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Health Economics Research in Cancer Screening: Research Opportunities, Challenges, and Future Directions

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Abstract

Cancer screening has long been considered a worthy public health investment. Health economics offers the theoretical foundation and research methodology to understand the demand- and supply-side factors associated with screening and evaluate screening-related policies and interventions. This article provides an overview of health economic theories and methods related to cancer screening and discusses opportunities for future research. We review 2 academic disciplines most relevant to health economics research in cancer screening: applied microeconomics and decision science. We consider 3 emerging topics: cancer screening policies in national as well as local contexts, "choosing wisely" screening practices, and targeted screening efforts for vulnerable subpopulations. We also discuss the strengths and weaknesses of available data sources and opportunities for methodological research and training. Recommendations to strengthen research infrastructure include developing novel data linkage strategies, increasing access to electronic health records, establishing curriculum and training programs, promoting multidisciplinary collaborations, and enhancing research funding opportunities.

Cancer screening occupies a unique space in the cancer care continuum in that it covers a large proportion of the population and has the potential to alter the natural history of cancer disease progression through early detection of cancers and their precursors. From a public health perspective, cancer screening (ie, identification of cancers when an individual is asymptomatic) can potentially be a worthy investment because early detection followed by timely treatment can be more effective in reducing long-term cancer mortality and morbidity than treatment after an individual has developed cancer-related symptoms, often once the cancer has progressed to an advanced stage. From an economic perspective, the national costs of cancer care have been rising rapidly and are projected to increase from $180 billion in 2015 to $246 billion by 2030—a 34% increase estimated based on population growth alone (1). Prior research has consistently shown that cancer care costs were lower for patients diagnosed at early stage than at late stage for all cancers (2,3). For example, a Surveillance, Epidemiology, and End Results–Medicare analysis reported that costs within the first 12 months of diagnosis for breast cancer patients who

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received lumpectomy followed by radiation therapy were $19 110, $21 803, $27 460, and $36 420 for patients diagnosed in stage I, II, III, and IV, respectively (3). By detecting cancer at an earlier stage, cancer screening can potentially reduce the economic burden of cancer for patients, their families, and society as a whole.

Screenings for breast, cervical, colorectal, and lung cancer are recommended by the US Preventive Services Task Force (USPSTF) (4–7), the American Cancer Society (ACS) (8–11), and many professional societies, such as the American College of Physicians (12,13), American College of Radiology (14), American College of Chest Physicians (15), the US Multi-Society Task Force on Colorectal Cancer (16). Despite public health efforts to promote cancer screening, the rate of screening remains suboptimal. Estimates using data from the National Health Interview Surveys (NHIS) reported the rates of screening for breast, cervical, and colorectal screening at 76.4%, 73.5%, and 67.1%, respectively, in 2019. None of the estimated rates of screening from NHIS 2019 met the goal of 81.1%, 93%, and 70.5% set for breast, cervical, and colorectal cancer screening in Healthy People 2020 (17). Analyses combining the 2018 and 2019 Behavioral Risk Factor Surveillance System (BRFSS) survey data found only 17.5% of eligible individuals had reported being screened for lung cancer (18). Although lung cancer screening with low-dose computed tomography (LDCT) is relatively recent and the Centers for Medicare and Medicaid Services did not start covering LDCT until February 2015 (19), the uptake has been exceedingly slow. Thus, research investigating economic and behavioral factors hindering or facilitating screening uptake or assessing the cost-effectiveness of interventions designed to increase cancer screening is timely, policy relevant, and impactful.

Cancer screening has been a topic of research interests for health economists, as evidenced by contributions to authoritative reference books devoted to health economics, such as the chapter on "Prevention" by Kenkel in the *Handbook of Health Economics* (20), and "The Economics of Cancer Prevention and Control" by Shih in the *Oxford Encyclopedia of Health Economics* (21). Shih pointed out that although many aspects of cancer screening offer ample opportunities for cancer health economics research, these research opportunities are often accompanied by unique methodological challenges (21). For instance, the tradeoff between short-term upfront costs of screening and long-term health gains highlights the investment aspect of cancer screening, emphasizing the importance of using modeling approaches to assess the effectiveness and cost-effectiveness of screening strategies with a lifetime time horizon that follows individuals from the initiation of screening through all subsequent screenings and follow-up clinical activities to death, either because of cancer or other causes. Further, the interplay between demand- and supply-side factors calls for multilevel study designs, interventions, and analyses in cancer screening research. Health economics offers the theoretical foundation and methods (eg, health econometrics, microsimulation models) to conceptualize and analyze these factors.

Understanding the economics of cancer screening is key to ensuring value, equitable distribution of resources, and appropriate design and evaluation of interventions to improve cancer outcomes through early detection. For cancer health economics research to be policy and clinically relevant, it takes collaborative effort between health economists and cancer researchers. To foster the development of the field of cancer health economics with a focus on cancer screening, this article provides an overview of the current state of the science in health economics of cancer screening, discusses the associated research opportunities and challenges, and offers recommendations to foster the development of this research field.

Overview of Theories and Methods of Health Economics Research in Cancer Screening

Health economics research studying cancer screening largely relies on methods from 2 academic disciplines: applied microeconomics and decision science. Each discipline contributes a unique set of analytical tool kits to address different topics of cancer screening. Applied microeconomics offers economic theories and econometric methods to assess causal relationships along with factors associated with screening uptake and adherence, typically using secondary data, whereas decision science introduces the use of simulation models to extrapolate beyond randomized trials and observational data alone to gain a better understanding of the long-term impact of screening at the population level.

Applied microeconomics addresses cancer screening by examining demand- and supply-side factors. From the demand side, the decision to undergo screening is affected by patients' observed and unobserved characteristics including individual preference, socioeconomic and demographic factors, and underlying comorbidities and risk profile, as well as insurance coverage, out-of-pocket spending for screening services, indirect and intangible costs associated with screening, recommendations from providers or medical associations, and accessibility of screening facilities (22). On the theory front, Grossman's human capital model offers 1 conceptual foundation for the economics of cancer screening and prevention (23,24). Under this framework, the demand for medical care, including cancer screening, is modeled as a key input entering into individual's health production function, which describes the relationship between health inputs, such as medical care, nutrition, and exercise, and the resulting health outputs, including outcomes such as deaths, infant mortality, life-years, and quality-adjusted life years. Another theoretical framework is the insurance model by Ehrlich and Becker (25). The model includes 3 behaviors reflecting decisions under uncertainty: 1) insurance-purchasing behavior to provide income protection had an illness occurred, 2) self-protection behavior to reduce the probability of the occurrence of an illness, and 3) self-insurance behavior to reduce loss if an illness occurred. Self-protection and self-insurance are risk-protection behaviors that interact with the insurance purchasing decision. This model has been adopted extensively in the health economics literature of cancer prevention and control. As Kenkel (20) pointed out, self-protection can be viewed as primary prevention because it captures behaviors to lower the risk of cancer, whereas self-insurance is considered secondary prevention because it reflects behaviors that increase the effect of cancer treatment through early detection from screening.

From the supply side, the decision to provide screening is facilitated or hindered by factors such as providers' knowledge of associated benefits and harms, financial incentives, documentation requirements for reimbursement, and the availability of screening-related health-care workforce and capital equipment in local markets. Supplier-induced demand, a phenomenon in which financially motivated physicians influence patient demand for care against physicians' interpretation of the best interest of the patient, has been documented in the health economics literature (26–28). Although supplier-induced

demand may explain screening behavior among individuals who do not meet the screening eligibility criteria (eg, lung cancer screening among nonsmokers younger than age 50 years), no empirical studies to date have examined this phenomenon in the context of cancer screening.

Cancer screening trials are rare in the United States because the large sample size and long duration of follow-up required to establish clinically and statistically meaningful inference make these trials exceedingly costly and time consuming. Moreover, such trials inform the efficacy of a specific screening modality, such as the efficacy of LDCT for lung cancer screening demonstrated by the National Lung Screening Trial (29), but provide little guidance on how to incorporate the new modality into existing real-world screening programs. Because of this, much of the information on the effectiveness of screening interventions is based on data from large observational studies, where participants are not randomized to different screening protocols but are followed in their real-world care patterns. However, results from observational studies often had lower-quality rating than randomized controlled trials based on the Grading of Recommendations, Development and Evaluation framework for the assessment of the quality of evidence because of concerns such as participation bias, confounding bias, measurement errors in exposure or outcome variables, and loss of follow-up in observational studies (30,31). For example, the systematic review article that was used in the development of breast cancer screening guidelines by the ACS identified 8 randomized clinical trials and 35 observational studies (13 case-control and 22 cohort studies) that provided evidence on the association between mammography and breast cancer mortality (32). However, the quality rating for 18 of these 35 observational studies was moderate, and the other 17 studies were rated as low quality based on the Grading of Recommendations, Development and Evaluation guidelines. Simulation models in decision science offer a set of analytical tools to assess the effectiveness and cost-effectiveness of screening strategies as such assessment cannot be done relying solely on trials or observational studies. The basic design of any screening strategy will hinge on 4 parameters: screening eligibility criteria, time to start, time to stop, and the frequency of screening. The combination of these parameters creates a large number of screening strategies for policy makers to consider. Microsimulation modeling offers a powerful analytical method capable of addressing a wide range of policy issues including optimal screening strategies, the effectiveness and cost-effectiveness of alternative screening strategies within different population subgroups, and the relative contributions of screening vs treatment in observed cancer mortality reduction. Findings from microsimulation models have been used to assist the USPSTF and the ACS in their development of screening guidelines for breast, colorectal, cervical, and lung cancer (33–36). Many of these models were developed by modeling teams participating in the Cancer Intervention and Surveillance Modeling Network, a research consortium funded by the National Cancer Institute (NCI) since 2000 (37,38).

Opportunities and Challenges for Health Economics Research in Cancer Screening

Two unique features characterize the current state of the science of health economics research in cancer screening. First, variations in the policy environment, such as the Affordable Care Act (ACA) (39), and screening guidelines from the USPSTF, ACS, or other professional societies, as well as payers' or providers' voluntary participation in alternative payment models such as the Oncology Care Model (40) allow researchers to employ natural experiment study designs to assess factors associated with changes in the uptake of screening. Second, microsimulation models are frequently used to design screening strategies and evaluate the effectiveness and cost-effectiveness of these strategies. These features create rich research opportunities as well as challenges for cancer health economics research. Opportunities for investigators include emerging research topics arising from recent changes in policy or clinical environment, data sources providing information for economic studies of cancer screening, the potential this new field offers for methodological research, and development of integrated training programs. Each research opportunity and the associated challenges are discussed below and summarized in Table 1.

Emerging Research Topic 1: Placing Policies Governing Cancer Screening in a Local Context

Under the ACA, 2 provisions most relevant to cancer screening are 1) the prevention provision that mandates health insurance plans, including for the self-insured and Medicaid, to waive cost-sharing requirements for preventive services with a grade A or B recommendation from the USPSTF; and 2) state Medicaid expansion and the creation of insurance exchanges. The timing of ACA enactment as well as states' participation in Medicaid expansion created natural experiments that allow for examination of how health policies affected screening uptake. Natural experiments refer to a quasi-experimental study design in which an intervention beyond the control of researchers divides the population into affected (exposed) and nonaffected (unexposed) groups, so that the impact of the intervention can be estimated through the natural variation in exposure to the intervention (41). Consistent with the methods and analyses of causal relationships that can be estimated within natural experiments pioneered by the 2021 Nobel Prize winners in economics (42), a well-designed natural experiment study allows researchers to make causal inferences using observational data. In the case of Medicaid expansion, although ACA expands Medicaid eligibility to individuals with an annual income lower than 138% of federal poverty line, a US Supreme Court's ruling in 2012 allows states to opt out of the Medicaid expansion provision (43), thus, creating a policy scenario for natural experiment study design. Aside from the Medicaid expansion, state mandates can also influence screening behaviors. For example, state breast density notification laws were found to be associated with a modest increase in supplemental breast imaging and biopsy (44). In addition, the changes in the recommendations from updated cancer screening guidelines offer further opportunities to examine the impact of guidelines on screening utilization (45). It should be noted, however, that neither ACA nor state mandates dictate Medicare coverage policy on cancer screening.

Although numerous health economic studies have assessed the impact of national or state mandates or guidelines on cancer screening, there is still the need to drill down to local markets and better understand demand- and supply-side factors that could hinder policy initiatives to promote screening or guideline adherence. For example, capacity constraints in mammography facilities may explain geographic variation in the rate of breast cancer screening across counties (46). Knowledge of local area factors can inform policy makers about modifiable

Table 1. Research opportunities and challenges of health economics research in cancer screening

	Research opportunities	Challenges
Emerging topics		
Cancer screening policy in local context	• Natural experiment policy environment under the Affordable Care Act, state mandates or screening guidelines updates • Drill down to local markets to understand demand- and supply-side factors	• Obtain detailed, up-to-date demand- and supply-side information in local markets • Address various sources of biases in making causal inference • Identify relevant data sources to capture the full array of potential benefits and costs of screening
"Choosing wisely" cancer screening practice	• Observational studies to identify low-value screening practices • Microsimulation model to project benefits, harms, and costs of screening strategies	• Difficult to use secondary data to estimate the magnitude of certain aspects of harms (eg, overdiagnosis) of screening • Modeling based on ideal practice offers limited guidance for value-based practices
Targeted effort of cancer screening	• Apply health econometric methods to evaluate policy impact on disparities • Disparity implications of newly established screening modality for lung cancer • Modeling studies to assess cost-effectiveness of risk-stratified screening strategies	• Interaction between screening policies and guidelines complicates analyses • Determine the risk threshold to justify the use of more expensive screening strategies • Identify credible data sources for different risk groups for risk-stratified models
Data sources		
National surveys, insurance claims, screening registries, and data from health-care systems	• National surveys are useful sources to estimate rate of screening • Claims data are useful to describe trends and obtain more recent estimates • Data from screening registries along with comprehensive electronic health records data from integrated health-care systems offer rich clinical data for broader age-eligible screening populations	• Screening information from national surveys is not available in all years or all states • Generalizability and ability to differentiate screening from diagnosis in claims data • Health system data are not readily accessible and require more extensive application process to request data access and approval
Methodological research and training		
Methodological research	• Applied econometrics offer a wide variety of methods to study impact of screening polies • Microsimulation models are powerful tools to determine optimal screening strategies and assess screening cost-effectiveness	• Verify the underlying assumption of each method, explore alternative when needed • Model validation is important, but data for validation are not always available • Obtain accurate cost estimates for the entire screening process and downstream events
Training	• Economics and health economics programs provide training in economic theory, econometrics, statistics, and knowledge of health-care system organization • Decision science curriculums provide training in simulation models and statistics	• Conventional economics programs offer limited training in cost-effectiveness analysis, decision modeling, and health-related causal inference • Decision science trainings often do not teach applied microeconomics

factors and lead to policy remedies unique to their local environment. Obtaining up-to-date and detailed information on demand- and supply-side factors at geographic units smaller than the state can be challenging given data access limitations, dissemination patterns, and higher variability because of smaller sample sizes. Moreover, measuring the causal effects of screening guidelines using existing economic models of behavior provides opportunities and challenges. For example, successfully addressing the selection effects associated with guideline-based recommendations, including changes to guidelines, is required to produce unbiased estimates of the benefits and harms associated with screening (47,48). The full array of potential benefits and costs of screening, including but not limited to the long-term health benefits from early cancer detection as well as the stress and anxiety associated with false-positive test results, are often difficult to measure, whether in monetary terms or as patient-reported outcomes (49). Moreover, the costs that individuals bear—including out-of-pocket expenses for initial screening and follow-up procedures, as well as the time costs associated with engaging in the screening process—can have a significant impact on uptake, in ways that ultimately exacerbate disparities in cancer-related outcomes (50,51).

Emerging Research Topic 2: "Choosing Wisely" in the Context of Cancer Screening

The discussion around cancer screening has shifted from a presumption that screening is always beneficial to a more careful evaluation of the harm-benefit tradeoffs. Discussions about the implications for overdiagnosis are now common in screening guidelines. Health economics research contributes to the assessment of over-, under-, or misuse of screening technologies by examining screening patterns observed in real-world practice settings and investigating whether these patterns were

driven by economic factors and may lead to adverse economic outcomes. Observational studies have documented the overuse of colonoscopy and mammography in older populations (52,53) and possible misuse of technologies (ie, chest x-ray) for lung cancer screening (54), although none of these studies have explored the concept of supplier-induced demand in their analyses.

Knowledge gained from modeling studies can be used to design implementation strategies to promote high-value screening practices while de-implementing low-value ones. For example, microsimulation models can help project the magnitude of harms of screening and estimate the associated costs across a variety of screening strategies in a comparative fashion. Many microsimulation analyses have traditionally focused on an ideal practice environment (eg, full adherence of screening followed by guideline concordant treatment dissemination). Although helpful in informing clinical practice guidelines, such framing has limited use in guiding policy actions toward value-based practice. Modifications of modeling parameters to better integrate the model with actual clinical practice to create several what-if scenarios would then provide important insights to inform policy makers about the health and economic outcomes associated with alternative screening practices.

Emerging Research Topic 3: Identify Vulnerable Subpopulations for Targeted Screening Efforts

Vulnerable subpopulations to consider in terms of cancer screening include but are not limited to individuals facing access barriers to screening and those at high risk of cancer. Extensive literature has documented factors associated with lower uptake of screening, including demographic characteristics, socioeconomic status, social determinates of health, health belief and literacy, and locality (55–58). For high-risk individuals, screening guidelines for the average-risk general public are likely insufficient to mitigate their cancer risk. Earlier screening initiation age, screening at more frequent intervals, or a different screening modality is often needed.

On the topic of cancer screening disparities, an important contribution of cancer health economics is empirical research examining the impact of policies designed to remove or reduce financial barriers to screening. Among the most studied screening programs are those supported through Medicaid and the National Breast and Cervical Cancer Early Detection Program (59–64). The ACA adds yet another dimension in appraising the policy impacts of such safety net programs (39,65). Interventions such as patient navigation services are found to be effective in increasing screening uptake among minorities (66). In addition, embedding race-specific recommendations in cancer screening guidelines offers another opportunity to reduce disparities through clinical practice guidelines. Examples can be found in the 2017 colorectal cancer screening guideline from the US Multi-Society Task Force on Colorectal Cancer, in which the recommended starting age of screening was lowered to 45 years for African Americans while keeping the starting age at 50 years for non-African Americans (16). New policies and updates of screening guidelines create many opportunities for cancer health economics research, though they also bring analytical challenges as they can amplify or impede effects achieved by previous policies or guidelines.

As science improves our knowledge of cancer risk factors, the natural question is whether a new screening strategy may be needed for the high-risk subgroups. Modeling studies are well suited to assess the effectiveness and cost-effectiveness of risk-stratified screening strategies. Findings from these studies provide important information to guide policies and clinical practice. An example of the contribution of modeling studies is the use of magnetic resonance imaging (MRI) for women with BRCA1 and 2 mutation (67). The lifetime risk of breast cancer for BRCA1 and 2 mutation carriers is 45%-65%, which is substantially higher than the 12.5% lifetime risk in women at average risk for breast cancer. Compared with mammography, MRI has higher sensitivity, making it an attractive screening modality for high-risk women. However, MRI is approximately 10 times more expensive than mammography, which raises a concern on costs of screening with MRI. This modeling study helps clinicians and payors assess the role of MRI in screening high-risk women by comparing the cost-effectiveness of MRI with mammography vs mammography alone in breast cancer screening for BRCA1 and 2 carriers. A major challenge for policy makers and guideline developers is to determine the risk threshold that justifies the use of more expensive screening strategies so as to maximize allocation efficiency. Information on the prevalence of risk factors, their classifications and associated cancer mortality, and the performance characteristics of screening modalities for different risk groups is critical but not always available.

Data Sources to Understand Uptake, Participation, Outcomes, Effectiveness, and Costs Associated With Screening

Surveys. Studies estimating cancer screening rates in the United States have often relied on self-report data from respondents to 2 national surveys: the NHIS and the BRFSS. The NHIS has been a useful source to estimate rates of breast, colorectal, cervical, and prostate cancer screening at national or census region levels, and the BRFSS has been informative for making state-level inferences about utilization trends. Data from these national surveys are publicly available and free of charge. Using these data to track screening use over time is challenging because information on each cancer screening is not consistently collected in each year of NHIS or in every state in the BRFSS. For example, before the information of lung cancer screening was collected in the 2020 NHIS, the most recent estimate of the rate of lung cancer screening available from the NHIS was from the Sample Adult Cancer file in the 2015 data (68). Although more recent estimates of lung cancer screening are available from the 2020 BRFSS, only 5 states collected this information (69). Additionally, these health surveys, although conducted annually, produce cross-sectional population estimates but do not allow longitudinal follow-up of screening-eligible cohorts. Also, cancer screening information from these surveys may be subject to biases associated with self-reported data, specifically those related to potential sampling bias and misclassification of diagnostic vs screening scans. Some issues raised above can be mitigated using the NHIS data linked to other data sources. For example, the linkage of NHIS to Medicare and Medicaid claims will allow researchers to verify the self-reported cancer screening information in the NHIS with screening-related billing records in claims data. In addition, one can use Medical Expenditure Panel Survey data linked to the NHIS to obtain screening information in the year prior to the survey year of the NHIS to expand the cross-sectional data to a 2-year longitudinal panel.

Insurance Claims. Alternatively, one can obtain more recent estimates from administrative claims data using Current

Procedural Terminology codes associated with specific screening modality. This approach, however, faces several challenges. First, other than the all-payer claims data available in a handful of states, claims data are typically tied to specific insurance plans, making it impossible to generate population-based estimates at the national level, given the fragmentation of the US health-care system. Second, several screening modalities (eg, breast MRI) share the same Current Procedural Terminology code regardless of whether the procedure was performed for screening or diagnostic purposes, which could lead to overestimation of screening rates. Lastly, certain screening eligibility criteria, such as smoking history or pack-years for lung cancer screening, cannot be ascertained from claims data.

Screening Registries and Health-care Systems. Data from screening registries and health-care systems, although collected on broader age-eligible screening populations for multiple purposes, have proven useful for health economics research in cancer screening. Examples include integrated health-care systems such as Kaiser Permanente (70–72); the Health Care Systems Research Network, a consortium of managed care systems with standardized electronic health record (EHR) data that has expanded from the Cancer Research Network (73); the Breast Cancer Surveillance Consortium, funded by the NCI since 1996, comprising breast cancer screening registries with linked data on risk factors, screening utilization, and long-term outcomes (74); and the NCI-sponsored Population-based Research to Optimize the Screening Process (PROSPR) network (75). PROSPR data include curated EHR, tumor characteristics, vital status, and claims and enrollment data from employer-sponsored, Medicare fee-for-service, Medicare Advantage, Medicaid (including dual eligible), and self-pay ACA compliant plans for adults both within and outside of screening-eligible ages. PROSPR data provide rich information for economic and comparative effectiveness research specific to cancer-related screening, diagnosis, costs, and outcomes (76). The PROSPR DataShare initiative will allow researchers, including those who are not part of the PROSPR network, to request access to subsets of PROSPR public use and de-identified datasets and to propose additional data collection activities that use the PROSPR infrastructure.

Methodological Research Opportunity

Cancer health economics encompasses a rich environment for methodological research and training opportunities. As noted, the economic analysis of cancer screening interventions is (or should be) grounded in the principles of microeconomics and related econometric analyses and in decision science, which guides the creation of models to capture the causal relationships as well as the benefits and costs of alternative screening strategies and to arrive at a recommended approach. Many health economics studies assessing the impact of regulations or guidelines on cancer screening have applied quasi-experimental study designs made feasible by changes in the policy environment. Econometric methods such as interrupted time series or difference-in-differences analysis, the method of moments, propensity score-based estimation, and instrumental variable approaches are common in health economics studies of cancer screening (77–80). Although discussing and comparing between these methods are beyond the scope of this paper, we recommend the articles by Wooldridge (81), Johnson et al. (82), Wing et al. (83), and Finkelstein et al. (84) for readers interested in learning more about these methods. In addition, new methods such as emulation of clinical trials have been proposed (85). Empirical studies need to carefully evaluate whether the conditions required for specific methods are met (eg, the parallel trend assumption for the difference-in-differences method), explore alternative methods when failing to meet these conditions, and investigate sources of potential endogeneity to make credible causal inference.

It is worth exploring opportunities to design and conduct randomized studies to allow robust evaluation of intervention effect on screening uptake. These studies, however, will require substantial resources. Examples of this effort include the Patient Navigation Research Program funded by the NCI and the Centers for Medicare and Medicaid Services Patient Navigation Demonstration Project (86,87). Partnering with implementation science researchers at the design phase is an efficient way to reduce barriers to implementation and streamline the transformation of evidence into practice. Although not directly addressed here, costs, cost-effectiveness, and value of implementation analysis inform decision makers about the cost implications of various implementation strategies and offer key insights on potential financial barriers to implementation. Information from cost as well as value of implementation analysis is especially important in understanding why an effective and cost-effectiveness intervention failed to be implemented in community settings (88,89). The partnership between health economists and implementation scientists facilitates the incorporation of economic information in the trial design and data collection.

Modeling studies of health economics of cancer screening have focused heavily on cost-effectiveness analysis. A valid model for cancer screening should address 2 biases statistically: lead time bias and length bias (90). Lead time is the amount of time by which cancer diagnosis has been advanced by screening, and lead time bias refers to the artificial addition to survival time for screen-detected cancer cases. Length bias reflects another artificial survival benefit of screening-detected cancers because slow-growing tumors are most likely to be detected by screening at fixed intervals. Although it is important to correct these biases, detailed data describing cancer natural history needed to make such correction do not typically exist. Wherever possible, models should also be validated against cancer statistics data, including incidence and/or mortality over time, to ensure that they correctly capture the disease progression. To evaluate the cost-effectiveness of screening strategies, it is also critically important but challenging to obtain accurate cost estimates for each modeling parameter that has a cost implication. With a lifetime horizon, these models need to capture costs of screening and the associated downstream events (eg, diagnostic workups), as well as costs of cancer treatment, supportive care, and end-of-life care. Potential data sources to generate cost estimates include insurance claims data, hospital billing records, and medical expenditures surveys. Researchers should be mindful regarding the representativeness and generalizability of these sources and make proper adjustments when necessary. Examples include adjusting costs from multiple years to the same year of currency (eg, 2021 US dollars), employing cost-to-charge ratios when only charges data are available, and applying multipliers for costs estimated from Medicare data to reflect higher costs observed in nonelderly patients because of more aggressive treatment patterns as well as higher reimbursement rates in private insurance (91,92).

Opportunity to Develop an Integrated Training Program

Applied microeconomics and decision science have traditionally been taught in different degree programs. Graduate programs in economics, including those focused on health economics, are generally designed to provide solid training in microeconomic theory, statistics, econometrics, and depending on the program, health-care system organization. But there is likely substantial variation in exposure to causal inference problems arising expressly in health-care and to cost-effectiveness analysis, behavioral economics, decision analysis, and microsimulation modeling. These latter skills and perspectives are especially relevant to cancer screening analysis. Training in the decision sciences prepares students for simulation studies but may or may not provide instruction on the conduct and interpretation of observational studies. Robust training in statistics, econometrics, behavioral economics, decision analysis, and simulation modeling is needed to prepare students to conduct, analyze, or interpret observational studies as well as policy-related clinical trials (93). More generally, there is a need to develop a well-rounded, comprehensive, and integrated curriculum to train the next generation of cancer health economics researchers for cancer prevention and control research. The curriculum should be cross-disciplinary and cover the theoretical foundations and a wide range of analytical skill sets required for health economics research in cancer screening, as well as the ability to articulate the clinical and policy relevance of research findings.

Discussion

We have identified a variety of opportunities, challenges, and unmet needs for conducting health economics research specific to cancer screening, including studies focusing on economic outcomes associated with screening and on supply, demand, and delivery of cancer screening services. Recent analyses by the Centers for Disease Control and Prevention researchers estimated that large numbers of deaths from cancer could be prevented through increased use of evidence-based screening and at relatively low cost (94,95). These findings highlight the importance and significance of screening-related health economics research. We have identified a set of recommendations and next steps to further develop this critical area of research.

First, there is a need for improved governmental and private sector policies and platforms that support increased data linkages within and across key data sources to improve research opportunities while maintaining patient privacy and confidentiality. As noted above, the fragmented nature of the US healthcare delivery system often leads to silos of datasets that are specific to individuals' insurer (eg, Medicare, Medicaid, or commercial insurers). However, to validly evaluate barriers to optimal uptake and outcomes of guideline-based screening, especially among disparate populations, key data linkages need to be improved. These linkages include EHR-based encounters and insurance claims that capture screening choices and their results (false negatives, true negatives, false positives, or true positives), along with patient-level linkages to cancer registry and vital status data. The data linkages also need to capture multilevel factors (patient, provider, facility, health-care system, societal, and geospatial) that can affect the screening process.

Second, and in support of the above, we need to promote continued funding and access to large-scale registries and cohorts like PROSPR and the Breast Cancer Surveillance Consortium, which are designed for screening research and offer research, collaboration opportunities. As noted above, NCI and the PROSPR entities are making progress via the PROSPR DataShare initiative, but additional large-scale public use data sources are needed.

Third, promotion of additional targeted training grants for cancer screening research, especially for PhDs is needed. Currently, training grant opportunities heavily focus on investigators with a MD degree. Training grants for new PhDs in population-based cancer research are extremely limited and do not exist for midcareer PhDs. Key to the expansion of this field is grants that support junior and minority researchers, along with policies that encourage cross-disciplinary training in health econometric methods, development and use of microsimulation models, the economic theoretical foundation of screening, and demand and supply issues related to cancer prevention and screening resource use and costs.

Lastly, policies and funding initiatives are needed more than ever to support and promote collaborations between health economics researchers, modelers, data partners, implementation scientists, policy makers, and stakeholders, including especially cancer patients, survivors, and their families. Currently, PROSPR and Cancer Intervention and Surveillance Modeling Network consortium scientists are actively pursuing key data collaborations. However, overt initiatives that support these types of collaborations and that can be expanded to include researchers from NCI-funded Implementation Science Centers in Cancer Control and researchers pursuing screening-related patient-engagement initiatives supported by the Patient Centered Outcomes Research Institute could facilitate the creation of a variety of impactful multilevel economic evaluations of cancer screening.

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Data Availability

Not applicable.

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