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Biennial lung cancer screening in Canada with smoking cessation—outcomes and cost-effectiveness

John R. Goffin (MD, FRCPC)[a,*], William M. Flanagan (BM)[b], Anthony B. Miller (MD, FRCPC)[c], Natalie R. Fitzgerald (MA)[d], Saima Memon (MBBS, MPH)[d], Michael C. Wolfson (PhD)[e], William K. Evans (MD, FRCPC)[a]

[a] Department of Oncology, McMaster University, 699 Concession St., Hamilton, ON, L8V 5C2, Canada
[b] Statistics Canada, Ottawa, ON, K1A 0T6, Canada
[c] Dalla Lana School of Public Health, University of Toronto, 155 College Street, Toronto, ON, M5T 3M7, Canada
[d] Canadian Partnership Against Cancer, 1 University Ave., Suite 300, Toronto, ON M5J 2P1, Canada
[e] Department of Epidemiology and Community Medicine, University of Ottawa, 600 Peter Morand Crescent, Room 301 K, Ottawa, ON, K1G 5Z3, Canada

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ABSTRACT

Background: Guidelines recommend low-dose CT (LDCT) screening to detect lung cancer among eligible at-risk individuals. We used the OncoSim model (formerly Cancer Risk Management Model) to compare outcomes and costs between annual and biennial LDCT screening.
Methods: OncoSim incorporates vital statistics, cancer registry data, health survey and utility data, cost, and other data, and simulates individual lives, aggregating outcomes over millions of individuals. Using OncoSim and National Lung Screening Trial eligibility criteria (age 55–74, minimum 30 pack-year smoking history, smoking cessation less than 15 years from time of first screen) and data, we have modeled screening parameters, cancer stage distribution, and mortality shifts for screen diagnosed cancer. Costs (in 2008 Canadian dollars) and quality of life years gained are discounted at 3% annually.
Results: Compared with annual LDCT screening, biennial screening used fewer resources, gained fewer life-years (61,000 vs. 77,000), but resulted in very similar quality-adjusted life-years (QALYs) (24,000 vs. 23,000) over 20 years. The incremental cost-effectiveness ratio (ICER) of annual compared with biennial screening was $54,000–$4.8 million/QALY gained. Average incremental CT scan use in biennial screening was 52% of that in annual screening. A smoking cessation intervention decreased the average cost-effectiveness ratio in most scenarios by half.
Conclusions: Over 20 years, biennial LDCT screening for lung cancer appears to provide similar benefit in terms of QALYs gained to annual screening and is more cost-effective. Further study of biennial screening should be undertaken in population screening programs. A smoking cessation program should be integrated into either screening strategy.

1. Introduction

Despite reductions in smoking rates in Canada, tobacco still imposes a significant health burden [1]. Lung cancer, the most common smoking induced malignancy, is associated with a high mortality rate [2,3], with only modest improvements in survival seen over the last 30 years [4].

Recently, the National Lung Screening Trial (NLST) showed that low dose CT (LDCT) screening reduces lung cancer specific and overall mortality [5]. Eligible individuals were randomized to either three annual LDCT scans or to chest X-rays and had a median follow-up of 6.5 years. The principal benefit was derived from greater

Abbreviations: ACER, average cost-effectiveness ratio; CT, computerized tomography; ICER, incremental cost-effectiveness ratio; LDCT, low dose computerized tomography; LYs, life years; NLST, national lung screening trial; QALYs, quality adjusted life years.

* Corresponding author at: Juravinski Cancer Centre, 699 Concession St., Hamilton, ON, L8V 5C2, Canada.
E-mail addresses: goffin@mcmaster.ca (J.R. Goffin), Bill.Flanagan@canada.ca (W.M. Flanagan), ab.miller@sympatico.ca (A.B. Miller), Natalie.Fitzgerald@partnershipagainstcancer.ca (N.R. Fitzgerald), saima.memon@partnershipagainstcancer.ca (S. Memon), michael.wolfson@uottawa.ca (M.C. Wolfson), Bill.Evans@cancercare.on.ca (W.K. Evans).

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detection of early stage, potentially curable disease. However, despite the reduction in mortality, prevention remains critical.

Behavioral and pharmacologic interventions are effective in inducing smoking cessation, but cessation efforts by healthcare workers are inconsistent [6]. A CT screening program could provide a framework for the introduction of a smoking cessation program to potentially motivated individuals. Data suggest that smoking cessation interventions are highly cost-effective [7], and that their use in screening programs improves cost-effectiveness [8–10]. A combined program would likely offer significant population health benefits.

A population-based screening program needs to determine the resource requirements for implementation. Guidelines for screening have generally suggested annual screening from ages 55 to 74 or greater [11,12]. An exception is the Cancer Care Ontario guideline, which advises biennial screening after three annual scans [13]. Biennial screening offers a potential reduction in use of resources, but in the absence of evidence from randomized clinical trials the benefits remain unclear. While opportunistic screening is underway in the United States, population-based screening pilots are only now beginning in Canada.

The OncoSim model (formerly the Cancer Risk Management Model), a decision-making tool of the Canadian Partnership Against Cancer, is a microsimulation model designed to assess the impact of cancer control interventions in the Canadian healthcare setting. In this paper, we examine the potential cost-effectiveness of biennial CT screening compared with annual screening. We also assess the impact of a smoking cessation program on a biennial LDCT screening program.

2. Methods

The lung cancer module of OncoSim version 2.1.2 (online at cancerview.ca/cancerriskmanagement) has been well described [14,15]. Briefly, the program simulates individual lives from birth through development of cancer and progression to death, tracking health-related quality of life, health care interventions, and costs. OncoSim then aggregates these results across millions of heterogeneous individuals. Data are derived from a wide range of sources including vital statistics, health surveys, cancer registry data, the medical literature, drug and hospital costs, and expert opinion when necessary. Cancer incidence and mortality data produced by the model have aligned well with cancer registry data, have been internally validated and compared with other models with good face validity [15].

The lung cancer screening module was based on NLST data, including eligibility criteria: age 55–74, a minimum smoking history of 30 pack years, and a history of quitting smoking no more than 15 years prior to starting screening. Diagnostic test use following positive screening scans was based on utilization reported in the NLST [15].

The stage shift for LDCT screen-detected NSCLC was derived by comparing the cancer stage distribution in the NLST LDCT screening arm with the general U.S. lung cancer population and then applying this shift to Canadian cancer registry data according to screen result and round of screening. Specificity was derived directly from NLST data. The median duration of the LDCT detectable preclinical cancer phase was estimated in conjunction with the sensitivity of screening through model fitting to match NLST incidence. The resulting mean preclinical cancer phase was 2.3 years for round one of screening and then 1.9 years for rounds 2 and onward. Lead time modifiers (to adjust for the duration of the preclinical period) and lung cancer stage-specific survival were determined by stage using NLST survival data according to stage and screening arm. Survival rates within stage were adjusted to align with patterns observed in the NLST. When simulating an NLST scenario, the lung cancer mortality reduction from screening was 23%, similar to the NLST figure of 20% [15].

Costs are given in 2008 Canadian dollars. Costs and quality adjusted life years (QALYs) gained are discounted at 3% annually. Health care costs are assumed to increase at 1% annually to reflect real cost increases. We analyzed cost-effectiveness by making two types of comparisons. Average cost-effectiveness ratios (ACERs) were generated by comparing a range of screening scenarios, whether annual or biennial, all to no screening. Then, a standard annual screening scenario was compared to biennial scenarios to yield incremental cost-effectiveness ratios (ICERs). Costs and health outcomes accrue from the time of eligibility during the recruitment period until the individual's death (i.e. a lifetime horizon). Ten and 20-year scenarios track cumulative costs and health outcomes from the time of eligibility during the recruitment period until the end of the 10 or 20-year recruitment period.

2.1. Screening scenarios

All simulated scenarios model screening to age 75 for persons recruited between 2014 and 2034. It was assumed that the uptake of screening was 60% by 10 years with a linear increase from time zero. Compliance with re-screening was set at 70%. The uptake and compliance figures are similar to those for breast cancer screening in Canada [16]. Previous work with OncoSim has shown that changes in uptake do not significantly alter cost-effectiveness [8].

The model projects background smoking quit rates between 2.8 and 5% over time. We have modeled the inclusion of a one-time smoking cessation intervention assuming a 22.5% quit rate and a cost of $440, reflecting one course of nicotine replacement or varenicline [17]. A sensitivity analysis modified the intervention quit rate and cost.

With the specifications above, the screen eligible population in the model in 2014 was approximately 1.4 million persons, 35% being female. Of the eligible population, 59% were current smokers [8]. Without screening, 25,042 lung cancers would be diagnosed in 2014.

For biennial screening, sensitivity, specificity, and stage shifts beyond the first screening scan could not be directly derived from NLST and various scenarios were assessed. In both the annual and biennial scenarios, sensitivity and specificity were set at 0.92 and 0.73, respectively for the baseline scan. The biennial scenarios were tested at four different values of sensitivity/specificity for subsequent scans (Table 1).

All cancers detected with baseline scans were aligned to the stage distribution observed in the baseline NLST scan. Similarly, for the first year after a negative screening CT scan, cancers detected in all annual and biennial cohorts had the same, lesser stage shift, as derived from NLST, with the stage shift changing beyond 12 months as described below for biennial scenarios.

The extent of favorable stage shift is unknown for biennial screening and, therefore, four stage distribution combinations were considered, which we have termed Possible, Plausible, Optimistic, and Pessimistic. In each, stage distributions were assigned to all post-baseline positive screening scans and also to cancers detected during the period from 12 to 24 months after a negative screening scan. In the Possible, Plausible, and Optimistic scenarios, the stage distributions after a negative scan were based on distributions observed in the NLST post screening period. In the Pessimistic scenario, the stage distribution after a negative scan reverted to that observed in the unscreened Canadian population. Cancers diagnosed by a post-baseline screen in the Possible scenario were assigned the same stage distribution as the NLST baseline scan, while those diagnosed by a post-baseline screen in the Optimistic and Pessimistic scenario were assigned the stage distribution