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Cancer Screening & Cancer Control

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KEY WORDS

- Primary care providers
- Cancer prevention
- Screening
- Early detection
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- Risk factors
- Health disparities
- Dissemination and implementation science

KEY POINTS

- Primary care providers (PCPs) are uniquely positioned to implement primary, secondary, and tertiary cancer prevention.
- PCPs should leverage their long-term patient relationships to promote cancer prevention practices.
- Cancer prevention practice faces significant barriers
- Emerging technologies are transforming cancer prevention by enabling more personalized and effective strategies.

ABSTRACT

Primary care providers (PCPs) play a crucial role in promoting cancer prevention practices. Cancer prevention, following the public health prevention model, is targeted at individuals and populations. Prevention practices aim to reduce cancer incidence and mortality while improving long-term outcomes for patients who develop cancer. Multiple factors significantly influence the adoption of cancer prevention practices, including behavioral, social, cultural, and financial

considerations. Barriers to implementation disproportionately affect underserved populations, creating substantial health disparities in cancer prevention access and outcomes.

PCPs can implement evidence-based cancer prevention clinical guidelines where available. Additionally, they can leverage emerging technologies to more precisely identify patients who will benefit most from preventive interventions. Primary care physicians should utilize their comprehensive understanding of patients' health histories and risk factors to deliver personalized, evidence-based cancer prevention education and strategies.

INTRODUCTION

Cancer is a significant public health concern as it is a leading cause of death globally accounting for nearly one in six deaths. Cancer-related deaths are expected to disproportionately affect low-income and middle-income countries, and globally projected to account for more than three-quarters of all cancer deaths over the coming ten years.¹ The population cancer burden also represents a significant opportunity for public health prevention efforts as about one-third of deaths can be attributed to tobacco use, high body mass index, dietary factors and lack of physical activity.² While this chapter is written mostly from a United States (US) perspective, the information is generally applicable across the globe.

In the US, cancer is the second leading cause of death and is estimated to have a huge economic burden ranging up to \$208.9 billion in 2020—including direct costs for prevention, diagnosis, treatment, rehabilitation and terminal care services but not including myriad indirect costs such as time and productivity lost by patients, family members, and friends. The public health consequences of cancer go far beyond the immediate period of diagnosis and treatment, extending to lasting impacts such as long-term treatment-related sequelae, psychosocial and productivity loss impacts.

Primary Care Providers

Primary care providers (PCPs) offer their patients a first line of defense for cancer prevention. Physician-directed efforts, including screening and early detection, have shown to be highly effective.³ PCPs can guide their patients' healthcare strategies toward lowering the risk of developing cancer, detecting new cancers earlier in their natural histories, and reducing cancer-related mortality and treatment-related sequelae. Using a proactive approach, PCPs can ensure their patients leverage personalized evidence-based cancer screening and early detection strategies. When cancer screening tests are positive, PCPs can ensure that patients are appropriately referred to specialists for test confirmation, subsequent treatment management, and follow-up. By often having long-term and comprehensive clinical familiarity of their patients, PCPs are uniquely positioned to observe symptomatic changes over time associated with increased cancer prevalence and to consider patient family histories and other factors that may predispose patients to cancer.

CANCER PREVENTION APPROACHES

Cancer prevention approaches are based on the public health prevention model. There are five levels of prevention ranging from primordial, primary, secondary, tertiary, and quaternary prevention.⁴ The prevention model includes preventing health challenges before they occur, identifying cancer earlier in its development, and managing disease after it has occurred to minimize long-term impacts.

Primordial Prevention

Primordial prevention targets entire populations by impacting social and environmental conditions that increase the risk of disease often by means of health policy and governmental regulation. Many US commercial zoning laws are implemented to reduce exposure to manufacturing-related environmental contaminants. The consequences of failing to regulate these environmental exposures were illustrated in Love Canal, New York in 1977 and in Toms

River, New Jersey in the 1980s and 1990s, where unusual cancer incidence patterns emerged. Common governmental tobacco use restriction policies for public spaces also represent primordial cancer prevention efforts to reduce secondhand environmental tobacco smoke exposure.

Primary Prevention

Figure 1 depicts a conceptual framework for primary, secondary and tertiary preventive interventions to reduce cancer burden. Primary prevention of cancer involves blocking the biological onset of disease either by reducing exposure to harmful substances, increasing exposure to protective agents or practices, or doing both. Individuals may also have predisposition to develop cancer. While inherited cancer susceptibility was initially clinically identified as an aggregation of certain cancers in families, direct causal evidence emerged when a key genomic pathway was identified for the very rare childhood cancer retinoblastoma, i.e., the tumor suppressor gene model. Knudson first described the tumor suppressor gene model with this *RB* germline mutation.⁵ Germline mutations in *P53* were later found to be associated with a cluster of several malignancies.⁶ Other cancer family syndrome mutations include *BRCA1* and *BRCA2*, strongly associated with breast and ovarian cancers, and Lynch syndrome and familial adenomatous polyposis (FAP) strongly associated with colorectal cancers. Patients with these mutations have higher lifetime incidence of cancer and should therefore receive rigorous ongoing surveillance screening. Knowledge about predisposition syndromes can be of great value in tailoring prevention strategies to the individual.

Biologic models of cancer predisposition delineated over the years suggest more common cancer have a complex etiology involving more than one genetic mutation (inherited or acquired), and an interplay with exogenous factors. The evolving technologies such as the discovery of -omics-related etiologic mechanisms, and increased knowledge of constitutional risk factors and gene-exogenous factor interactions, has facilitated more precise characterization to target populations that would gain the most from specific preventive interventions. The

interplay between environmental exposure, ranging from carcinogenic industrial chemicals to ambient pollutants to tobacco use, and genetic factors allows for more efficient application of lifestyle change interventions and other preventive measures. To formulate the most effective primary prevention strategies for their patients, PCPs should consider multifaceted approaches that integrate knowledge about constitutional risk factors, environmental/occupational influences and modifiable health behaviors, e.g., tobacco use, excessive alcohol consumption, a sedentary lifestyle, and unhealthy dietary practices.

Secondary Prevention

Secondary prevention aims to detect cancers at their earliest stage of progression to reduce mortality, treatment-related morbidity, and economic costs. Detecting malignancies closer to their biologic onset portends better clinical outcomes. Ideally, prevalent malignancies can be detected in their asymptomatic stages of progression by screening patients in clinical settings or conducting mass screening in population settings using standardized protocols. Successful early detection strategies can employ regular screening but can also include one-time screening for constitutional susceptibility by comprehensive genetic testing.

Tertiary Prevention

Tertiary prevention focuses on managing disease and its treatment to prevent future harm. For cancer, tertiary prevention includes approaches to prevent complications of cancer therapy and related impacts on quality of life. This can involve proactive preventive measures to reduce the long-term toxicity of cancer treatment, rehabilitation, and ongoing strategies that improve quality of life. It may also include measures prevent a recurrence or development of second malignant neoplasms. Because of the very high overall cure rates for childhood cancers, much of the primary therapeutic focus has shifted to preventing or ameliorating treatment-related sequelae. While also true for adult cancer survivors, there is emerging evidence that lifestyle interventions can directly impact the risk of recurrence of cancer and cancer-related mortality.⁷

Quaternary Prevention

Quaternary prevention involves protecting patients from unnecessary or harmful medical interventions by identifying those at risk of overmedicalization, especially for individuals with symptoms but no actual disease.⁸ For example, avoiding unnecessary screening for men over 70 years of age who are not recommended to undergo routine prostate cancer screening with prostate-specific antigen (PSA). Breast cancer screening guidelines also need to be calibrated to the consequences of overdiagnosis where there have been overdiagnosis rates of roughly 30% in the US with little positive impact on mortality.⁹

Cancer Control Strategies

The purpose of cancer control strategies is to reduce cancer incidence, mortality, and improve long-term outcomes for patients who develop cancer.¹⁰ Research and application of comprehensive prevention strategies at all levels of the public health prevention model drive strategies. They are directed at both individuals and entire populations and include population-based cancer surveillance with registries, application of prevention efforts across diverse communities to ensure equitable access to health resources, and the development of health care policies to reduce access barriers to prevention services.

CANCER PREVENTION CLINICAL PRACTICE GUIDELINES

Several organizations develop and disseminate cancer prevention clinical practice guidelines including the U.S. Centers for Disease Control and Prevention, the World Health Organization, and the American Cancer Society. The National Comprehensive Cancer Network (NCCN) Consortium established in 1995, brings together cancer experts to inform patient care and includes guidelines for both cancer risk reduction as well as early detection of breast, colorectal, lung, prostate cancers and cancers associated with familial genetic high-risk factors.

The implementation of evidence-based cancer screening recommendations remains challenging due to multiple factors. For many malignancies, cost-effective, widely accessible,

and non-invasive screening modalities are lacking—most notably for pancreatic cancer where no validated general population screening test exists. For low incidence cancers, screening programs may be impractical due to low sensitivity or low positive predictive value, leading to an unfavorable risk-benefit balance. Conversely, screening tests with low specificity can result in excessive false-positive findings, increasing the burden of confirmatory diagnostics and unnecessary interventions such as for some cases of PSA-positive prostate cancer, mammography in younger women with dense breast tissue, and positive CA-125 blood test results for ovarian cancer screening. Overdiagnosis of cancer can occur when a malignancy is correctly diagnosed but would not otherwise cause symptoms or premature death if left undetected such as with some prostate and breast cancers.¹¹

Behavioral factors significantly influence individual screening uptake. Limited public awareness regarding cancer risk can deter screening participation. For example, non-familial colorectal cancer in younger adults (<50 years old) was historically underappreciated, though recognition is improving due to rising incidence and patients' willingness to be more public in their diagnoses. Additional screening barriers include low health literacy, culturally ingrained health beliefs, misinformation, perceived risk and fear associated with screening procedures or potential results, and prior negative experiences with screening tests. Practical constraints such as time limitations, financial burden, and accessibility challenges further reduce adherence to screening guidelines.

Primary care practices often have limited preventive medicine expertise, particularly in areas such as nutritional counseling and smoking cessation interventions. Additionally, time constraints and competing clinical priorities during routine visits frequently reduce opportunities for structured cancer prevention discussions. Financial barriers also impede prevention efforts including inadequate insurance coverage (e.g., for HPV vaccination) and non-reimbursable lifestyle counseling, limit patient access to effective interventions. Furthermore, low awareness about the benefits of risk factor modification contributes to suboptimal uptake of preventive strategies.

As with secondary cancer prevention, primary prevention is hindered by cultural and behavioral factors, including low health literacy and deeply embedded cultural beliefs which can negatively impact adherence to evidence-based recommendations. Enhancing primary cancer prevention efforts requires a multifaceted approach, including expanding provider and patient education, leveraging community health workers, improving access to preventive services, and integrating decision support tools within electronic health records (EHRs) and primary care workflows to facilitate delivery of guideline-concordant care.

SPECIAL POPULATIONS

Cancer prevention benefits are unevenly distributed across the population. Racial and ethnic minorities have historically faced barriers to healthcare, including cancer prevention services as have people with limited economic resources, individuals with disabilities, and rural residents. Adolescents, young adults, and older adults often receive fewer prevention benefits than middle-aged populations. Inequities stem largely from obstacles that limit access to preventive care, with social determinants of health playing a central role in creating both access barriers and disparate health outcomes.

High-risk groups require special consideration such as patients employed in certain occupations including those exposed to carcinogenic industrial chemicals, ambient pollutants, and tobacco use. Individuals with inherited cancer predisposition also require special considerations. Understanding the interplay between individual genetic factors and environmental factors may be more important, especially for those with inherited susceptibility to cancer development.

Introducing cancer prevention to young individuals presents an opportunity to initiate these strategies earlier in the life. Pediatricians and primary care physicians who care for adolescents and young adults can play a unique role in promoting cancer prevention later in life by implementing early interventions and encouraging lifestyle modifications.¹² Knowledge about childhood and life course exposure to certain environmental factors, coupled with lifestyle and

genetic factors, can help tailor early detection, genetic testing, vaccination, and harmful substance-avoidance interventions.

With increasing effectiveness of cancer treatments, PCPs should also consider the unique tertiary prevention needs of cancer survivors who may require special surveillance monitoring for cancer recurrence and development of new primary malignancies. While childhood and adolescent cancer is relatively rare, advances in treatment have significantly improved outcomes achieving 5-year overall survival rates over 85%. This has resulted in nearly a half million childhood cancer survivors in the US who need primary care. There are a wide range of long-term impacts of cancer and its therapy on survivors including sequelae such as cardiovascular and pulmonary disease, neuropathy, and psychological distress, all needing proactive management of these conditions with effective communication between PCPs and oncology teams to ensure comprehensive survivorship care. Cancer survivors from underserved minority populations may be at higher risk of poor outcomes necessitating tailored interventions to reduce cancer health disparities. The transition from pediatric to adult medical care also poses unique challenges for adolescents and young adults with chronic conditions or complex medical needs such as childhood cancer survivors.¹³ Many adult providers are unfamiliar with managing the late effects of childhood cancer treatment, including the use of risk-based surveillance methods. This represents an opportunity to develop evidence-based primary care prevention guidelines for child and adolescent survivors aging into adulthood.

FUTURE OF CANCER PREVENTION

Technology is playing an increasing role in clinical care delivery including cancer screening and cancer control interventions. Electronic health records (EHRs) systematically generate alerts for patient records indicating overdue or upcoming cancer screenings to support timely preventive care. PCPs have instant electronic access to continuously updated evidence reviews and decision aids to inform cancer prevention practices. Guided screening recommendations can be based on individual patient profiles that include genetic predisposition, lifestyle behaviors,

and known environmental exposures.¹⁴ Environmental exposures that influence cancer risk over a lifetime can be more precisely characterized by integration of exposome information.¹⁵

Artificial intelligence (AI) and machine learning (ML) are transforming clinical care, contributing to the discovery and development of new drugs and preventive agents, and streamlined healthcare workflows. They aid in medical image assessment and the integration of test results to assist in risk determination and improve cancer diagnosis. AI and ML are increasingly being integrated into analyses of large patient datasets to draw population inferences for precision public health for both cancer risk assessment and precision population targeting cancer prevention interventions. Generative AI-powered virtual assistants and chatbots interact with patients, answer their questions, provide basic healthcare information, and can promote cancer preventive behaviors. Overall, the integration of AI and ML is revolutionizing healthcare delivery by improving diagnostic accuracy, enhancing clinical research and population health management, accelerating drug discovery, optimizing administrative workflows, and influencing patient lifestyle-related behaviors.

Technologies incorporating the exposome that integrate lifetime environmental exposure data with biologic, genetic, and clinical health information will play an increasingly crucial role in cancer prevention by identifying modifiable risk factors well beyond genetic predisposition. Advancements in precision public health will enhance the personalization of cancer preventive interventions, optimizing risk assessment and disease mitigation strategies. The ability to integrate information about environmental exposures across an individual's lifetime and linkage to biologic/genetic and clinical health information will play an increasingly crucial role in cancer prevention by identifying modifiable risk factors and interactions with genetic predisposition factors. Precision public health approaches will refine targeting for preventive interventions.

Dissemination and implementation (D&I) science methods can assist in translating cancer prevention research into routine primary care practice. Despite strong evidence supporting preventive strategies, their adoption remains hindered by systemic, behavioral, and logistical challenges. By integrating evidence-based frameworks, D&I science enhances provider

engagement by facilitating the incorporation of risk assessment, screening recommendations, and behavioral counseling into primary care workflows. Additionally, it can support policy and reimbursement initiatives that promote access to preventive care. By improving implementation fidelity and sustainability, D&I science enables the scaling of effective interventions across diverse healthcare settings and populations, reinforcing the role of primary care in cancer prevention.

PCPs are uniquely positioned to educate patients on the benefits of screening and primary prevention, while also addressing concerns and misconceptions regarding the safety and efficacy of preventive measures. Their long-term, holistic understanding of patient health, including comorbidities, family history, occupational exposures and environmental risk factors enables the development of individualized cancer prevention strategies that align with evidence-based recommendations.

DISCUSSION

Because nearly 40% of all US cancers (excluding nonmelanoma skin cancers) can be attributed to known risk factors, with cigarette smoking accounting for 19.3% of overall cancer incidence,¹⁶ many of these exposures like tobacco use, along with dietary and other lifestyle factors could be potentially modified. These, along with preventive measures such as protecting against UV exposure and vaccination for HPV and hepatitis B, can significantly reduce population burden of cancer. For breast, cervical, colorectal, lung and prostate cancer, screening practices and preventive interventions were estimated to have averted 80% of cancer deaths for the period 1975–2020.¹⁷

The U.S. Preventive Services Task Force (USPSTF) develops evidence-based guidance on preventive health services primarily targeted at primary care professionals. They include recommendations for early detection, use of preventive medications, and counseling for cancer. Current recommendations target a variety of malignancies including breast, prostate, colorectal, lung, cervical and ovarian, skin, oral, bladder, pancreatic, thyroid, and familial germline BRCA

mutations related to cancer predisposition. But there are clearly gaps for other malignancies and specific subsets of the population, e.g., adolescents and young adults, and elderly individuals.

Because cancer ranks as the second most common cause of death in the United States, cancer screening and prevention are essential components of public health strategy. Public health approaches to cancer prevention focus on reducing exposure to modifiable risk factors, promoting early detection, and guaranteeing equitable access to preventive services. Robust scientific evidence demonstrates the effectiveness of practice-based and community-wide interventions that decrease cancer rates and deaths through proven methods, including comprehensive cancer surveillance systems, widespread screening programs, behavior modification initiatives, and policy reforms designed to advance cancer control efforts. PCPs function as crucial proponents and practitioners of cancer prevention while playing a central role in diminishing cancer burden across communities.

SUMMARY

Effective clinical cancer control, based on the public health prevention model, principally involves three key levels: primary (reducing risk), secondary (screening for early detection), and tertiary (managing care after diagnosis), with primordial and quaternary prevention playing more minor roles. Primary care providers (PCPs) are essential at the forefront, tailoring screening efforts and addressing patient health behaviors such as smoking and unhealthy lifestyle choices. However, various obstacles hinder prevention efforts, including limited access to affordable screenings for many cancers, behavioral challenges in adopting preventive measures, health inequities, and a lack of specialized prevention training among PCPs. Emerging tools such as integrated electronic health records, artificial intelligence, and precision public health approaches offer promising ways to enhance preventive care through more individualized interventions. Since many cancers are associated with avoidable risk factors, prevention remains a vital part of managing population health. PCPs are instrumental in championing these practices, safeguarding the well-being of both individuals and their broader communities.

CLINICS CARE POINTS

There are four key themes that comprise the expanded significance of cancer prevention efforts in primary care.

1. Primary care providers (PCPs) serve as the frontline defense against cancer by being uniquely positioned to implement primary, secondary, and tertiary cancer prevention.
2. PCPs should use their long-term patient relationships to leverage their comprehensive knowledge of patients' family histories and health conditions, guide risk reduction, encourage cancer screening, ensure appropriate specialist referrals.
3. Cancer prevention faces significant barriers including inadequate screening methods, behavioral factors, limited primary care expertise, and time constraints that disproportionately impact underserved populations and create substantial health disparities.
4. Emerging technologies including electronic health records, artificial intelligence, precision public health approaches, and dissemination and implementation science are transforming cancer prevention by enabling more personalized and effective strategies.

FIGURE LEGEND

Figure 1. Opportunities for primary, secondary and tertiary cancer prevention interventions. The figure depicts the transition from the cancer-free population on the left side to the onset, progression and clinical outcomes on the right side. The vertical arrows represent opportunities to block progression to disease advancement that causes death or disability.

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