



Building Capacity for Global Cancer Research: Existing Opportunities and Future Directions

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Abstract

Cancer incidence and mortality are increasing in low- and middle-income countries (LMICs), where more than 75% of global cancer burden will occur by the year 2040. The primary drivers of cancer morbidity and mortality in LMICs are environmental and behavioral risk factors, inadequate prevention and early detection services, presence of comorbidities, and poor access to treatment and palliation. These same drivers also contribute to marked cancer health disparities in high-income countries. Studying cancer in LMICs provides opportunities to better understand and address these drivers to benefit populations worldwide, and reflecting this, global oncology as an academic discipline has grown substantially in recent years. However, sustaining this growth requires a uniquely trained workforce with the skills to pursue relevant, rigorous, and equitable global oncology research. Despite this need, dedicated global cancer research training programs remain somewhat nascent and uncoordinated. In this paper, we discuss efforts to address these gaps in global cancer research training at the US National Institutes of Health.

Keywords Global cancer · Capacity building · Cancer research

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Introduction

The burden of cancer is increasing in low- and middle-income countries (LMICs), where it is estimated that by 2040, 75% of the world's projected 21 million new cancer cases and 13 million annual cancer deaths will occur in LMICs [1]. This increase is attributable to aging populations and an epidemiological transition that is occurring in parallel with improving economic prosperity and control of infectious diseases. As most of the world's population now lives in LMICs, educators and policymakers are increasingly focused on developing a research workforce with appropriate skills to investigate important questions and test cancer control interventions in LMICs.

In the United States (US), incidence rates for all cancer sites have decreased on average 1.1% each year over the last 10 years, but significant disparities persist in cancer incidence and mortality among certain racial and ethnic minorities and immigrant communities [2]. The primary drivers of these disparities—environmental and behavioral risk factors, inadequate prevention and early detection services, presence of comorbidities, and poor access to treatment services—similarly contribute to the high cancer-related morbidity and mortality seen in LMICs.

In this review, our primary goal is to highlight the value of training and education in global cancer research to advance cancer knowledge. We will do this by first describing the global epidemiology of cancer, including key risk factors, highlighting notable advances in cancer control based on global research initiatives, and discussing unique scientific opportunities that can be pursued in global settings. Next, we will describe the current landscape of global cancer research

training strategies and programs at the US National Cancer Institute (NCI) and the Fogarty International Center (FIC) at the US National Institutes Health (NIH). Finally, we will discuss current gaps in global cancer research education and describe some directions to consider in developing future global research training initiatives.

We define cancer education and training broadly as efforts to impart skills and experiences essential to initiate, conduct, and maintain an independent career in cancer research. Our use of the term global indicates our focus on efforts which span high-income countries (HICs) and LMICs as defined by the World Bank [3].

Global Cancer Epidemiology

Cancer Incidence and Mortality

Cancer is a leading cause of mortality across the globe and kills more people than HIV, tuberculosis, and malaria combined. Figure 1 shows data abstracted from the Global Burden of Disease project that demonstrate an increasing proportion of deaths attributed to cancer from 1997 to 2017, particularly in LMICs. GLOBOCAN, a database of global cancer statistics, estimates that the top three incident cancers among women are breast cancer; colorectal and lung cancers. Among men, the top three incident cancers are lung, prostate, and colorectal cancers [4]. Between 1990 and 2010, the percentage of all deaths due to cancer increased at a higher rate in LMICs as compared to high-income regions of the world. For example, cancer death rates increased by as much as 30–50% within many LMICs from 1990 to 2010, including China, India, and Ethiopia [5]. These increasing

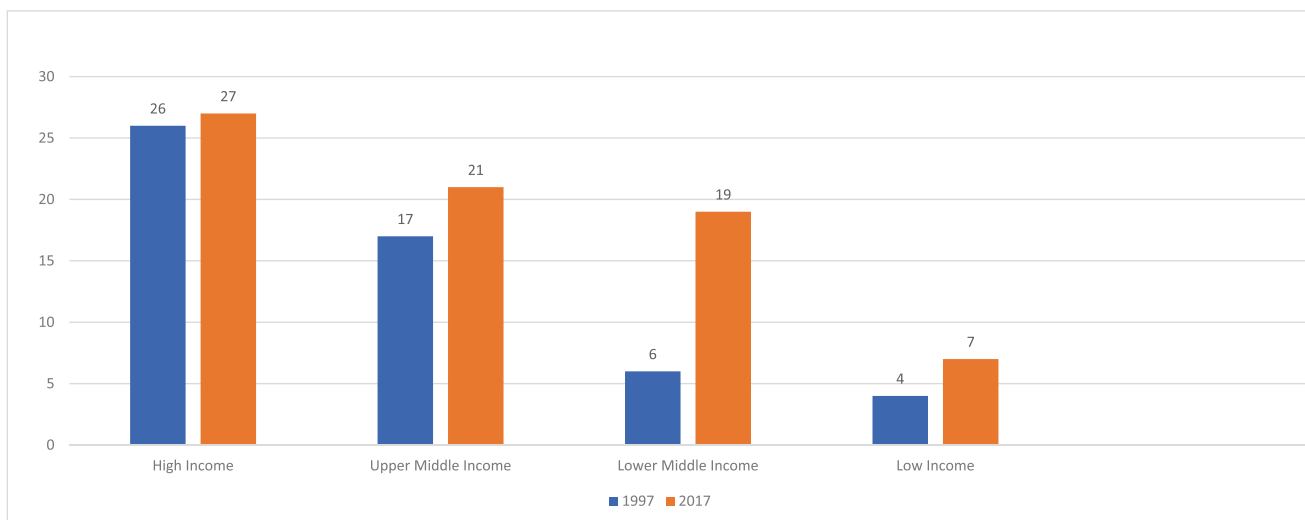


Fig. 1 Proportion of all deaths attributable to cancer by World Bank income group: 1997 to 2017

Top cancer per country, estimated age-standardized incidence rates (World) in 2020, females, all ages

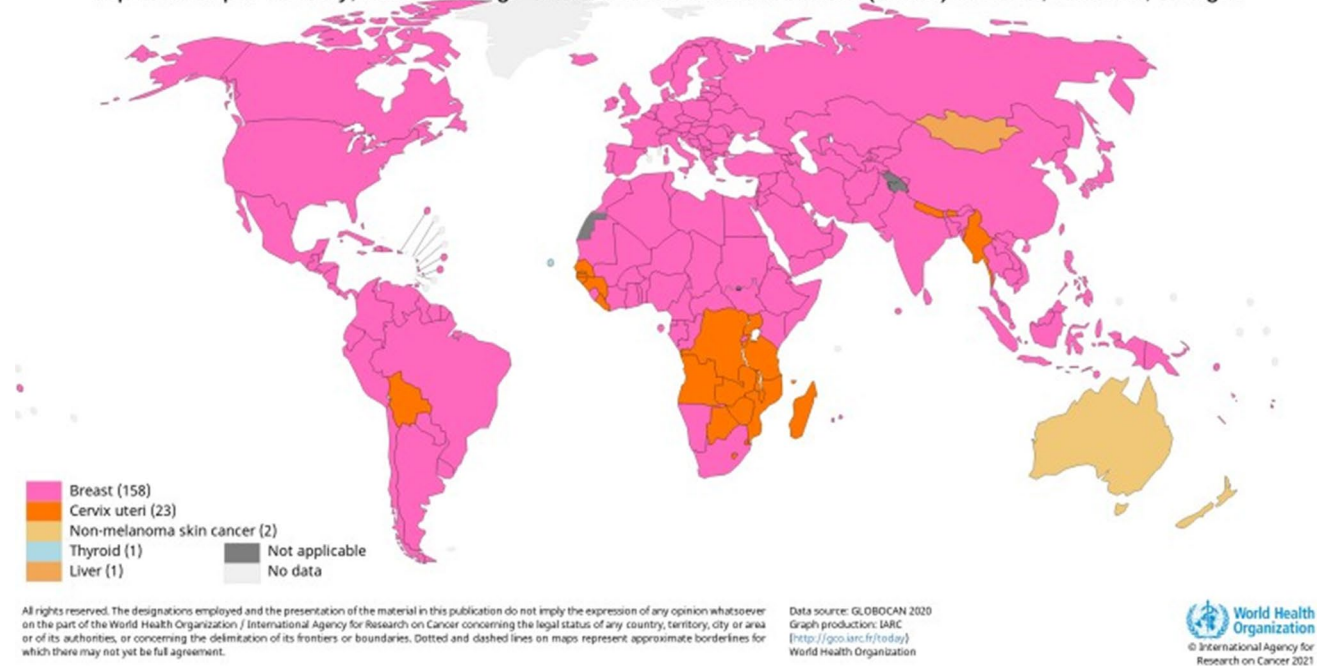


Fig. 2 Top cancer per country, estimated age-standardized incidence rates (world) in 2018, females, all ages

rates of cancer mortality are largely due to sociodemographic transitions in LMICs, but also reflect disparities in

late stages in LMICs [6]. Advanced stage presentations can be attributed to limited cancer awareness in many LMICs,

Top cancer per country, estimated age-standardized incidence rates (World) in 2020, males, all ages

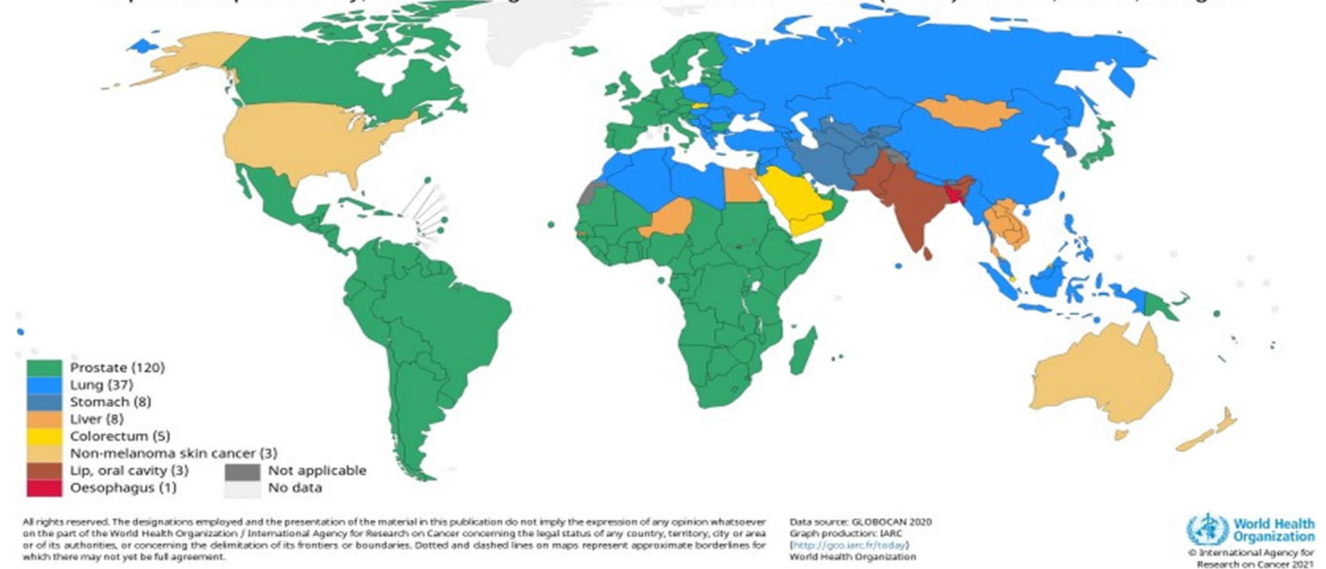


Fig. 3 Top cancer per country, estimated age-standardized incidence rates (world) in 2018, males, all ages

access, affordability, and quality of cancer care in LMICs. A recent analysis suggests that 74% of cancer is diagnosed in

as well as health system factors that lead to cancer diagnosis and treatment delays.

Geographical Distribution

A unique feature of global cancer epidemiology is the marked regional differences in cancer rates. Figures 2 and 3 show the dominant cancer sites among women and men, respectively, across the globe [7]. These data demonstrate significant variations between and within world regions in cancer frequency and mortality. For instance, liver cancer is prevalent in Asia and Africa and very rare in Latin America. Gall bladder cancer is another regionally associated cancer with unique geographical variations in incidence and mortality [8]. Rates are also higher in American Indian populations in the US and in Southeast Asia. Rates of esophageal cancers are high in parts of east Africa but low in other parts of Africa [9]. Cervical cancer, which is preventable through vaccination and screening, disproportionately affects poor, rural, and underserved communities worldwide [10]. These between-country differences accompany some stark differences within countries. In India, not only are overall cancer rates different between communities in the east compared to those in the west, but top cancer types are also different from region to region within the country [11]. Breast cancer rates in China reveal considerable geographical diversity between regions of the country in 5-year survival rates as well as between urban and rural populations [12]. Indigenous communities in Latin America experience higher rates of cervical and stomach cancer compared to the rest of the population in these same countries.

Modifiable Risk Factors for Cancer in LMICs

The burden of cancer in LMICs is also being driven by trends in known and well-studied lifestyle-related modifiable risk factors, including tobacco use, harmful use of alcohol, poor diet, and physical inactivity, as well as high prevalence of infectious agents associated with cancer. Tobacco use, while decreasing in many HICs, is not decreasing at the same rate in many LMICs, where over 80% of the world's tobacco users reside [13]. For example, over half of the adult male population in Vietnam and China continue to smoke [14]. Additionally, while the Framework Convention on Tobacco Control (FCTC) provides a global mechanism to advance tobacco control efforts, its implementation remains incomplete. Only 22% of the world's population is covered by smoke-free policies that meet FCTC guidelines [15]. Control of tobacco use globally is also complicated by the diversity of tobacco products in use across different regions, including hookah, various forms of smokeless tobacco, and e-cigarettes. While cigarette smoking tends to be lower among women in most LMICs, smokeless tobacco use is prevalent among women in South Asia [16].

Alcohol use is also emerging as a key public health concern globally. Globally, 5.5% of all new cancer cases and 5.8% of cancer deaths are attributed to alcohol [17]. Alcohol is causally associated with cancer of the oral cavity, colorectum, esophagus, female breast, and liver [18]. While the per capita consumption of alcohol in many LMICs remains low compared to Europe and North America, alcohol risk behaviors such as heavy episodic drinking and risky patterns of consumption such as drinking to intoxication are increasing in countries in the Russian Federation, Mexico, Pakistan, and South Africa [19]. Alcohol also operates in synergy with tobacco to increase risk of esophageal cancers and oral and laryngeal cancers. Addressing alcohol abuse will help develop control strategies for cancer and other adverse health outcomes [20].

A similar challenge is posed when the roles of diet and physical exercise in cancer risk in LMICs are considered. Many LMICs are undergoing a nutrition transition—a shift in dietary patterns and energy consumption attributed to socioeconomic factors including globalization [21]. This transition has led to diets with higher fat content and more sedentary lifestyle and is being implicated in the rapid rise in rates of diabetes, obesity, and overweight status. Increasing obesity is currently seen across the world, with children, women, and urban populations being most affected. Recent analysis of global data shows that over three decades beginning in 1980, obesity rates in children in LMICs have risen from 8.1 to 12.9% in boys and from 0.4 to 13.4% in girls [22]. Overweight status and obesity may be contributing to increased frequency of cancer, particularly among younger adults [23]. Moreover, research suggests that cancer-related risk behaviors, including tobacco and alcohol use, poor diet, and sedentary behavior, tend to cluster together in individuals [24]. Additionally, in low-income households, household income spent on tobacco is associated with poorer dietary quality [25].

Exposure to environmental carcinogens, including indoor and outdoor air pollution, is a serious problem in some LMICs, as evidenced by recent reports from major world capitals in middle-income countries on urban air pollution [26, 27]. In HICs, measures such as controlling outdoor air pollution, banning asbestos, and imposition of controls on other toxic agents and chemicals have been successful in limiting these exposures. Despite variability between countries in exposure assessment, it is estimated that between 7 and 19% of cancers globally are attributable to toxic environmental carcinogens [28]. In 2017, 14% of global lung cancer deaths were attributed to PM_{2.5} (measure of fine particulate matter in the air with a diameter of less than 2.5 μm) air pollution, and about 5% to household air pollution from solid fuels [29, 30]. For example, while tobacco smoking prevalence is very low among women in China, lung

cancer mortality is relatively high due to household air pollution exposure [31]. Second-hand smoke (SHS) exposure in the home and workplace also poses a significant additional environmental risk for cancer. Reported exposure to SHS at home remains high in some LMICs, ranging from 17.3% in Mexico to 73.1% in Vietnam, as well as in work places, restaurants, and public transportation [25].

A final risk factor for cancers in LMICs discussed in this paper is exposure to cancer-causing infectious pathogens. Of the estimated 2 million new cancers in LMICs in 2008, 80% were infection-associated cancers [32]. The attributable fraction for infection in cancer ranges from less than 5% in HICs to greater than 50% in some countries in sub-Saharan Africa [32]. *Helicobacter pylori*, hepatitis B and C viruses, and human papilloma viruses (HPV) were the dominant infectious agents causing gastric, liver, and cervical cancer, respectively, in LMICs. Over 80% of cervical cancer cases and deaths occur in LMICs [10]. Research in LMICs to better understand the role of infections in cancer is an important scientific opportunity and is discussed in more detail in a later section of this paper.

Notable Advances in Global Cancer Control

Notable advances in cancer control resulting from research in global settings are in the areas of cancer prevention and early detection. In cancer prevention, the availability and introduction of HPV vaccination is an important step in global cervical cancer prevention [33]. One hundred countries around the world have introduced the HPV vaccination in their immunization schedules as of 2018 [34]. Even as many HICs work to increase vaccination rates, they remain low in many LMICs. However, countries such as Malaysia have instituted school-based vaccination programs and report an estimated population coverage of 83 to 91% [35]. Hepatitis B vaccination for infants was introduced nationwide in 189 countries by 2018 and the WHO estimates that 84% of infants globally receive vaccination [34].

In cancer early detection, several advances in tools and strategies for cancer early detection stem from global cancer research. These take into consideration barriers of access to health care, social and cultural factors including stigma that contribute to late care seeking as well as health system factors that pose barriers to initiation and completion of cancer treatment among those in whom cancer is detected. Cervical cancer research has resulted in innovative methods to address these barriers. Training community health workers to perform visual inspection of the cervix, educating and motivating women particularly in rural areas to self-collect

cervical swabs, and instituting more sensitive detection test such as HPV DNA testing are examples of low-cost approaches to facilitate cancer early detection [36–38]. Inherent in these approaches are efforts to pair innovations with implementation science and health system strengthening so the most impactful cancer control interventions can be delivered at scale to diverse populations.

The burden of breast cancer in LMICs is also increasing, with a typically younger age of onset and more advanced presentation at diagnosis compared with HICs [39]. Early detection methods such as mammography, may not be practical given costs, and international expert groups such as the Breast Health Global Initiative advocate resource-specific, as well as age-specific, screening guidelines [39]. Breast health education programs to inform communities in LMICs about risk factors and the importance of early detection are recommended by these and other global initiatives [39]. Here again, as with cervical cancer, the use of trained community health workers in countries such as Bangladesh, Botswana, and Sudan has been shown to increase breast cancer referrals and awareness [40–42].

Colorectal cancer is the third most common cancer in men globally; while there are many advances in screening, incidence rates for this cancer remain low in LMICs. Many HICs (not including the United States) have nationally coordinated screening programs, while in LMICs, cancer screening is opportunistic [43, 44]. Oral cancer is most frequently diagnosed and causes high mortality rates in south Asian countries (Pakistan, India, Bangladesh, and Sri Lanka). Oral cancer screening trials that have targeted high-risk users of tobacco for screening by trained community health workers using visual inspection of the mouth have demonstrated efficacy reducing mortality in LMICs [45]. There are also reports of use of novel screening technologies to visualize the mouth, detect lesions, and link to treatment that may have practical application in LMICs [46].

Unique Opportunities in Global Cancer Research

Global epidemiology, and advances in cancer prevention and early detection based on research in international settings suggest that there may be several unique opportunities to study cancer and improve cancer control through equitable collaboration in LMICs. This necessitates expanded opportunities for global cancer education and research training. Table 1 outlines some unique opportunities to advance cancer knowledge by conducting research in LMICs, and these are discussed in more detail below.

Table 1 Unique scientific opportunities to advance cancer knowledge through global research

Unique scientific opportunity in LMIC-based research	Areas of research focus
Understanding the role of disparities and structural factors in cancer outcomes	Cancer biology: Understand disease etiology, ancestry-related determinants of tumor progression; co-infections; microbiota and cancer Cancer genetics: Ancestry-based genetic risk and protective factors Health systems research; community-engaged research; policy evaluations
Developing implementation strategies to translate evidence from cancer research	Implementation science: Developing innovative evidence delivery and quality improvement strategies in low-resource settings
Improving understanding of infections cancer risk	Understand the role of pathogens in cancer etiology and risk; building on infectious diseases and other non-communicable diseases (heart disease, diabetes) research capacity
Understand the role of comorbidities in cancer risk and control	Cancer epidemiology: Evaluation of unique lifestyle factors and patterns of behavior, environmental risk factors in cancer; region-specific cancer risk behaviors and patterns; social norms and support models in cancer care; evaluating role of comorbidities and cancer; global migration and cancer risk
Investigating technology and data science applications	Developing and evaluating affordable technologies for cancer detection and treatment, mHealth approaches to improve patient outcomes

Understanding the Factors Which Underlie Cancer Health Disparities and Developing Effective Interventions

As the evolving COVID-19 pandemic is demonstrating, health disparities are leading to a disproportionate number of infections among underserved communities in the United States, and as a result appeals to include diverse populations in planned vaccine trials are drawing attention [47]. The need to be more inclusive of diverse populations in cancer research is also being underscored as studies suggest that participation of populations of non-European ancestry in cancer research studies is low [48, 49]. As cancer is fundamentally a genetic disease, studying cancer research among global populations can help deepen our understanding of the biological and genetic basis of cancer. Ancestry-related determinants of gene expression, tumor progression, and tumor microenvironment; co-infections and cancer; role of microbiota and cancer; and biomarkers in cancers that are rare in HICs but more prevalent in LMICs are some examples of investigations that can lead to a deeper understanding of the biological basis of cancer, its prevention, and treatment [50–52]. However, it is also clear that in addition to biological and genetic factors, structural factors such as poverty and policies that perpetuate the disparities experienced by underserved communities play a likely even more prominent role in cancer control and outcomes. These factors are not limited to LMICs but are equally applicable to populations experiencing disparities in the United States and other HICs. More research is needed to better understand

and measure these non-biologic contributors to cancer health disparities, develop and test approaches for addressing them, and translate effective approaches into evidence-based public health policies. Examples of structural-level interventions designed to address disparities include policies that provide health insurance coverage for cancer in Mexico [53], mandatory vehicle-free zones to promote physical activity in Colombia [54], facilitating outreach and triage to cancer treatment in rural India [55], nurse- and navigator-led approaches to cancer education and screening in rural Appalachia in the US [56], and geographically targeted breast cancer control initiatives in Chicago [57].

Developing Effective Implementation Strategies to Translate Evidence From Cancer Research

Global settings offer many opportunities to conduct implementation research to develop effective and pragmatic approaches for evidence translation. Implementation science is the study of methods to promote the adoption and integration of evidence-based practices, interventions, and policies into routine health care and public health settings to improve the impact on population health. This discipline is characterized by a variety of research designs and methodological approaches, partnerships with key stakeholder groups (e.g., patients, providers, organizations, systems, and/or communities), and the development and testing of ways to effectively and efficiently integrate evidence-based practices, interventions, and policies into routine health settings. Examples of cancer implementation research in global

Table 2 Infections and cancer: a rationale for global research

Infectious agent	Cancer	Opportunities for global research
Bacteria		
<i>Helicobacter pylori</i>	Stomach cancer	Highest rates in East Asia (South Korea, Mongolia, and China) followed by Middle East (Iran) Central Asia and Latin America Research to identify strategies to deliver screening and treatment; <i>H. pylori</i> eradication strategies
Viruses		
Human papilloma virus	Cervix, oropharyngeal, anogenital	85% of all cervical cancers are in low- and middle-income settings Research to understand acceptable approaches to deliver vaccine. Adaptation of screening and triage to treatment; quality improvement studies
Hepatitis B virus; hepatitis C virus	Liver cancer	East Asia has the highest rates of liver cancer. Liver cancer cases in Mongolia are 6 times that of the global average. Mozambique ranks second in this cancer site. Behavioral interventions for reducing alcohol abuse. Dissemination of hepatitis B vaccine; screening and treatment research for hepatitis C infections
Epstein-Barr virus	Burkitt lymphoma, nasopharyngeal carcinoma	Overall, cancers attributed to EBV have increased in recent years. Burkitt Lymphoma accounts of 50% of childhood lymphomas in Africa and over 80% are infected with EBV; nasopharyngeal rates are highest in east Asia (Brunei, Indonesia); half of all EBV attributed cancer occur in E Asia.
Human herpes virus 8 (HHV8)	Kaposi sarcoma	Most common HIV-associated malignancy in sub-Saharan Africa
Human immunodeficiency virus (HIV)	Many cancers with increased risk in HIV including Burkitt lymphoma, cervical cancer, and liver cancer	HIV is highly prevalent in many LMICs. Global research investments in HIV prevention and treatment may be leveraged for cancer control
Other parasites		
Liver flukes	Bile duct cancer	High rates in Southeast Asia Community-based studies to improve cancer literacy
<i>Schistosoma haematobium</i>	Bladder cancer	Highest rates in Middle East (Lebanon) and Mediterranean (Greece). Parasite control strategies

settings include developing protocols to improve adherence to treatment guidelines for tobacco cessation in Vietnam [58], developing community-based strategies to provide cancer screening hard-to-reach communities in Argentina [38], and evaluating adoption and acceptability of novel cervical sample collection methods for screening in India [37]. Considering the variation in health care systems and availability of health delivery personnel, implementation science in LMICs also offers the opportunity to understand innovative quality improvement models and models of integration cancer services into existing disease control programs. Tools available in implementation science allow for adapting evidence in LMIC settings and evaluating their adoption in communities, and they are being widely applied in evidence

translation in fields such as global mental health, infectious disease control, and diabetes prevention [59].

Improving Understanding of Infections in Cancer Risk

Infectious pathogens remain an important and modifiable risk factor for cancer. Table 2 outlines the list of major pathogens, their associations with cancer, and brief rationale and opportunities for research on infections and cancer in LMICs. The four most important pathogens that contribute to the global burden of cancer include *Helicobacter pylori* (stomach and gastric cancer); human papillomavirus (HPV, cause of cervical cancer); and hepatitis B and hepatitis C viruses (liver cancer). Infection rates were

highest in eastern Asia and sub-Saharan Africa. China accounted for a third of worldwide cancer cases attributable to infection, driven by high rates of *H. pylori* and hepatitis B virus infection [60]. Globally, 85% of cases of cervical cancer occur in LMICs [61]. Epstein-Barr virus (EBV)-associated cancers have increased 14.6% in recent decades, including endemic Burkitt lymphoma in Africa and nasopharyngeal cancer in east Asia [62]. Kaposi sarcoma, caused by human herpes virus 8, remains a primary AIDS-defining cancer in sub-Saharan Africa [63]. Other infectious agents such as liver flukes are associated with bile duct cancer—a rare cancer in HICs but more prevalent in Southeast Asia [64]. Trematodes such as *Schistosoma haematobium* are associated with bladder cancer [65]. Research to understand etiology of cancers associated with infections can be more efficiently conducted in global settings where there are larger number of infections and in many cases existing local capacity to conduct research, due in part to substantial global investment in infectious disease research. Opportunities for research and intervention in LMICs include implementation research to identify strategies for eradication and delivery of screening and treatment for *H. pylori* infection, context-relevant vaccine delivery strategies for HPV and hepatitis B, and screening and timely treatment for hepatitis C infection. Implementation research can also inform adoption of screening and linkage to treatment for cervical cancer. Treatment of parasites might begin with behavioral intervention to improve cancer literacy in populations at risk for infection [66].

As global cancer research develops as a discipline, the immense investments made by national governments and international agencies in infectious disease research and control provide valuable resources and infrastructure for cancer investigations. This includes world-leading LMIC experts and scientists, and established global research collaborations and infrastructure [67]. These resources provide an important foundation for the global cancer researcher community to build upon.

Understanding the Role of Comorbidities and Behaviors in Cancer Risk and Control

As many LMICs undergo an epidemiological transition, there is increasing prevalence of chronic disorders such as diabetes, liver disease, and cardiovascular disease. These conditions share common risk factors with cancer. Diabetes for instance is increasing dramatically in LMICs. In 2019, India and China with 77 and 116 million cases of diabetes, respectively, far surpassed the US (31 million cases) and other HICs [68]. According to the International Diabetes Atlas, Pakistan and Indonesia will have also higher cases than the US by 2045 [69]. Similarly,

liver cirrhosis has the highest rates in Asia, where 24% of deaths from cirrhosis and 19% of deaths from liver cancer are attributed to alcohol use [70]. Collaborative efforts to address these comorbid conditions and behaviors in high-burden settings can thus generate new knowledge that is applicable worldwide.

Investigating Technology and Data Science Approaches in Cancer Control

As the COVID-19 pandemic demonstrated, some countries readily embraced technology to assist in the prevention of virus transmission. This included mobile applications for contact tracing, telehealth, and triage of patients as well as more comprehensive digital technology platforms that helped government and physicians plan, track, and coordinate patient care and management [71, 72]. Globally, access to smart phones and other portable communication devices and comfort with their use is high. Engineers and oncologists working together have employed technology-mediated solutions to cancer screening, detection, and treatment in settings with limited access to expert oncologists and physicians. These solutions also serve to partially circumvent health system infrastructure barriers. In addition to affordable cancer technologies, data sharing and capacity building in big data analytics are leading to global collaborations that allow complex questions to be addressed in new ways. Capacity development in data science is the next frontier in cancer research with computational skills coming to be regarded as a second language in cancer research [73]. An emerging and important focus area, data science research in LMICs can help expand our understanding of precision medicine and risk prediction in cancer [74], but such efforts require validation of innovative tools and algorithms in diverse populations.

Workforce Development in Global Cancer Research

Understanding and addressing these unique opportunities requires well-developed interdisciplinary and interactive programs to teach research skills at the individual level, and capacity to support cancer research and career development at the institutional level in both US and LMIC settings. However, dedicated global cancer research training is lacking both at US and LMIC institutions. This gap in global oncology training was also underscored by an expert panel convened by the American Society of Clinical Oncology. This panel noted the growing interest in global oncology training and the uncoordinated and disjointed approach at both individual and institutional level to train

cancer researchers seeking to work in LMICs. Opportunities for clinical research and practice experiences in global settings, defining competencies needed in training, and developing resources and repositories to help guide interested individuals to available training opportunities are examples of activities suggested by this panel to develop a global oncology workforce [75].

Seeking to pursue the scientific opportunities in global cancer research, many institutions are beginning to develop global oncology programs and initiatives. One approach adopted by many US institutions is building on historical US-LMIC institutional collaborations for HIV/AIDS research. These past research collaborations were built on a foundation of consultation with country ministries of health and policy makers, as well as with LMIC researchers and institutions committed to research. This foundation has allowed researchers with interest in global oncology to begin research projects relevant to the LMIC setting and based the country's cancer control priorities. These research opportunities also coincide with better management of HIV/AIDS, resulting in infected individuals living long enough to become afflicted with non-communicable diseases, including cancer.

Typically, these cancer research collaborations are built and sustained by individual leaders whose commitment and ability to attract funding helps grow the program and develop a pipeline for mentorship and training [76–78]. However, these growing global oncology programs have unstable financial support and are limited to a narrow scope of research and training that is allowed by granting agency and philanthropy priorities. Furthermore, training may begin with a focus on immediate LMIC needs to develop cancer care and treatment capacity and not with a focus on research capacity building.

Trainees reporting on their global oncology experiences note that this rise in cancer research programs is not accompanied by investments in training junior faculty to conduct research. Research training remains fragmented and limited (in some cases to a single course or grand rounds in global oncology), and opportunities for research are often driven by individual trainees' interest [79]. Furthermore, trainees and mentors may have mismatched expectations of research experiences, maturity of trainee, cultural awareness, and competency that can influence the conduct of research and relationships with collaborators in LMICs [80].

Although global cancer research training is an emerging field, its development can be informed by the field of global health education and research that is relatively well established in the US and other countries [81]. The Consortium of Universities in Global Health (CUGH) was formed in 2008 to support global health curricula and programs and has membership from over 100 international institutions.

There has been an increase in offerings of global health courses and programs, high enrollment in these programs, and increased demand for research experiences in global settings at all levels of education (undergraduate to medical college) [82–84]. Evaluations and observations from these programs offer important lessons for institutions as well as individuals seeking global cancer research training. At the institution level, value of proposed research training to host organization in LMIC, joint development of research program, and providing adequate mentoring and supervisions are emphasized as key principles to facilitate training. Recognizing the true cost of training to the LMIC host and clear bidirectional communication about the program goals and objectives also help develop sustainable institutional collaborations [85]. Trainees further experienced several barriers in research training in LMICs. These include lack of mentorship, lack of funding to support research training, and inadequate consideration of family and work-life balance in available research training programs [86]. Another important lesson while planning both institutional and individual training programs is to invest in mentor training. Mentors need protected time to guide mentees and facilitate development of research skills. These skills include strategies for communicating questions and ideas and scientific conduct topics such as engaging with peers and senior faculty [87]. Cancer research training programs have the advantage of building on these experiences and lessons.

Role of the US NIH in Global Research Training

Training and capacity building for research is central to the mission of the US NIH, the world's leading supporter of biomedical research and training [88]. The NIH comprised 27 institutes and centers and many of these entities have important investments in global research and training [89]. We will discuss the role of the Fogarty International Center and the National Cancer Institute (NCI) in global cancer education and training. Administratively, NIH and NCI identify a funding opportunity using a three character alphanumeric number that is specific to its purpose (research or research training) or the way the grant program is implemented (by the awardee alone or in cooperation with the funding agency NIH instituter center).

Fogarty International Center

FIC advances the mission of NIH by supporting and facilitating global health research conducted by US and international investigators, building partnerships between health research institutions in the US and abroad, and training the next generation of scientists to address global health needs

[90]. Many NIH institutes and centers participate in FIC programs so that they can support global training relevant to their respective missions. FIC's programs may broadly be grouped in two categories: programs that support institutions and those that support individuals. An early and impactful FIC program is the AIDS International Training and Research Program (AITRP; in its current form as the HIV Research Training Program, HIVRT)—an institutional research training program in HIV/AIDS research. Established in the early 1980s, AITRP/HIVRT has been a catalyst in the career development of many leading HIV/AIDS researchers today [91]. Similar institutional research training supported by the Global Health Fellows and Scholars initiative provides funding to US-based consortia and their LMIC partners to train future leaders in global research and also provide one-time 1-year support to trainees for mentored research projects—this is not restricted to HIV/AIDS research training and includes pre- and postgraduate clinical research [92, 93]. This program utilizes research experts and existing global research networks and has resulted in improved scholarly productivity and helped in career advancement of many trainees from LMICs and the US [90].

While FIC support for research training is not specific to any cancer site or research topic, in the past almost two decades, in recognition of the epidemiological transition in LMICs, FIC has been growing its portfolio of funded research in non-communicable diseases (NCDs) [94]. In 2008, FIC expanded the program to explicitly include areas such as cancer, with participation from NCI. FIC's current Chronic, Non-communicable Diseases and Disorders across the Lifespan (NCD-Lifespan) research training program began in 2011 as a continuing initiative that is competed annually for 5-year awards to build institutional research capacity in NCD research, including cancer. One-year planning grants for LMICs have allowed for the assessment of training needs and strategic planning to directly submit later proposals for research training programs. To complement NCI's D43 initiative [95], future cancer awards from this program will focus on direct D43 awards to LMIC institutions, while NCI awards will be to US institutions partnering with LMIC institutions. Institutional awards for training and curriculum development in key cancer-relevant research areas such as bioethics [96], global infectious diseases, HIV, tobacco control [97], and environmental and occupational health further support focused training and curriculum development to pursue important questions in global health [98].

Individual capacity building programs at Fogarty include career development awards for US (the International Research Scholar Development Award (IRDSA)) and LMIC (Emerging Global Leader Award) trainees who have completed doctoral degrees are committed to a career in global health research. These use the K01 and K43 funding

opportunity mechanisms, respectively. In both these programs, applicants propose 5-year research training and mentorship plans. As these grants allow for dedicated time for research, these awards aim to facilitate trainee career development and transition to career independence. In addition to these programs, FIC also works in partnership with other US agencies and international organizations to support research training and education [99].

National Cancer Institute

The US NCI, one of the 27 institutes and centers that form the US National Institutes of Health (NIH), has a long history of supporting and investing in the training of the scientists to conduct cancer research. It works closely with FIC. In 2018, the NCI provided \$2.8 million and FIC \$520,000 towards global cancer research and training grants. A large proportion of NCI support in this year was towards the tobacco control research training program (32%) and training and research in environmental health (32%). This was followed by research support for HIV and AIDS malignancy research (13%) and support of individual career development grants (10%). In the same year, 96% of FIC's support of NCI programs went towards HIV and AIDS malignancy research, reflecting strategic efforts to leverage prior HIV-related investments for non-communicable disease (NCD) programs.

Many divisions, offices, and centers within the NCI also support research training in general and global research training. The Center for Cancer Training (CCT) supports cancer research training programs primarily in US institutions. Support for training in these institutions is also provided by NCI's Center to Reduce Cancer Health Disparities (CRCHD). The Center for Global Health (CGH) supports US and foreign institutions interested in global research training. The Office of HIV and AIDS Malignancy (OHAM) supports training in HIV and AIDS malignancy research. Considering the global distribution of HIV/AIDS, a significant number of programs of OHAM support collaborative research and training in international settings. The Office of Cancer Centers (OCC) provides research and infrastructure support to the 71 NCI-Designated Cancer Centers in the US. Table 3 is a review of the NCI's research training portfolio for fiscal years 2010 to 2019.

Training the Next Generation of Cancer Researchers

The mission of the NCI's CCT is to catalyze the development of a workforce capable of advancing cancer research through a scientifically integrated approach [94]. CCT accomplishes this by coordinating and providing research

Table 3 Domestic and global extramural research training support at the US National Cancer Institute in fiscal year 2010–2019: Fellowship, career development, research education, and institutional training awards

	Domestic	Foreign collaborator	Foreign direct
Fellowship Awards			
F30—Predoctoral MD/PhD Fellowship	408	11	0
F31—Predoctoral Fellowship	875	16	2
F32—Postdoctoral Fellowship	531	5	4
F99/K00—Predoctoral to Postdoctoral Fellow Transition Award	106	6	0
Total	1920	38	6
Career Development Awards			
K00—Postdoctoral Transition Award	49	2	0
K01—Mentored Research Scientist Development Award	159	3	0
K05—Established Investigator Award in Cancer Prevention and Control	32	1	0
K07—Cancer Prevention and Control, Behavioral Sciences, and Population Sciences Career Development Award	198	13	0
K08—Mentored Clinical Scientist Research Career Development Award	315	9	0
K18—Career Enhancement Award for Experienced Investigators	1	0	0
K22—NCI Transition Career Development Award	157	4	0
K23—Mentored Patient-Oriented Research Career Development Award	79	1	0
K24—Mid Career Investigator Award in Patient-Oriented Research	36	0	0
K25—Mentored Quantitative Research Career Award	39	0	0
K43—Fogarty Emerging Global Leader Award		0	3
K99/R00—Pathway to Independence Award	331	21	0
Total	1424	54	3
Research Education Awards			
R25—Cancer Research Education Grants Program	179	18	4
U2R—Global Training in Environmental and Occupational Health	0	2	0
Total	179	20	4
Institutional Training Awards			
D43—Strengthening HIV/AIDS Research Capacity in LMICs	0	23	0
T15—Continuing Education Grants	6	0	0
T32—The Ruth L. Kirschstein NRSA Institutional Research Training Grant	282	2	0
K12—Paul Calabresi Career Development Award for Clinical Oncology	28	0	0
Total	288	25	0

training and career development activities for fellows and trainees in NCI's laboratories, clinics, and other research groups (intramural research training); developing, coordinating, and implementing opportunities in support of cancer research training, career development, and education at institutions in the US (extramural training); identifying workforce needs in cancer research; and adapting NCI's training and career development programs and funding opportunities to address these needs.

CCT supports training as part of NCI's Intramural Research Program (IRP) alongside and in collaboration with training directors across Divisions/Offices/Centers at NCI, including the Center for Cancer Research, the Division of Cancer Epidemiology and Genetics, the Division of Cancer Control and Population Sciences, and the Division of Cancer Prevention. The IRP includes scientists, physicians, and clinicians who conduct basic, translational, clinical, genetic, epidemiological, and population-based research

in NCI's laboratories and centers and at the NIH Clinical Center. The training activities at NCI support a pipeline that starts from outreach to students in middle and high school through post-doctorate level training. There are about a thousand trainees at NCI at any one time. Approximately one-quarter are postbaccalaureate students doing research for a year or two after obtaining their bachelor's degree; another quarter are postdoctoral fellows who are US citizens or permanent residents; 40% are visiting fellows through the NIH Visiting Program [100]; and the remainder are graduate students. Postdoctoral scientists and visiting fellows from over 68 countries around the world work in NCI labs. The NCI Future Fellows program is a database of candidates to be considered for postdoctoral fellowships, internships, and professional positions that allows prospective fellows to upload their resumes for consideration. There is also guidance on applying and contacting laboratories and scientists

at NCI with whom applicants can discuss research interests and explore collaborations.

In addition to the IRP, CCT plays a role in the development and administration of NCI's extramural research training programs alongside CRCHD. This portfolio shows four categories of research training grants: individual fellowship awards, individual career development awards, research education awards, and institutional training awards as shown in Table 3. We stratified these categories further based on where proposed training was to be conducted as follows: training awards to US institutions that had no foreign collaboration (domestic awards), training awards to US institutions that work with a foreign collaborator or performance site (foreign collaborator awards), or grants directly awarded to a foreign principal investigator or institution (foreign direct awards).

Individual fellowship awards include the National Research Service Award (NRSA) program that offers fellowships at predoctoral and postdoctoral levels (F30, F31, F32 mechanisms) and fellowships for senior fellows who are transitioning to a new area of cancer research (F33). All fellowships are awarded to US citizens and permanent residents of whom almost all conduct research at US institutions. Foreign components of fellowship awardees signal that the US institution where fellow works may have a collaboration with a foreign site to conduct research, or that the laboratory where the fellow works in the US may have a collaboration with a foreign laboratory to obtain specific compounds or data necessary for the research. Foreign direct fellowship awards are to US citizens or permanent residents who are based in a foreign institution as they conduct their research.

In addition to fellowships, NCI supports *career development awards* aimed at mentored research support of clinician scientists (K08 mechanism) and postdoctoral candidates in cancer research (K01), as well as career development focused on specific areas such as quantitative science (K25). The NCI K12 institutional grant provides career development support to clinician scientists for training in leading clinical trials. The K01 program uses the same mechanism as the earlier mentioned IRDSA initiative of FIC but does not allow training in foreign settings. Other now-discontinued NCI career development awards supported training in specific cancer research areas such as population and behavioral sciences and patient-oriented research (K05, K07, K23, and K24). CCT also makes career transition awards to fellows who are transitioning from a predoctoral program to a postdoctoral degree (F99/K00), or from a postdoctoral program to an independent career as a researcher (K99/R00 and K22 mechanisms). In contrast to other career development awards, which are limited to US citizens and permanent residents, the F99/K00 and K99/R00 transition

programs are open to foreign nationals who are working in a US institution.

Finally, in addition to the institutional K21 program, CCT supports a range of *institutional training programs* (R25 and T32 grant programs) that focus broadly on curriculum development and research education as well as to develop institutional capacity for cancer research. As shown in Table 3, among the total of about 3800 training awards in the period 2010 to 2019, only 138 awards (4%) had a foreign collaborator and 11 (0.3%) were awarded directly to a foreign institution, largely because foreign institutions are not eligible for most of these training awards.

Leveraging the Training Infrastructure at NCI-Designated Cancer Centers to Include Global Communities

The Office of Cancer Centers (OCC) manages the NCI's Cancer Centers Program, which was created by the National Cancer Act in 1971 and is one of the main anchors of the nation's cancer research effort. The mission of the NCI Cancer Centers Program is to foster highly interactive transdisciplinary and translational cancer research through supporting formalized and centralized infrastructures in cancer research-intensive institutions, including leadership and administration, strategic planning and evaluation, shared resources, education and training, community outreach and engagement, scientific oversight, and safety and quality control of cancer clinical trials. NCI recognizes cancer centers across the United States that have successfully met a spectrum of rigorous standards with the Cancer Center Support Grant (CCSG) and accompanying NCI designations reflecting their research focus and scope (Basic Cancer Center, Clinical Cancer Center, Comprehensive Cancer Center). Over the past several decades, the number of NCI-designated Cancer Centers has grown, and as of 2020, there are 71 NCI-Designated Cancer Centers, located in a variety of organizational settings in 36 states and the District of Columbia. Each year, about two-thirds of NCI's Research Project Grant (RPG) funding goes to investigators in NCI-Designated Cancer Centers. Although the CCSG does not directly fund the wide range of research activities conducted by cancer centers, it links state-of-the-art research across the cancer research continuum from basic laboratory research to translational, clinical, and population-based research at cancer centers. Cancer centers must renew their CCSG and the NCI designation every 5 years through a competitive application and review process.

Under the CCSG guidelines specified in "Cancer Research Training and Education Coordination" component, all three types (basic, clinical, comprehensive) of NCI-Designated Cancer Centers are expected to integrate cancer training and education of biomedical researchers and community health

care professionals into programmatic efforts to enhance the scientific mission of the Center. NCI-Designated Cancer Centers have invested in and supported a comprehensive portfolio of cancer-related education and training programs that span from high school, undergraduate, graduate, and postgraduate students to young faculties. In addition to training a domestic workforce in cancer research, a significant number of NCI-Designated Cancer Centers have also extended their efforts to global oncology. By leveraging the existing training infrastructure and research collaborations with LMICs, these cancer centers have contributed to the expansion of the global cancer research workforce both in the US and in LMICs. As shown in a recent survey conducted by the NCI and the American Society of Clinical Oncology, 33 out of the 71 NCI-Designated Cancer Centers have reported having a global oncology program. The top focus of these programs includes research, capacity building and training, and LMIC activities. Among these centers, 27 centers provide certain level of global oncology training, 17 centers have trainees who have completed global oncology rotations outside of the US, 17 centers have enrolled trainees from LMICs, and 15 centers have engaged with non-enrolled trainees in LMICs through activities such as capacity building. Supported by funds from a variety of sources (NIH, institutional, non-profit organizations, industry, and international), NCI-Designated Cancer Centers have become hubs for sharing information, building research collaboration, and training next generation of investigators for global oncology across the US [101].

Supporting Research in HIV and AIDS Malignancy

The NCI has played a major role in human immunodeficiency virus/acquired immunodeficiency syndrome (HIV/AIDS) research since the beginning of the epidemic when a cluster of cases of Kaposi sarcoma was one of the harbingers of this new disease. NCI scientists have made several key discoveries in both HIV/AIDS and HIV-associated cancers. Since 2007, this research is coordinated by the Office of HIV and AIDS Malignancy (OHAM). Recognizing the need for HIV/AIDS malignancy research training, OHAM began providing research training supplements to existing HIV training programs supported by FIC to specifically train the workforce in key areas of HIV-associated malignancies research. Following these supplements, in 2013, OHAM issued its own institutional training program for HIV/AIDS malignancies research and supported 9 awards to US research institutions collaborating with LMIC institutions to conduct research training focused on HIV-associated malignancies. Following this training program, OHAM developed several initiatives that focused on increasing research capacity in HIV-associated malignancies. These initiatives support partnerships that allow trainees, and US and LMIC investigators opportunities to advance and establish collaborative research programs in HIV and cancer. These initiatives support research projects that are mainly conducted in LMICs by LMIC investigators.

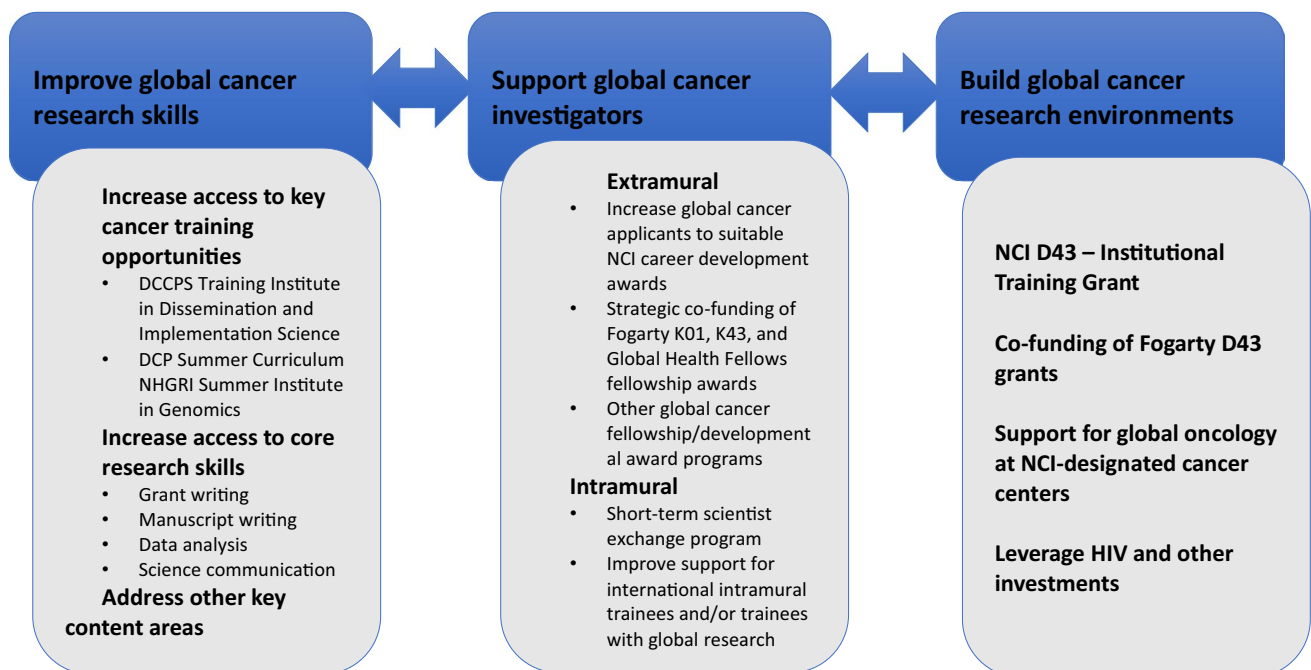


Fig. 4 Towards a more comprehensive global cancer research training strategy

Supporting and Facilitating Global Cancer Research and Training

Established in 2011 with a vision to reduce worldwide cancer suffering through global scientific discovery and dissemination, NCI's CGH supports the NCI mission by advancing global cancer research and by coordinating NCI engagement in global cancer control. CGH does this by supporting innovative research that addresses key scientific issues in global cancer control and/or leverages unique scientific opportunities afforded by global collaboration. CGH is also committed to supporting global cancer research training, particularly in LMICs, that enables impactful scientific collaboration. Finally, through a variety of partnership and dissemination activities, CGH promotes science-based global cancer control.

Recognizing the demand for global cancer research training and the gaps in the funded portfolio, NCI CGH is leading the development of programs and initiatives that will enable the next generation of US and LMIC scientists to develop skills and gain experiences to lead innovative and significant cancer research investigations in global settings. An evolving conceptual framework for research training and programs supported in global training by CGH is shown in Fig. 4. This framework has three pillars which support the goals of education, individual capacity building, and institutional capacity building, respectively, to conduct global cancer research. This framework guides CGH in developing programs and initiatives that support trainees who navigate a pathway that begins with gaining research education skills and culminates in an independent research career.

Improve Global Cancer Research Skills

This first pillar in this pathway are investments in research education that are available to predoctoral as well as postdoctoral candidates from the US and LMICs. Research education programs allow trainees to develop foundational knowledge needed in the conduct of cancer research. Didactic courses provide expertise in specific scientific topics such as genomics and implementation science, and research experiences that teach skills relevant to research such as assays, or genomics or statistical analysis are examples. CGH has several programs to facilitate research education. These include travel support to individuals to attend research training courses at NIH such as the Training Institute for Dissemination and Implementation Research in Cancer [102], the NCI Summer Curriculum for Cancer Prevention [103], and the National Human Genome Research Institute's Summer Institute in Genomics [104]. CGH programs in this area also include awards to institutions to build educational programs (workshops, courses) in cancer research and to support travel of eligible LMIC scientists to attend these programs [105].

Research education efforts such as courses and workshops are also proposed by scientists applying to the NIH conference grants mechanism; these provide learning opportunities on specific topics to candidates from LMICs, usually within the proceedings of a scientific conference or meeting. Finally, in recognition of the lessons learned from other global research training programs, there are cross-cutting areas where education and skills development are key to productive global engagement and collaborations. These include skills in grant writing, instruction, and mentorship in manuscript writing, as well as introduction to principles of science communication. CGH has organized sessions at international conferences on topics of interest to the cancer trainees such as scientific manuscript writing and grant writing [106].

Support Global Cancer Investigators

The second pillar of the framework are programs that support individual research capacity building for those trainees who have training in research methods. CGH has programs to support investigators in both extramural institutions and intramural programs. In extramural support, CGH seeks to increase global cancer applicants to suitable NCI career development programs. This includes *career development awards* that support individuals from LMICs and US through FIC's Emerging Global Leader Award program (K43 program) and the International Research Scholar Development Award (K01 program) respectively. CGH support of these programs began in 2018, and as of 2020, two K01 and two K43 awards shown in Table 3 support US and LMIC postdoctoral trainees to conduct research in LMICs. These funded applications build on ongoing global cancer research collaborations and have the support of established experts/mentors in their chosen field of training. CGH has also partnered with other global cancer fellowship/developmental award programs for early career researchers. Some examples include partnership with ASCO, Union of International Cancer Control, and the African Organization for Research and Training in Cancer (AORTIC). These fellowships allow wider outreach to prospective applicants and support cancer research in specific topics such as palliative care and technology transfer or research in specific regions of the world [107–109].

CGH's Short-Term Scientist Exchange Program [110] supports LMIC fellows through collaboration with the NCI's IRP. Meritorious candidates from LMICs come to the NCI to spend up to 6 months to work on collaborative research projects. NCI scientists also visit international institutions for scientific collaboration. CGH continues to work with NCI divisions to develop programs that support international intramural trainees and/or trainees with global research interests.

Reports from similar career development and fellowship programs awarded by other agencies suggest that support of early career investigators is an important catalyst in career growth and independence. Evaluation of the IRSDA program at Fogarty showed that K01 awardees have gone on to lead future research grants, and assumed leadership positions in their institutions suggesting that this investment by NCI CGH might see similar results [111]. Evaluation of CGH fellowship awards suggests that these early career awards help support locally relevant cancer research and allow for talented scientists in LMICs advance in their careers [108, 109].

Build Global Cancer Research Environments

Building a research environment is a key catalyst to trainee success. Providing access to resources and mentorship, facilitating collaborations and access to study populations, and a strong scientific environment help trainees develop research skills and thinking and establish foundations for an independent research career. Supporting institutions is an important approach in building cancer research-supportive environments. It is noteworthy here that all the CGH-supported individual career development awards are to applicants who are part of institutions with experience in global oncology research. Institutional capacity building therefore is central to developing a pool of cancer research trainees committed to a career in global oncology. CGH announced the Strengthening Institutional Capacity for Global Cancer Research program in 2020 [95]. This is an institutional training program using the D43 mechanism at NCI that is specifically designed to support global research training. The overarching goal of this grant program is to provide training to investigators and health professionals needed to conduct innovative and collaborative global research projects that will contribute to the advancement of basic, clinical, translational, and population-based cancer research. Principal investigators will be from US and LMIC research-intensive

institutions with the capabilities to conduct cancer research projects relevant to specific LMIC settings and certain US subpopulations. Trainees who can participate in the program can either be from the US or from LMICs. US trainees will be recruited at the postdoctoral level and LMIC trainees will be recruited at either the predoctoral or the postdoctoral level. A combination of length of training (from degree granting programs to research-relevant short-term courses or workshops) and research experiences may be proposed by the applicants to achieve their training goals.

This funding opportunity aims to provide a strong foundation in research design, methods, and analytic techniques appropriate for the proposed cancer research area, with the goal of developing independent research careers for US and LMIC scientists. This also seeks to strengthen and develop global cancer research leadership and mentorship at US institutions, with the expectation that the awarded training programs and trainees in the US and LMICs will attract additional funding from other resources (NIH, philanthropic organizations, etc.) and continue to develop global oncology research programs. This grant program anticipates supporting a total of 7 US and LMIC collaborating teams who propose novel and relevant programs to develop workforce capacity in cancer research.

Other CGH programs such as support of global cancer research at cancer centers aim to facilitate strong scientific environments for cancer research. Integral to supporting these environments is also the availability of funding for trainees and institutions to sustain their global cancer research interests. CGH also develops funding opportunities and leverages existing mechanisms to provide funding for global cancer research. Recent examples of funding supplements to existing grants to pursue global cancer health disparities research [112] and implementation science as well as new initiatives to support tobacco control research [113] are some examples of recent CGH efforts to facilitate progress in the pathway to career independence and maintenance.

Table 4 Future directions in global cancer research training

Focus area	Tactical approaches in training and education
Moving from training individuals to developing high-functioning research teams	Individual and institutional capacity building; mentorship training; training and orientation in cultural competency; other “soft skills” for collaboration; mentor-mentee communication of expectations and competencies; HIC-LMIC team communication of timeline, workload, leadership, administration, and other costs
Fostering sustainable global cancer research careers	Creation of practical and sustainable research environments for trainees: instruction in logistics of living and working in a foreign country, cultural competency, work-life balance; Develop trainee networks for peer learning and mentoring Developing sustainable research training funding programs
Strengthening cancer research environments in LMICs	Understanding and addressing regulatory requirements—study approval; ethical reviews; data sharing Health systems strengthening Cancer surveillance and registries training

Future Directions in Global Cancer Research Training

The research training experiences at NCI and NIH have stimulated discussion of future needs and focus areas. These areas are outlined in Table 4 and discussed below:

- (1) *Moving from trained individuals to high-functioning equitable teams.* High-functioning equitable teams in global cancer research consists of members from LMICs and HICs committed to research collaborations built on mutually agreed research aims and objectives relevant to LMICs, conducted in an environment that is respectful and equitable. In addition to investing in individuals and institutions, this team building also requires training of mentors [106], developing cultural competency, and creating frameworks and capacity to discuss research administration, finances, and expectations [80, 114]. Furthermore, “soft” skills—learning to network, establishing trust, developing cultural competencies, and emotional intelligence—are essential to team success and have not yet been adopted widely by the global research community [115]. These skills can be taught to some degree and can be encouraged to be incorporated into global cancer research training programs. Finally, it is important to recognize expectations of research output, conduct and shared leadership between HIC and LMIC teams. Mentor-mentee communication of research and productivity expectations and competencies, and HIC-LMIC team communication regarding timeline of research, workload, leadership, administration, and other costs are some examples of specific areas where lack of communication and engagement can lead to breakdown in collaboration and fuel feelings of disrespect.
- (2) *Fostering sustainable approaches to cancer training.* The work of functioning teams is enabled with sustainable environments for research conduct and funding. Assessing and addressing the needs of trainees and mentors with regard to logistics of working outside their home country, instituting reasonable accommodation to balance work and family life, and promoting awareness regarding social determinants of cancer in the study will facilitate conduct of research that is respectful and sustainable. Developing trainee networks for exchange of information and experience may facilitate generation of new ideas and approaches and foster peer learning and mentoring [116]. This is further facilitated by available financial support for global cancer research and training. International funding coalitions and partnerships can play a role here.

- (3) *Strengthening cancer research environments in LMICs.* Cancer research resources to consider in global settings include regulatory systems, health systems, and data systems. Building these out as part of a research training project will help establish a foundation for rigorous research. Regulatory systems include government agencies that oversee human subjects research and exchange of research data, institutional review boards that oversee research ethics and requirements for employment, and residence in country where training will be conducted. Substantial time and resources can be spent to become familiar with and then meet these regulatory requirements, and research teams should prepare for this. Other research resources are more proximate to the conduct of cancer research. These include cancer registries and cancer treatment capacity. An important challenge to cancer research in global settings is the poor quality of cancer registries and unavailability of cancer incidence, mortality, and treatment outcome data [117]. Training in cancer surveillance and in the analysis of cancer registry data is necessary to support global cancer research. While research agencies such as the NCI cannot support infrastructure for treatment, this gap might be filled by forging partnerships and alliances with other institutions that can provide such support. Training to study health systems and research to optimally utilize a diverse range of cancer care providers such as nurses and community health workers are key to understand context-appropriate strategies for patient care and support [118].

In conclusion, as cancer continues to pose a global challenge and the burden increasingly falls on LMICs, there is a critical need for training and education to develop a new generation of cancer researchers experienced in working in global settings. NIH has used a variety of mechanisms to support global cancer research training and this portfolio continues to grow.

Declarations

The findings and conclusions in this paper are those of the authors and do not necessarily represent the official position of the National Institutes of Health or US Department of Health and Human Services.

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