

From Eligibility to Uptake: Dynamics of Participation in Lung Cancer Screening

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Dismal participation in initial (baseline) low-dose CT screenings and suboptimal adherence to subsequent follow-up exams undermines the life-saving potential of lung cancer screening. Despite lung cancer's status as the leading cause of cancer mortality in the United States accounting for nearly 130,000 deaths each year—real-world data show that fewer than one in five eligible individuals undergo recommended screening. A recent study showed that even among individuals eligible for multiple cancer screenings, participation in lung cancer screening is nearly 40% lower than in screening for potentially less fatal cancers such as breast cancer—highlighting the unique dynamics and challenges surrounding lung cancer screening uptake. Moreover, even among those who do participate initially, only around half return for their annual follow-up scans. These low rates of uptake and adherence mean that many high-risk individuals are not benefiting from early detection opportunities, thereby contributing to continued high mortality and missed chances for more effective treatment. Consequently, identifying the behavioral, social, and structural factors driving this participation gap is an urgent public health priority.

Low uptake and adherence in US lung cancer screening can be traced to a combination of limited awareness, stigma and fear, complex eligibility and logistical barriers, provider and system-level knowledge gaps, and broader social determinants of health. Effective strategies to improve screening rates typically involve increasing provider education, developing patient-centered and culturally tailored communication, implementing systematic reminder and referral programs, ensuring coverage and reducing out-of-pocket costs, and making LDCT screening more accessible through coordinated healthcare networks.

For this modeling project, we will develop a system dynamics model that captures the progression of lung cancer as driven by the accumulation of smoking history over time. Because screening eligibility is based on a combination of age and smoking exposure, it is essential to incorporate mechanisms that track both age cohorts and the accumulation of Pack-Years—a composite metric reflecting smoking intensity and duration. These dynamics will be represented using an aging chain to model the flow of individuals through age cohorts, alongside a coflow that accumulates each cohort's smoking history. The probability of developing pulmonary nodules—and their subsequent progression to lung cancer—will also be modeled as functions of both age and Pack-Years, reflecting their critical role in disease development.

Participation in regular screening increases the likelihood of detecting lung nodules at an early, asymptomatic stage—substantially improving treatment effectiveness and survival outcomes.

However, psychosocial barriers such as fear and anxiety related to screening outcomes can alter the perceived balance of benefits and costs, leading individuals to forgo or discontinue participation. In this model, we propose representing these barriers as components of perceived cost, which directly influence screening uptake. For example, stigma related to smoking history and fear of a cancer diagnosis may elevate the emotional burden of screening, while the perceived prevalence of false-positive results—despite being clinically manageable—can further reduce the perceived benefits of participation and contribute to perceived cost due to the anticipated burden of follow-up procedures. The primary driver of perceived benefit in the model is the difference in treatment effectiveness between individuals who participate in screening and those who do not. We integrate all these mechanisms into a perceived cost-benefit framework, treating them as components of the expected psychological and procedural disutility associated with screening. This perception-based approach allows the model to reflect how individuals weigh screening's potential benefits (early detection and improved survival) against its emotional and logistical downsides.

By the end of this exercise, the model should depict how individual smoking history accumulates and ultimately triggers eligibility for low-dose CT screening. It will also illustrate how screening uptake evolves over time in response to both clinical factors (e.g., probability of early-stage detection and associated survival gains) and psychosocial perceptions (e.g., fear, stigma, and anticipated burden of screening). Uptake decisions will be modeled as a function of perceived costs and benefits, informed by disease prevalence, test sensitivity and specificity, and survival conditional on stage at detection. On the disease progression side, age-stratified cohorts will advance through the model while accumulating Pack-Years of smoking, enabling eligibility thresholds to be reached dynamically.

It is useful to consider running tests to examine how changes in screening eligibility criteria—such as lowering the minimum Pack-Year threshold or adjusting the eligible age range—affect screening participation, false-positive rates, and early detection outcomes. Additional experiments might explore the impact of interventions aimed at reducing perceived costs (e.g., public awareness campaigns, stigma reduction, improved communication about false positives) or increasing perceived benefits (e.g., clearer messaging about survival gains from early detection). Another valuable test could examine how variations in test sensitivity and specificity influence cost-benefit perceptions and, in turn, screening uptake. These experiments can help uncover leverage points in the system and deepen understanding of the dynamic interplay between disease progression, individual decision-making, and population-level screening outcomes.

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