costs, QALYs, and Incremental Cost-Effectiveness of the 8 Screening Plus Cessation Scenarios and the Screening-Alone Scenario for the Screen-Eligible Population in the 1960 US Birth Cohort[a]

Scenario	Quit rate, %	Composite treatment class costs, $	Total costs, $	Total QALYs	Incremental costs, $	Incremental QALYs	ICER, $ per QALY[c]	Incremental net monetary benefits, $[b]	
								$50 000	$100 000
HighMED + LowCSL and screening	22.5	320.5	1 538 817 433	2 264 033	NA	NA	NA	1 338 130 486	2 583 989 081
HighMED + HighCSL and screening	27.3	803.1	1 545 169 610	2 270 442	6 352 177	6409	991.1	1 652 224 307	3 218 528 900
HighMED + ModCSL and screening	15.0	341.0	1 584 665 348	2 253 909	NA	NA	Dominated	786 074 385	1 525 724 793
LowMED + LowCSL and screening	11.8	39.0	1 585 538 856	2 249 564	NA	NA	Dominated	567 977 553	1 090 404 638
ModMED + LowCSL and creening	12.8	193.2	1 590 948 425	2 250 958	NA	NA	Dominated	632 229 193	1 224 317 486
ModMED + ModCSL and creening	12.5	218.3	1 597 502 666	2 250 658	NA	NA	Dominated	610 687 760	1 187 788 862
LowMED + ModCSL and screening	10.1	108.2	1 602 234 603	2 247 248	NA	NA	Dominated	435 455 901	842 057 080
ModMED + HighCSL and screening	10.3	292.7	1 616 900 843	2 247 466	NA	NA	Dominated	431 700 860	849 213 239
Screening alone	0	0	1 631 089 324	2 239 116	NA	NA	Dominated	NA	NA

Abbreviations: CSL, counseling intensity; ICER, incremental cost-effectiveness ratio; HighCSL, high CSL (>82 minutes); HighMED, high MED (>8 weeks of nicotine replacement therapy [NRT] and/or prescription drugs); LowCSL, low CSL (<60 minutes); LowMED, low MED (0-3 weeks of NRT); MED, medication (pharmacotherapy) intensity; ModCSL, moderate CSL (60-82 minutes); ModMED, moderate MED (4-8 weeks of NRT); NA, not applicable; QALYs, quality-adjusted life-years.

[a] Absolute numbers are per 100 000 screen-eligible population. Strategies were ordered from least to most costly.

[b] Incremental net monetary benefit was calculated as λ × (QALYs of strategy − QALYs of screening alone) − (costs of strategy − costs of strategy alone), using screening alone as the reference strategy and a willingness-to-pay threshold λ = $50 000 per QALY or $100 000 per QALY.

[c] Strategies that were more expensive and yielded fewer QALYs were considered dominated.

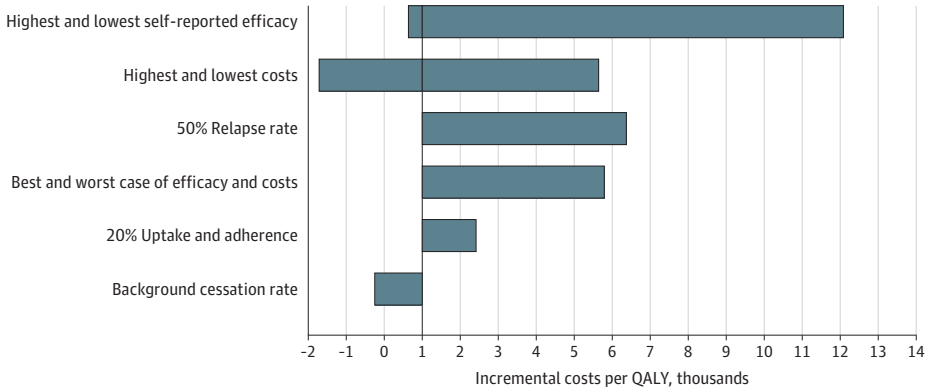
intervention costs (largely due to the predominant use of NRTs). These improvements in both cost and efficacy led to the enhanced cost-effectiveness in this study.

Our results could provide actionable evidence to guide health systems in selecting the modality and intensity of smoking cessation interventions based on their budgetary and implementation capacity. Despite national recommendations to integrate smoking cessation into shared decision-making for lung cancer screening, substantial gaps remain between counseling discussions and the actual delivery of cessation services. Although most clinicians advise smoking cessation during shared decision-making, few arrange follow-up to support quitting, raising concerns about the actual receipt of cessation services.[44] Health systems with established tobacco treatment programs are better positioned to connect patients to pharmacotherapy and counseling, whereas hospitals without such programs face greater implementation barriers.[45] The new 2026 Healthcare Effectiveness Data and Information Set performance measures—which, for the first time, require reporting on tobacco screening and receipt of cessation interventions—create a strong incentive for health systems to strengthen cessation support.[46] In this context, our findings suggest that proactive referral and enrollment in quit-line services may represent a cost-effective short-term approach for hospitals with limited capacity, as many state quit-line services provide free NRT and telephone-based or web-based counseling.[47,48] For systems with centralized lung cancer screening programs and established cessation programs, increasing the intensity of pharmacotherapy and counseling offers the potential of yielding substantial long-term health gains and cost savings. Policy and reimbursement strategies that better align hospital financial incentives with downstream health benefits and cost offset may be necessary to facilitate the adoption of high-intensity cessation support.

Strengths and Limitations

Several strengths of this study are noteworthy. We incorporated actual observed cost and efficacy data from 4 randomized clinical trials (23 arms in total) conducted within lung cancer screening settings. To our knowledge, this is the first study to pool cessation intervention data from trials conducted in screening settings across different health care systems and implementation programs, which enhances the generalizability of our findings and supports their relevance for diverse health care systems and lung cancer screening programs. These trial arms spanned a broad range of pharmacotherapy and counseling intensity, allowing for an evaluation of how varying intervention intensities were associated with cost-effectiveness. Using trial data, we estimated short-term outcomes (costs per quit), and, using a validated CISNET lung model, we projected lifetime cost-effectiveness (ICERs), providing a comprehensive assessment of intervention performance. The modeling framework also enabled evaluation of joint screening and cessation programs under a wide range of assumptions, including screening and cessation intervention uptake and adherence

Figure 2. Bar Graph of the Effects of 1-Way and 2-Way Sensitivity Analyses on Incremental Costs Per Quality-Adjusted Life Year (QALY)



The high medication (pharmacotherapy) intensity (HighMED) + high counseling intensity (HighCSL) treatment class (ie, >8 weeks of nicotine replacement therapy [NRT] and/or prescription drugs and >82 minutes of counseling) compared with the HighMED + low counseling intensity (LowCSL) treatment class (ie, >8 weeks of NRT and/or prescription drugs and <60 minutes of counseling).

(20%-100%), intervention costs, efficacies, and no-intervention quit rates. Of importance, the relative ranking of intervention strategies remained stable, and incremental cost-effectiveness ratios remained at or under $12 075 per QALY, which is well under the commonly used $50 000 or $100 000 US willingness-to-pay threshold.[49] This underscores the robustness of our findings.

Similar to our team's previous analyses,[19,20] this study has several limitations. First, while we modeled competing mortality by smoking, we did not model the incidence of other tobacco-related diseases (eg, chronic obstructive pulmonary disease), which may have led to underestimation of the health benefits and cost savings associated with smoking cessation. We also did not account for improvements in quality of life following cessation. Additionally, we did not include patient and caregiver time costs or productivity losses associated with lung cancer screening, diagnostic procedures, and treatments. These omissions likely resulted in conservative cost-effectiveness estimates. Second, we relied on self-reported quit rates, as they were consistently available across trials. However, self-reports may overestimate the quit rates. Hence, we varied efficacy widely in sensitivity analyses to account for this uncertainty. Third, smoking relapse was not explicitly modeled because relapse data were not available in the trials. In sensitivity analyses, we assumed a uniform 50% reduction in quit rates to gauge the potential impact of relapse, and the conclusions were unchanged. Moreover, we did not consider repeated interventions at subsequent screens, given the limited data on the effectiveness in lung cancer screening populations. Future modeling efforts incorporating these features are warranted as data become available. Fourth, we harmonized 23 intervention arms from 4 trials into 8 intervention groups based on the intensity of pharmacotherapy and counseling. Although this approach facilitated meaningful comparisons, each trial had unique characteristics and populations that could have differentially influenced outcomes. We addressed such heterogeneity through sensitivity analyses that varied intervention costs and quit rates across the observed range, which likely captured some of the variability across trials. In addition, we did not evaluate the heterogeneity in cost-effectiveness across sociodemographic subgroups, although differences in smoking behaviors, access to care, and baseline lung cancer risk may lead to variation in intervention efficacy and cost-effectiveness across populations.[50-52] Further research is needed to evaluate subgroup-specific cost-effectiveness and the potential of joint cessation and screening programs to reduce tobacco-related health disparities.

Conclusions

In this economic evaluation of smoking cessation interventions integrated into lung cancer screening, the LowMED + LowCSL treatment class had the lowest short-term cost per quit, whereas the HighMED + LowCSL and HighMED + HighCSL treatment classes yielded favorable long-term cost-effectiveness. Across all intensity levels, integrating smoking cessation into screening was cost-saving compared with screening alone, supporting implementation of cessation support in all screening programs. Notably, although the highest-intensity treatment class may require greater start-up and implementation resources, it was associated with the largest health gains and was the most cost-effective in the long term. Health care systems can use these results, in conjunction with their own budgetary and resource considerations, to guide decisions on the types and intensity of cessation interventions to adopt within their screening programs.

ARTICLE INFORMATION

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SUPPLEMENT 2.

Data Sharing Statement