Lung Cancer Screening With Low-Dose Computed Tomography: Costs, National Expenditures, and Cost-Effectiveness

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Key Words

Screening, CT scan, lung cancer

Abstract

A recent randomized trial showed that low-dose CT (LDCT) screening reduces lung cancer mortality. Health care providers need an assessment of the national budget impact and cost-effectiveness of LDCT screening before this intervention is adopted in practice. Using data from the 2009 National Health Interview Survey, CMS, and the National Lung Screening Trial (NLST), the authors performed an economic analysis of LDCT screening that includes a budget impact model, an estimate of additional costs per lung cancer death avoided attributed to screening, and a literature search of cost-effectiveness analyses of LDCT screening. They conducted a one-way sensitivity analysis, reporting expenditures in 2011 U.S. dollars, and took the health care payer and patient perspectives. LDCT screening will add $1.3 to $2.0 billion in annual national health care expenditures for screening uptake rates of 50% to 75%, respectively. However, LDCT screening will avoid up to 8100 premature lung cancer deaths at a 75% screening rate. The prevalence of smokers who qualify for screening, screening uptake rates, and cost of LDCT scan were the most influential parameters on health care expenditures. The additional cost of screening to avoid one lung cancer death is $240,000. Previous cost-effectiveness analyses have not conclusively shown that LDCT is cost-effective. LDCT screening may add substantially to the national health care expenditures. Although LDCT screening can avoid more than 8000 lung cancer deaths per year, a cost-effectiveness analysis of the NLST will be critical to determine the value of this intervention and to guide decisions about its adoption. (*JNCCN* 2012;10:267–275)

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Lung cancer is the leading cause of cancer deaths in the United States, accounting for 221,000 new cancer cases and 157,000 deaths in 2011.[1] This high mortality rate occurs partly because most patients present with advanced stages, when the disease is rarely curable. Lung cancer screening tests can potentially reduce cancer mortality through detecting tumors at earlier stages, when treatments have higher chances of cure.[2,3]

The NCI-sponsored National Lung Screening Trial (NLST) is the first randomized trial to show a reduction in lung cancer mortality from any screening modality; in this case, low-dose chest CT (LDCT) screening.[4] From August 2002 to April 2004, the study enrolled 53,454 high-risk individuals aged 55 to 74 years, defined as current smokers of 30 packs-per-year (ppy) or more, or former smokers with the same smoking history who quit no longer than 15 years before enrollment, and randomly assigned them to receive screening with LDCT versus chest radiograph. Persons assigned to the intervention arm received annual LDCT scans for 3 consecutive years and underwent follow-up thereafter, and persons assigned to the control arm received annual chest radiographs for the same period. With a median follow-up of 6.5 years, the study showed a 20% relative reduction in lung cancer mortality favoring the LDCT screening arm.[4]

The NLST results have sparked intense debate among health care providers and policy-makers about the logistics and economic implications of implementing LDCT screening nationwide.[5,6] The main concerns include the financial burden that a national LDCT screening program would impose on the U.S. health care system, which currently struggles to contain escalating expenditures, and the patient burden that results from a high false-positive screening rate (estimated as 96.4% in the NLST), including unnecessary costs and harms caused by additional imaging tests and surgical procedures.

In response to these concerns, the authors developed a budget impact model to estimate the additional national expenditures expected if LDCT is widely adopted in the United States. Because part of the national burden of screening will be paid directly by patients in the form of copays, the authors also estimated the out-of-pocket patient costs for the population that would be eligible for LDCT screening. Finally, they reviewed the pertinent literature to identify factors that will most influence the cost-effectiveness of this test.

Methods

Budget Impact Assessment

Population Eligible for LDCT Screening: Data from the U.S. 2009 Census and the CDC National Health Interview Survey (NHIS) were used to estimate the number of persons eligible for annual LDCT screening, based on the inclusion criteria reported in the NLST trial.[4,7,8] The U.S. 2009 Census provides the estimated number individuals in the United States aged 55 to 74 years, and the NHIS provides the estimated prevalences of current and former smokers within this age group in 2009, but it does not provide the prevalence of smoking stratified by tobacco exposure in packs per year. The Minnesota Adult Tobacco Survey (MATS) provides the prevalence of heavy smokers for that state, defined as those who smoke 25 or more cigarettes per day. In 2010, this prevalence was estimated at 6.3% of all smokers.[9] Because Minnesota has a lower smoking prevalence compared with the national average, and because MATS did not define heavy smoking based on ppy, the authors assumed that 10% of current and former smokers in the United States have 30 or more ppy tobacco exposure. They multiplied the number of persons eligible for LDCT screening by screening uptake rates of 50% and 75%, respectively, to estimate the actual number of persons undergoing screening in the United States per year. They based these rates on the currently reported screening rates for colorectal and breast cancers, respectively.[10,11]

LDCT Screening Performance: The annual number of persons with positive LDCT screening was based on the proportion of NLST subjects with a positive test on the second year of screening (28%) to reflect a steady state of prevalent and incident cases. This number was multiplied by the false-positive rate (96.4%) to obtain the number of persons with false-positive screening tests, and the difference between all positives and false-positives was the number of persons with true-positive, screen-detected lung cancer cases.

Health Resource Use Related to LDCT Screening: For individuals with a positive LDCT screening test, the number of confirmatory imaging tests, percutaneous biopsies, bronchoscopies, and surgical procedures was based on the proportions of NLST patients who underwent these tests and procedures after a positive LDCT scan. The authors used the proportions of follow-up tests reported cumulatively after 3 consecutive years in the NLST instead of the proportions reported in the first year to better reflect the use of health care resources nationwide. The NLST reported the proportions of major, intermediate, and minor complications attributed to the follow-up procedures in the patients with and without a final diagnosis of lung cancer. Weighted-average proportions of major and intermediate complications were calculated for all patients with a positive LDCT screening in the NLST to estimate the total number of major and intermediate complications that occurred in screened persons in the United States after receiving a positive LDCT screening. Minor complications were not included because these occurred infrequently (2% of NLST subjects) and there was no easily identifiable way to estimate their unit costs.

Lung Cancer Cases: The authors applied the tumor stage distribution of the 1060 lung cancer cases diagnosed in the LDCT arm of the NSLT to estimate the number of national lung cancer cases detected through LDCT screening within each stage. They reclassified the TNM stage reported in the NLST into the SEER historical staging system as follows: stages I and II as "localized," stage III as "regional," and stage IV as "distant."[12] They opted to use the SEER historical staging because it allows a comparison between the stage distribution in screening-detected cases and the current stage distribution in the nonscreened U.S. lung cancer cases as reported by Siegel et al.[1]

Annual Health Care Expenditures: To estimate annual health care expenditures related to LDCT screening, the Centers for Medicare and Medicaid Service Healthcare Common Procedure Coding System (HCPCS) and Diagnostic Related Group codes were used together with the relevant Medicare fee schedules to obtain the unit costs for the tests, procedures, and complications that followed a positive LDCT scan in NLST.[13] From these expenditures, the authors subtracted the expenditures related to the diagnostic workup procedures that would have been performed for patients diagnosed with lung cancer without screening, based on the proportions of confirmatory tests reported in the NLST control arm. Because no specific reimbursement has been set for LDCT screening, the HCPCS reimbursement rate for conventional noncontrast chest CT was used as a proxy for the unit cost of an LDCT. All expenditures consist of the product of the unit cost of a health care resource by the number of patients who used that resource. The model estimates expenditures from the health care payer and patient perspectives, with a time horizon of 1 year.

The authors estimated net treatment expenditures as the difference between the expenditures from treating both screen-detected cases and cases who missed screening (because the screening rates are not 100%) and the expenditures from treating lung cancer cases that would have been diagnosed without any screening program. They estimated overdiagnosis (those diagnosed through screening that would otherwise not have been detected during the individual's lifetime) as the proportion of excess lung cancer cases in the LDCT arm relative to the control arm of NLST, according to the following formula: 1 – (1060/941) = 0.13, or 13%.[4]

Treatment expenditures in screening and no-screening scenarios consisted of the number of lung cancer cases multiplied by the unit costs of stage-specific treatment of lung cancer. The lung cancer treatment unit costs were based on a recent study of costs in Medicare enrollees.[14] For localized stage, the authors used treatment costs reported in the first 12 months after diagnosis per male enrollee older than 65 years. For regional and distant stages, the costs reported for the last 12 months of life were used, because these stages are associated with a median overall survival of 12 to 18 months.[15,16]

Cost Per Lung Cancer Death Avoided

To provide an initial estimate of the value of LDCT screening, the authors calculated the ratio of additional costs of LDCT screening per lung cancer death avoided by screening. This ratio consists of the total annual health care expenditures attributed to LDCT screening divided by the additional lung cancer deaths avoided by LDCT screening. The number of lung cancer deaths avoided related to screening consisted of the total number of persons screened divided by the number needed to screen to avoid one lung cancer death as reported by the NLST.[4]

Sensitivity Analysis

To address the uncertainty related to model parameters, the authors varied one parameter at a time and reported the ranges of total health care expenditures attributable to screening expected for these parameter variations.

Out-of-Pocket Individual Cost

Medicare and private health insurers currently do not have a policy regarding coverage for LDCT screening.[17,18] To estimate the individual out-of-pocket costs from LDCT screening, the unit cost of an LDCT scan was multiplied by hypothetical copay rates of 0%, 10%, and 20%. These costs were added to the average cost of subsequent tests, procedures, and treatments that follow a positive scan per screened individual, assuming a fixed copay of 20% for all costs that follow the LDCT scan.

When appropriate, the Consumer Price Index – Medical Practice was used to adjust costs for inflation, and all costs were reported in 2011 U.S. dollars.

Literature Review to Identify Factors Influencing the Cost-Effectiveness of LDCT Screening

To place this study in the context of current knowledge regarding the cost-effectiveness of LDCT screening, a literature review was performed to provide an insight into the likelihood that LDCT screening will be cost-effective and to identify the factors that will likely drive the cost-effectiveness. The EconLit, Embase, PubMed, and Web of Science databases were searched using the search terms "lung cancer screening" and "computerized tomography."

Results

U.S. National Budget Impact

The NHIS reported a prevalence of current and former smokers aged 55 to 74 years of 21% and 42%, respectively, in 2009.[8] If 10% of all smokers qualify for LDCT screening, approximately 3.5 million persons will be eligible for LDCT screening annually. For a screening rate of 75%, about 2.6 million eligible individuals will undergo screening (Table 1).

Table 1 Expected Annual Health Care Resource Use Attributable to Low-Dose CT Screening

	%	N (50% Screening Rate)	N (75% Screening Rate)
Population eligible for screening			
Age 55–74 y in 2009 Census[7]		55,579,000	55,579,000
Prevalence current smokers ≥ 30 ppy[8,9]	2.1	572,464	858,696
Prevalence former smokers ≥ 30 ppy past 15 years[8,9]	4.2	1,164,380	1,746,570
Population screened	6.3	1,736,844	2,605,266
Test performance			
Positive screening rate[4]	28.0	486,316	729,474
False-positive rate[4] (0.964)	27.0	468,809	703,213
True-positive rate	1.0	17,507	26,261
Health resource use (for those with positive findings on screening CT)[4]			
Positive low-dose CT scan	100.0	486,316	729,474
Follow-up chest radiograph	14.4	70,030	105,044
Follow-up chest CT scan	49.8	242,185	363,278
Follow-up PET/CT scan	8.3	40,364	60,546
Percutaneous biopsy	1.8	8,754	13,131
Bronchoscopy without biopsy	1.8	8,754	13,131
Bronchoscopy with biopsy	2.2	10,699	16,048
Mediastinoscopy	0.7	3,404	5,106
Thoracoscopy	1.3	6,322	9,483
Thoracotomy	2.9	14,103	21,155
Major complications	0.06	292	438
Intermediate complications	1.3	6,322	9,483
Lung cancer cases: screening adopted[4]			
Screening-detected cases			
Localized	57.1	9,997	14,995
Regional	21.2	3,712	5,567
Distant	21.7	3,799	5,699
Total cases	100.0	17,507	26,261
*Cases in persons who missed screening**			
Localized	16.1	2,457	1,228
Regional	23.7	3,603	1,802
Distant	60.2	9,172	4,586
Total cases	100.0	15,231	7,616
*Lung cancer cases: screening not adopted**[1]			
Localized	16.1	4,913	
Regional	23.7	7,206	
Distant	60.2	18,343	
Total expected cases	100.0	30,463	

Abbreviation: ppy, packs per year.
*Based on the number of lung cancer cases that would be detected if all eligible persons undergo screening, adjusted for 13% of overdiagnosis.

The number of positive and false-positive screening tests will be approximately 729,000 and 703,000, respectively. Most subsequent imaging tests consist of follow-up chest CT scans, followed by chest radiographs and PET/CT scans. Most subsequent procedures consist of bronchoscopies (with and without biopsies), followed by thoracotomies and percutaneous biopsies. Screen-detected lung cancer cases will occur in 26,000 screened individuals. All of these estimates decrease proportionally, for a screening rate of 50% (Table 1). Conversely, approximately 15,000 and 8,000 lung cancer cases will occur in individuals who missed screening for screening rates of 50% and 75%, respectively, accounting for 13% of overdiagnosis. Without any screening, approximately 30,000 lung cancer cases will be diagnosed in this population.

More than half (57.1%) of screening-detected lung cancer cases are of localized stage, compared with 16.1% in those who miss screening or do not participate in any screening program. A shift from distant stage to localized stage cases accounts for most of the difference in stage distribution in screened versus nonscreened cases. The proportion of regional-stage cases is similar in screened versus nonscreened cases (21.2% vs. 23.7%; Table 1).

For a screening rate of 75%, the authors' model estimates approximately $2.0 billion in national expenditures related to the LDCT scan and the imaging tests and procedures that follow a positive screening test (Table 2). The LDCT scan accounts for most (59%) of these expenditures, followed by thoracotomies (14%) and follow-up CT scans (11%), respectively. In this scenario, treatment expenditures will total $2.7 billion, including expenditures related to treating lung cancer cases in individuals who missed screening. Procedure and treatment expenditures for screen-detected cases decrease proportionally for a screening rate of 50% (Table 2). The similar total treatment expenditures for the 2 screening rates occur because more patients miss screening at a rate of 50% compared with 75%, and 60% of the lung cancer cases who miss screening are diagnosed with distant stage, which costs more to treat than localized stage.

The expected treatment expenditures without any screening are $2.8 billion, accounting for overdiagnosis. A screening rate of 75% will result in a treatment cost offset of $66 million. Accounting for treatment cost offsets, overdiagnosis, and all other expenditures, LDCT screening will cost a total of $1.3 to $2.0 billion per year to the U.S. health care system for screening rates of 50% and 75%, respectively.

Sensitivity Analysis

Table 3 shows how changes in model parameters affect the expected annual U.S. health care expenditures attributable to LDCT screening. The 3 most influential parameters affecting expenditures were smoking prevalence of 30 ppy or more (expenditure range of $2.0 billion), screening uptake rate (range of $1.3 billion), and cost of LDCT scan (range of $0.7 billion), respectively. If all eligible individuals undergo screening, the national expenditures will be $2.6 billion.

Additional Cost of LDCT Screening Per Lung Cancer Death Avoided

Using the number needed to screen to avoid 1 lung cancer death of 320 reported in the NLST,[4] an additional 5400 and 8100 premature lung cancer deaths will be avoided annually if 50% and 75% of eligible persons undergo LDCT screening, respectively (Table 4). LDCT screening costs approximately an additional $240,000 per additional lung cancer death avoided, compared with no screening and accounting for overdiagnosis.

Individual Out-of-Pocket Costs

The average individual out-of-pocket costs are $151, $99, and $46 per year for LDCT scan copays of 20%, 10%, and 0%, respectively, assuming a fixed copay of 20% for all tests, procedures, and treatments that follow a positive screening test.

Literature Review of Cost-Effectiveness Analyses of LDCT Screening

Black et al.[19] conducted a systematic review of the clinical and cost-effectiveness of LDCT screening for lung cancer from the perspective of the United Kingdom's National Health Service. The review included 6 economic evaluations published from 2000 to 2003; 5 from the United States[20–24] and 1 from Japan.[25] The review was unable to draw any definitive conclusion on cost-effectiveness based on the available evidence at the time. The main limitations found in the reviewed studies were the lack of evidence supporting a mortality benefit from LDCT screening, lack of consideration for the costs of procedures caused by false-positive results, no consideration for screening adherence, and no assessments of the budget impact of LDCT screening on national health care expenditures.

Table 2 Expected Annual Health Care Expenditures Attributable to Low-Dose Chest CT Screening

Health Care Resource	Unit Cost (2011 US$)[13,14]	Expenditures if 50% Screening Rate (US$ Millions)	Expenditures if 75% Screening Rate (US$ Millions)
Low-dose CT (LDCT) scan	527	915.0	1,372.5
Follow-up chest radiograph	92	6.5	9.7
Follow-up chest CT scan	527	127.6	191.4
Follow-up PET/CT scan	1,491	60.2	90.2
Percutaneous biopsy	979	8.6	12.9
Bronchoscopy without biopsy	1,226	10.7	16.1
Bronchoscopy with biopsy	1,270	13.6	20.4
Mediastinoscopy	3,814	13.0	19.5
Thoracoscopy	3,795	24.0	36.0
Thoracotomy	11,285	159.2	238.7
Major complications	10,096	2.9	4.4
Intermediate complications	6,072	38.4	57.6
Workup for lung cancer without screening*		32.5	32.5
Total procedure and complication expenditures		**1,347.1**	**2,036.9**
Treatment expenditures in screen-detected cases[14]			
Localized stage	62,833	628.1	942.2
Regional stage	98,368	365.1	547.6
Distant stage	98,368	373.7	560.6
Treatment expenditures in cases who missed screening[†,10]			
Localized stage	62,833	154.4	77.2
Regional stage	98,368	354.4	177.2
Distant stage	98,368	902.2	451.1
Screening treatment expenditures		**2,777.9**	**2,755.9**
Treatment if screening not adopted[†,14]			
Localized stage	62,833	308.7	308.7
Regional stage	98,368	708.9	708.9
Distant stage	98,368	1,804.4	1,804.4
Total treatment if no screening		**2,822.0**	**2,822.0**
Treatment cost offset from screening		**44.1**	**66.1**
Annual total expenditures attributable to LDCT screening		**1,303.0**	**1,970.8**

*The expenditures related to the workup for lung cancer without screening were subtracted from the expenditures related to screening to obtain the actual workup costs of LDCT screening.
†Based on the number of lung cancer cases that would be detected if all eligible persons undergo screening, adjusted for 13% of overdiagnosis.

Since the Black et al.[19] report, the authors identified 4 additional cost-effectiveness analyses of LDCT screening for lung cancer; 1 from Australia and 2 from the United States (a third meeting abstract was excluded because of insufficient information).[26–28] The Australian report evaluated the cost-effectiveness of "opportunistic" spiral LDCT screening in high-risk individuals for lung cancer, concluding that reductions in lung cancer mortality of less than 20% are unlikely to be cost-effective at a $50,000 per quality adjusted life year (QALY) threshold.[26] Castleberry et al.[27] argued that the number of long-term survivors,

Table 3 Impact of Variation in Model Parameters on Total Annual Health Care Expenditures Attributable to Low-Dose CT Screening

Parameter*	Range	Expenditures (US$ Millions)
Prevalence of smoking ≥ 30 ppy†	5%–15%	969.2–2,972.5
Positive results rate	20%–40%	1,790.6–2,241.2
False-positive screening rate	75%–96.4%	1,578.0–1,970.8
Screening uptake rate	50%–100%	1,303.0–2,638.6
Cost of LDCT scan‡	$250–$527	1,249.6–1,970.8
Overdiagnosis	0–20%	1,649.7–2,143.7
Lung cancer workup cost without screening	± 20%	1,964.3–1,977.3
Cost of treatment: localized stage‡	$40,000–$70,000	1,712.5–2,051.8
Cost of treatment: regional stage‡	$70,000–$130,000	1,966.2–1,975.9
Cost of treatment: distant stage‡	$70,000–$130,000	2,199.4–1,715.9

Abbreviations: LDCT, low-dose CT; ppy, packs per year.
*The base case assumes a 75% screening uptake rate.
†For both former and current smokers.
‡All costs are in 2011 US$.

rather than QALYs, is the most important outcome measure in screening cost-effectiveness, particularly for patients at high risk for lung cancer. However, this report does not provide objective cost-effectiveness results for LDCT screening.

In response to the findings of the NLST trial, McMahon et al.[29] used an existing lung cancer model to estimate the cost-effectiveness of lung cancer LDCT screening in the U.S. population and identify screening program characteristics that have the greatest influence on cost-effectiveness. Their conclusion was that achievable smoking cessation rates will be strongly linked to the cost-effectiveness of LDCT lung cancer screening. Annual screening of current and former smokers aged 50 to 74 years would cost between $126,000 and $169,000 per QALY for smokers with a minimum of 20 ppy, or $110,000 and $166,000/QALY for smokers with a minimum of 40 ppy, compared with no screening and assuming no difference in smoking cessation. If screening (as a "teachable moment" to motivate cessation) doubles background quit rates, the cost per QALY ratio drops to $75,000. In contrast, if screening serves as an artificial confirmation that smoking is safe, then it provides fewer QALYS than smoking cessation therapies.

In summary, until the publication of the NLST trial, previous cost-effectiveness analysis could not conclusively show that LDCT screening is cost-effective, mainly because of the lack of high-level evidence showing reduction in cancer mortality from screening. Published results from the NLST trial provide insight into the effectiveness piece of LDCT screening for lung cancer, and further analysis of this trial will help determine if LDCT is cost-effective. As the NLST trial organizers note, the cost-effectiveness of an LDCT screening program will depend on factors other than costs and cancer mortality, including the population targeted for screening, the frequency of screening, interpretation

Table 4 Additional Costs Per Lung Cancer Death Avoided in Persons Eligible for Low-Dose CT Screening, Compared With No Screening

Parameters	N (50% Screening Rate)	N (75% Screening Rate)
Number of persons screened per year	1,736,844	2,605,266
Number needed to screen to avoid one lung cancer death[4]	320	320
Additional lung cancer deaths avoided by screening per year	5,428	8,141
Additional costs of screening per year (US$ millions)	1,303.0	1,970.8
Additional cost per lung cancer death avoided (2011 US$)	240,081	242,074

thresholds, the impact of adherence, the costs and harms of radiation exposure, positive screening results and flow-on diagnostics and treatments, overdiagnosis, and the impact on competing smoking cessation interventions.

Discussion

Using nationally representative estimates of the prevalence of current and former smokers, data from the NLST, and Medicare expenditures, the authors estimated that LDCT screening for lung cancer will increase national annual health care expenditures by $1.3 to $2.0 billion, depending on adherence. These expenditures represent a 12% to 19% increase over the current $12.1 billion spent annually for lung cancer care in the United States.[14] The substantial expected budget impact of a national LDCT screening program will impose additional challenges to public and private insurers who struggle to contain the escalating costs of health care. Given a fixed budget, insurers will likely have to choose which health care services they could restrict coverage to generate the funds to cover the adoption of LDCT screening for their enrollees. This could be done, for example, through reducing coverage for expensive interventions of unproven health benefits, such as fourth or fifth line of chemotherapy in advanced non–small cell lung cancer.[30]

Despite its substantial impact on national health care expenditures, screening high-risk individuals for lung cancer with LDCT can potentially avoid more than 8000 additional premature lung cancer deaths annually, compared with no screening. This benefit comes at an additional annual cost of $240,000 per death avoided. Although the NLST has not yet released data on QALYs and costs to allow a cost-effectiveness analysis of LDCT screening, the ratio of additional cost to lung cancer death avoided may represent an initial assessment of the value of this intervention; however, no thresholds based on costs per death avoided are available to determine if LDCT screening is cost-effective. A standard cost-effectiveness analysis based on the NLST data will be critical to inform the value and guide the decision regarding nationwide implementation of LDCT screening.[31]

The prevalence of persons eligible for screening (smoking history ≥ 30 ppy) is the most influential parameter that determines the overall burden of LDCT. This suggests that expanding LDCT screening to individuals who do not meet the NLST screening criteria (e.g., smoking history of 20 ppy) could increase expenditures sharply, with no evidence showing a mortality benefit of screening these individuals. The high false-positive rate of LDCT screening, as reported in the NLST, will clearly contribute to these expenditures, because a false-positive screening result leads to unnecessary follow-up tests and procedures, and their respective costs. Careful interpretation of LDCT scans may reduce the number of false-positive results, which will reduce the impact of this intervention on health care expenditures. In addition, if health care providers adhere to diagnostic algorithms that follow a positive LDCT screening test, the number of false-positive results will likely decrease, which will likely help contain LDCT screening expenditures.[32]

This study has several limitations. Because of the lack of published data, the budget model assumed that 10% of current and former smokers would qualify for screening based on the NLST criteria, and that the cost of LDCT scan equals the cost of a conventional noncontrast chest CT, but the true value of these parameters is unknown. The authors' model assumed fixed parameter values, but costs and number of screened individuals will likely vary over time, and health care expenditures will change as a result of these parameter variations.[10,11] The authors estimated overdiagnosis as the proportion of excess cases diagnosed in the LDCT screening arm of the NLST relative to its control arm, but no standard method exists to allow an accurate estimate of overdiagnosis. Costs related to cancers that occur as a result of radiation from LDCT scans were not accounted for, because the NLST has not yet provided information on the incidence of these cancers. This study also did not account for indirect medical costs, including days of missing work.

Conclusions

Implementation of LDCT screening will add $1.3 to $2.0 billion in annual national health care expenditures for screening rates of 50% to 75%, respectively. LDCT screening has the potential to avoid more than 8000 premature lung cancer deaths per year, but the true value of this intervention awaits the results of a formal cost-effectiveness analysis of long-term costs and outcomes compared with no screening. Efforts to reduce false-positive screening results and adherence to diagnostic algorithms after a positive LDCT screening test will likely reduce the impact of LDCT screening on health care expenditures.

References

1. Siegel R, Ward E, Brawley O, et al. Cancer statistics, 2011: the impact of eliminating socioeconomic and racial disparities on premature cancer deaths. CA Cancer J Clin 2011;61:212–236.
2. Patz EF Jr, Goodman PC, Bepler G. Screening for lung cancer. N Engl J Med 2000;343:1627–1633.
3. Mulshine JL, Sullivan DC. Clinical practice. Lung cancer screening. N Engl J Med 2005;352:2714–2720.
4. Aberle DR, Adams AM, Berg CD, et al. Reduced lung-cancer mortality with low-dose computed tomographic screening. N Engl J Med 2011;365:395–409.
5. National Institute for Occupational Safety and Health. Helical CT scans and lung cancer screening. Available at: http://www.cdc.gov/niosh/blog/nsb011011_ct.html. Accessed October 20, 2011.
6. Fiore K. Mortality benefit seen with CT halts lung cancer screening trial. MedPage Today. Available at: http://www.medpagetoday.com/HematologyOncology/LungCancer/23158. Accessed October 20, 2011.
7. U.S. Census Bureau. Population Estimates. U.S. Census Bureau, 2010. Available at: http://www.census.gov/popest/estimates.php. Accessed October 20, 2011.
8. Pleis JR, Ward BW, Lucas JW. Summary Health Statistics for U.S. Adults: National Health Interview Survey, 2009. Vital Health Stat 2010;10:1–217.
9. Centers for Disease Control and Prevention. Decrease in smoking prevalence—Minnesota, 1999–2010. MMWR Morb Mortal Wkly Rep 2011;60:138–141.
10. Breen N, Gentleman JF, Schiller JS. Update on mammography trends: comparisons of rates in 2000, 2005, and 2008. Cancer 2011;117:2209–2218.
11. Centers for Disease Control and Prevention. Vital signs: colorectal cancer screening, incidence, and mortality—United States, 2002–2010. MMWR Morb Mortal Wkly Rep 2011;60:884-889.
12. National Cancer Institute. Surveillance Epidemiology and End Results. National Institutes of Health, 2011. Available at: http://seer.cancer.gov/. Accessed October 24, 2011.
13. Centers for Medicare & Medicaid Services. U.S. Department of Health & Human Services, 2011. Available at: http://www.cms.gov/. Accessed October 24, 2011.
14. Mariotto AB, Yabroff KR, Shao Y, et al. Projections of the cost of cancer care in the United States: 2010–2020. J Natl Cancer Inst 2011;103:117–128.
15. Ou SH, Zell JA. Validation study of the proposed IASLC staging revisions of the T4 and M non-small cell lung cancer descriptors using data from 23,583 patients in the California Cancer Registry. J Thorac Oncol 2008;3:216–227.
16. Sandler A, Gray R, Perry MC, et al. Paclitaxel-carboplatin alone or with bevacizumab for non-small-cell lung cancer. N Engl J Med 2006;355:2542–2550.
17. Blue Cross of Idaho. MP 6.01.30: Screening for lung cancer using CT scanning or chest radiographs. Available at: https://www.bcidaho.com/providers/medical_policies/rad/mp_60130.asp. Accessed November 1, 2011.
18. Centers for Medicare and Medicaid Services. Medicare National Coverage Determinations Manual. Baltimore, MD: U.S. Department of Health & Human Services; 2011:1–143.
19. Black C, Bagust A, Boland A, et al. The clinical effectiveness and cost-effectiveness of computed tomography screening for lung cancer: systematic reviews. Health Technol Assess 2006;10:8.
20. Chirikos TN, Hazelton T, Tockman M, et al. Screening for lung cancer with CT: a preliminary cost-effectiveness analysis. Chest 2002;121:1507–1514.
21. Mahadevia PJ, Fleisher LA, Fric KD, et al. Lung, cancer screening with helical computed tomography in older adult smokers: a decision and cost-effectiveness analysis. JAMA 2003;289:313–322.
22. Marshall D, Simpson KN, Earle CC, et al. Potential cost-effectiveness of one-time screening for lung cancer (LC) in a high risk cohort. Lung Cancer 2001;32:227–236.
23. Marshall D, Simpson KN, Earle CC, et al. Economic decision analysis model of screening for lung cancer. Eur J Cancer 2001;37:1759–1767.
24. Wisnivesky JP, Mushlin AI, Sicherman N, et al. The cost-effectiveness of low-dose CT screening for lung cancer: preliminary results of baseline screening. Chest 2003;124:614–621.
25. Okamoto N. Cost-effectiveness of lung cancer screening in Japan. Cancer 2000;89:2489–2493.
26. Manser R, Dalton A, Carter R, et al. Cost-effectiveness analysis of screening for lung cancer with low dose spiral CT (computed tomography) in the Australian setting. Lung Cancer 2005;48:171–185.
27. Castleberry AW, Smith D, Anderson C, et al. Cost of a 5-year lung cancer survivor: symptomatic tumour identification vs proactive computed tomography screening. Br J Cancer 2009;101:882–896.
28. Chien CR, Chen TH. Cost-effectiveness analysis of lung cancer screening with computed tomography. Value in Health 2009;12:A43.
29. McMahon PM, Kong CY, Bouzan C, et al. Cost-effectiveness of computed tomography screening for lung cancer in the United States. J Thorac Oncol 2011;6:1841–1848.
30. Smith TJ, Hillner BE. Bending the cost curve in cancer care. N Engl J Med 2011;364:2060–2065.
31. Weinstein MC, Siegel JE, Gold MR, et al. Recommendations of the Panel on Cost-effectiveness in Health and Medicine. JAMA 1996;276:1253–1258.
32. Libby DM, Smith JP, Altorki NK, et al. Managing the small pulmonary nodule discovered by CT. Chest 2004;125:1522–1529.