Received: 11 December 2024, Revised: 04 March 2025, Accepted: 06 April 2025, Published Online: 04 August 2025

Journal of Chronic Disease Epidemiology

DOI: https://doi.org/10.62160/JCDE9

REVIEW ARTICLE

Epidemiological Relationship Between Infectious Diseases and Cancer: Implications for Public Health Policies and Therapeutic Approaches

Taiwo Temitope Ogunjobi[1,*], Ajayi Oluwagbemileke Rufus[2], Anegbe Emmanuel[3], Musa Adnan[4], Inusah Abdul-Hanan Saani[5], Agyei-Nkrumah Kenneth Lord[6], Mufutau Oyewale Kabiru[7], Aigbagenode Augustine Aiyebor[8], Afuape Rapheal Akinwunmi[9], Ahorlu Kwasi Elim[10], Oyeyemi Nuratullahi Ashade-Ogunfuwa[11], Stephen Ajuluchukwu Echesi[12], Temitope Ayinde Ajamu[13], Daniel Ebubechi Obasi[14]

[1] Department of Biochemistry, Faculty of Basic Medical Sciences, Ladoke Akintola University of Technology, Nigeria.
[2] Department of Public Health, University of Illinois at Springfield, USA.
[3] Department of chemistry and Chemical technologies, University of Calabria, Italy.
[4] Faculty of Public Health, First Moscow State Medical University, Sechenov University, Russia.
[5] School of Medicine, University for Development Studies, Ghana.
[6] Department of Community Medicine, University of Cape Coast Department, Ghana.
[7] Department of Pure and Applied Mathematics, Ladokite Akintola University of Technology, Nigeria.
[8] Department of Clinical Pharmacy and Pharmacy Practice, Faculty of Pharmacy, University of Benin, Nigeria.
[9] Department of Biology, School of College of science and Technology, North Carolina Agriculture and Technical University, USA.
[10] School of Medicine, University for Development Studies, Ghana.
[11] Department of Microbiology, Faculty of Science, Lagos State University, Nigeria.
[12] Department of Microbiology, Faculty of Biological Sciences, University of Portharcourt, Nigeria.
[13] Department of Biological Science, College of Science and Technology, Covenant University, Nigeria.
[14] Department of Medicine and Surgery, University of Ibadan, Nigeria.

***Corresponding author:** Taiwo Temitope Ogunjobi, Department of Biochemistry, Faculty of Basic Medical Sciences, Ladoke Akintola University of Technology, Nigeria. Email: ttogunjobi@student.lautech.edu.ng

Abstract: A crucial area of cancer epidemiology is the interaction between infectious illnesses and cancer, which has significant effects on treatment approaches and public health. This review elucidates the epidemiological associations between infectious agents and cancer, underscoring the importance of these relationships in the development of cancer prevention and treatment protocols. Through the application of a comprehensive review of the literature methodology, we examine studies that show how infectious agents-like Helicobacter pylori, hepatitis B and C viruses (HBV and HCV), human papillomavirus (HPV), and human immunodeficiency virus (HIV)—have a role in the genesis of cancers, such as gastric, liver, cervical, and Kaposi's sarcoma. According to our research, infectious agents contribute to certain types of cancer incidences globally, as identified by the International Agency for Research on Cancer (IARC). This suggests that specific infectious disease control interventions, including immunization and antimicrobial therapy, may be able to prevent cancer. This research additionally discusses the ways by which infectious agents, such as immune evasion, genetic modifications, and chronic inflammation, contribute to the development of cancer. These findings have important ramifications for methods of therapy and public health regulations. The integration of infectious disease control methods, such as vaccination programs and antibiotic prophylaxis, could greatly improve cancer prevention strategies. Furthermore, novel therapeutic techniques that target these microbial components become possible as a result of understanding how infectious pathogens contribute to the development of cancer. To better understand the complex relationship between infectious diseases and cancer, this review highlights the necessity of conducting multidisciplinary research in the future. Advancements in molecular techniques and data analysis are essential for identifying new infectious agents linked to cancer, understanding their mechanisms of action, and developing effective prevention and treatment strategies. This comprehensive strategy highlights the essential junction of infectious illnesses and oncology in the creation of public health strategies and holds the possibility of drastically reducing the worldwide cancer burden owing to infectious agents.

Keywords: infectious diseases, cancer epidemiology, public health policies, therapeutic approaches, oncogenic infections, cancer prevention, epidemiological implications

1. Introduction

1.1. Epidemiological association between infectious diseases and cancer

The complex relationship of biological pathways that lead to the growth of cancer is shown in the epidemiological relationship between infectious diseases and cancer, which is a major subject of research within the fields of oncology and public health. Infectious agents are thought to be responsible for 15 – 20% of cancer cases worldwide, which emphasizes the significance of comprehending these connections in order to develop preventive, diagnosis, and treatment plans (de Martel et al., 2020). Through a variety of ways, infectious organisms such as parasites, viruses, and bacteria, can aid in the emergence of cancer (Jain et al., 2019b). Some viruses, such as the human papillomavirus (HPV), hepatitis B and C viruses (HBV and HCV), Epstein-Barr virus (EBV), and human immunodeficiency virus (HIV), are known to directly disrupT-cell regulatory processes, resulting in unchecked cell proliferation and malignancy (Figure 1 (Münz, 2023)). To promote cervical and other anogenital malignancies, for example, HPV integrates its DNA into host T-cells, altering genes that act as tumor suppressors (Golrokh Mofrad et al., 2020). In a similar vein, cirrhosis and chronic liver inflammation brought on by HBV and HCV infection raise the risk of hepatocellular carcinoma.

Carcinogenesis is also influenced by bacterial infections. Helicobacter pylori, a bacterium associated with chronic gastritis, has been extensively linked to stomach cancer and mucosa-associated lymphoid tissue (MALT) lymphoma. H. pylori-induced chronic inflammation can lead to genetic changes, DNA damage, and eventually malignant transformation (Ishikura et al., 2019). Additionally, chronic inflammation caused by Schistosoma japonicum and Opisthorchis viverrini raises the incidence of colorectal and cholangiocarcinoma, respectively, whereas parasite infections like Schistosoma haematobium are connected to bladder cancer. Through the production of carcinogenic chemicals and the induction of persistent inflammation, these parasites aid in the growth of cancer (Nacif-Pimenta et al., 2019).

Employing case-control, cohort, and cross-sectional study methods, epidemiological studies have been crucial in establishing these correlations and clarifying the part played by infectious agents in the genesis of cancer. The discovery of oncogenic infectious agents has prompted important public health initiatives, such as HPV and HBV vaccination campaigns, which have been shown to be successful in lowering the prevalence of cervical and liver malignancies (de Martel et al., 2020). Knowing the epidemiological link between infectious infections and cancer is vital for developing preventative and control measures for the disease. It underlines the necessity of all-encompassing public health strategies that prioritize immunization, infection detection, and treatment, and include infectious disease control as a crucial element of cancer prevention. Continued research in this field is expected to reveal novel correlations and processes, providing additional avenues for intervention and mitigating the amount of cancer caused by infectious agents (Budisan et al., 2021).

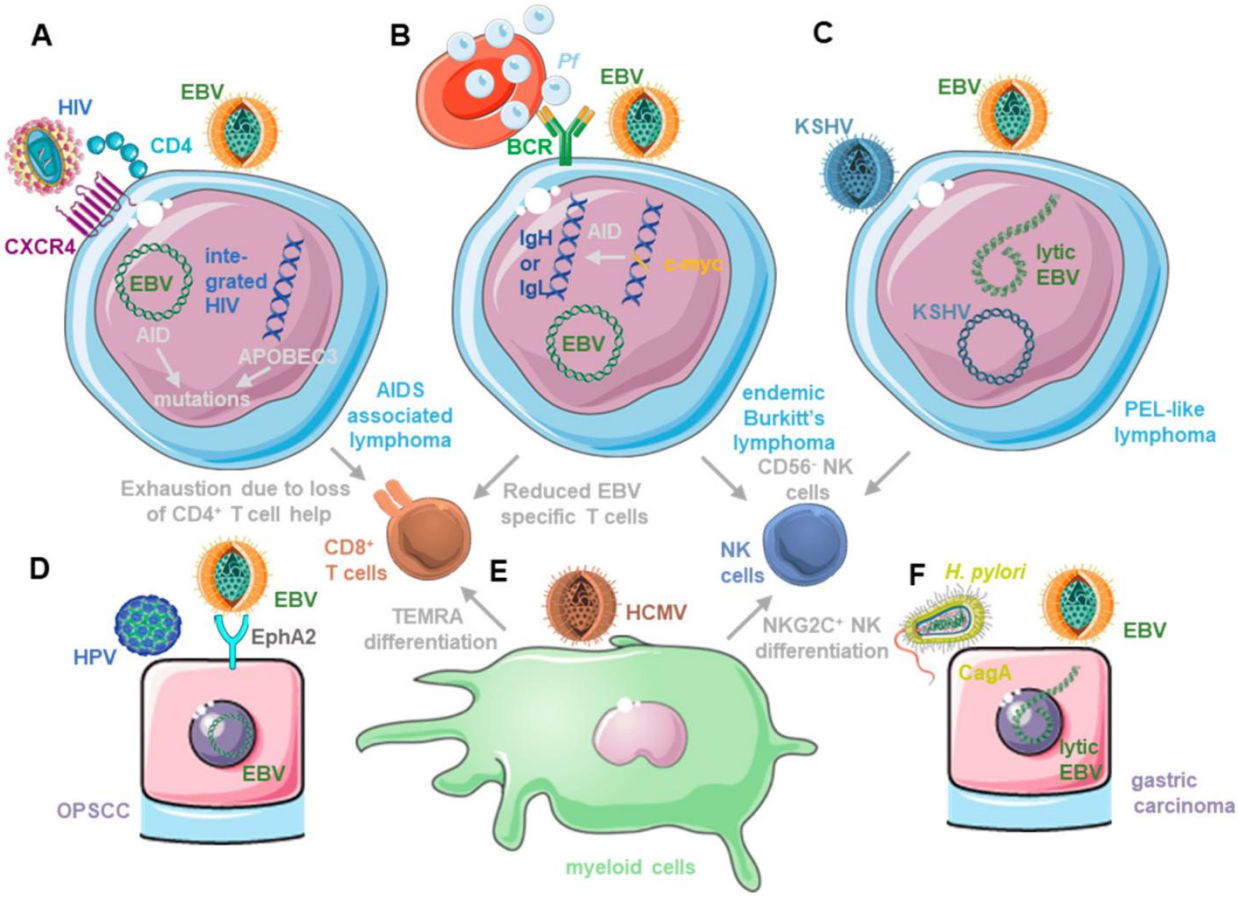

Figure 1. Co-infections influence the immune system's regulation of EBV-associated carcinogenesis as well

(A). By increasing APOBEC3 and activation-induced cytidine deaminase (AID), EBV infection increases the susceptibility of B cells to HIV infection and both HIV and EBV infection contribute to mutagenesis. Moreover, HIV impairs EBV-specific immune regulation by wearing down CD8+ T-cells following the exhaustion of CD4+ T-cell support. (B) Decreased EBV-specific T-cell immunity and CD56−NK cell differentiation with limited ability to inhibit lytic EBV replication are connected to the ensuing endemic Burkitt's lymphoma. Erythrocytes infected with Plasmodium falciparum (Pf) not only activate B cells infected with EBV, which could aid in AID-dependent c-myc translocation. (C) The resulting endemic Burkitt's lymphoma is linked to decreased EBV-specific T-cell immunity and CD56−NK cell differentiation with reduced ability to prevent lytic EBV replication. Erythrocytes infected with Plasmodium falciparum (Pf) not only activate B cells infected with EBV, which could aid in AID-dependent c-myc translocation. (D) In approximately 10 percent of instances of OPSCCs, oropharyngeal squamous cell carcinomas, co-infection with HPV and EBV is detected. HPV may facilitate the transition of a latent EBV infection in epithelial cells by upregulating the ephrin A2 receptor (EphA2) and the entrance receptor for EBV into epithelial cells. It also dampens lytic EBV infection. (E) Terminal CD8+ T-cells (TEMRA cells that reexpress CD45RA) and adaptive NKG2C+ NK cells are the results of HCMV infection. The immune system requires early-differentiated CD8+ T-cells and NK cells to effectively combat EBV. (F) Cytotoxin-associated gene A (CagA), which expresses Helicobacter pylori (H. pylori), is related with most stomach carcinomas. 10% of the tumor has latent EBV infection. Lytic EBV replication is induced by H. pylori, and EBV obstructs CagA's inhibitory dephosphorylation, hence augmenting its carcinogenic potential.

1.2. Investigating relationships to improve public health outcomes

It is crucial for studying the relationship between infectious diseases and cancer in order to enhance public health outcomes. This intersection offers prospects for early intervention, prevention efforts, and the development of designed medicines, as well as unique insights into cancer etiology. Worldwide, viruses, bacteria, and parasites are among the infectious agents that cause between 15% and 20% of cancer cases. By identifying at-risk populations and implementing focused public health measures, an understanding of these linkages helps to lower the incidence and death of some malignancies drastically (Nacif-Pimenta et al., 2019). New preventive techniques, especially immunization campaigns, have been made possible by the identification of oncogenic infectious agents. The development and widespread application of vaccinations against the human papillomavirus (HPV) and

hepatitis B virus (HBV) are two prime examples of how understanding these relationships can directly aid in the prevention of cancer. Vaccines may considerably reduce the incidence of cancer linked to infectious diseases. Cervical, oropharyngeal, and other anogenital malignancies can be prevented by vaccination against HPV. Hepatocellular carcinoma risk is decreased by the HBV vaccine (Naran et al., 2018). Early detection and treatment are made possible by screening for infectious agents in high-risk populations, which may delay the start of cancer. For instance, it has been shown that identifying H. pylori infections and using eradication medication to cure them reduces the risk of stomach cancer. These tactics demonstrate how important it is for public health laws to incorporate the management of infectious diseases into frameworks for the prevention of cancer (Gaisa et al., 2021). Furthermore, researching the connection between infectious infections and cancer helps to create new treatment approaches. Understanding how infectious agents contribute to the development of cancer can aid in the development of targeted medicines, such as antiviral, antibacterial, and antiparasitic drugs, which may be used to treat or prevent tumors linked to infections. (de Martel et al., 2020). Investigating the epidemiological relationships between infectious diseases and cancer also tackles more general public health issues, such as health inequalities. To improve cancer survival rates globally, global health initiatives centered on infection control, immunization, and education are necessary. People living in low- and middle-income countries bear a disproportionate share of the burden of infection-related cancers. (Naran et al., 2018).

1.3. Purpose and scope of the review

This review aims to summarize the most recent research on the epidemiological relationship between infectious diseases and cancer, clarifying how infectious agents cause cancer and their consequences for treatment and public health strategies. By highlighting the need to incorporate infectious disease control into cancer prevention programs, this thorough analysis hopes to improve public health outcomes and lower the incidence of cancer worldwide (Nwizu et al., 2020). This review's scope includes a review of several infectious organisms that are recognized to play a role in the emergence of cancer, such as bacteria, viruses, and parasites. It explores the molecular mechanisms of oncogenesis brought on by various infections, including direct genetic changes, immunological evasion, and chronic inflammation (Tsujimoto et al., 2021). It also discusses how vaccinations and antimicrobial therapies, among other preventive measures, can lower the prevalence of malignancies linked to infections. It also looks at cutting-edge treatment approaches that focus on the confluence of cancer and infectious diseases, providing insights into potential future paths for both clinical research and patient care. By consolidating knowledge from diverse studies, the purpose of the review is to educate medical professionals, scientists, and public health experts about the critical relationship between infectious diseases and cancer. (Sexton et al., 2020). It emphasizes how important it is to use multidisciplinary techniques to develop successful cancer prevention and treatment plans that make use of developments in immunology, oncology, microbiology, and public health.

2. Understanding the Epidemiological Relationships

2.1. In-depth review of cancer-linked infectious agents (e.g., HPV, Hepatitis B/C, H. pylori)

2.1.1. Human papillomavirus (HPV)

Of the more than 200 related HPV viruses, at least 14 are believed to have a substantial cancer risk. The most frequent virus infection of the reproductive system, HPV, is mostly associated to cervical cancer, the fourth most common disease in the world among women. High-risk HPV strains 16 and 18 are responsible for about 70% of cases of cervical cancer (Anna Szymonowicz & Chen, 2020). HPV is associated with oropharyngeal cancer as well as other anogenital (anal, vulvar, vaginal, and penile) cancers in addition to cervical cancer. One major accomplishment in public health that has helped lower the incidence of HPV-related malignancies worldwide is the introduction of preventative vaccinations (Rapado-González et al., 2020).

2.1.2. Hepatitis B and C viruses (HBV and HCV)

The most frequent type of liver cancer, hepatocellular carcinoma (HCC), is mostly caused by persistent HBV and HCV infections. HBV and HCV contribute to the development of cancer through cirrhosis, direct genetic mutations in liver cells, and persistent inflammation (Shen et al., 2023). There are variations in the prevalence of HBV and HCV throughout the world. East Asia and sub-Saharan Africa have the greatest rates of HBV incidence, while Egypt has the highest rates of HCV prevalence. It has been demonstrated that the HBV vaccination effectively lowers the incidence of HCC, and antiviral medications for HBV and HCV can also reduce the risk of liver cancer (Cheng et al., 2021).

2.1.3. Helicobacter pylori (H. pylori)

The stomach lining can become infected with the H. pylori bacteria, which can cause gastric cancer, peptic ulcer disease, and chronic gastritis. The International Agency for Research on Cancer (IARC) has categorized it as a class I carcinogen. It is the main cause of mucosa-associated lymphoid tissue (MALT) lymphoma and stomach adenocarcinoma (Stewart et al., 2020). The bacteria cause the stomach mucosa to become chronically inflamed, which leads to genetic instability and changes that may eventually

result in cancer. The incidence of stomach cancer is decreased when H. pylori is eradicated by antibiotic therapy, underscoring the significance of early identification and treatment in high-risk individuals. (Tian et al., 2020).

In order to avoid infection-related malignancies, targeted public health measures such as vaccination, screening, and antimicrobial therapies are made possible by an understanding of the carcinogenic potential of these infectious agents. It will need additional investigation into the mechanisms of pathogen-induced carcinogenesis and the development of effective therapeutics to reduce the global cancer burden associated with infectious diseases. (Tian et al., 2020).

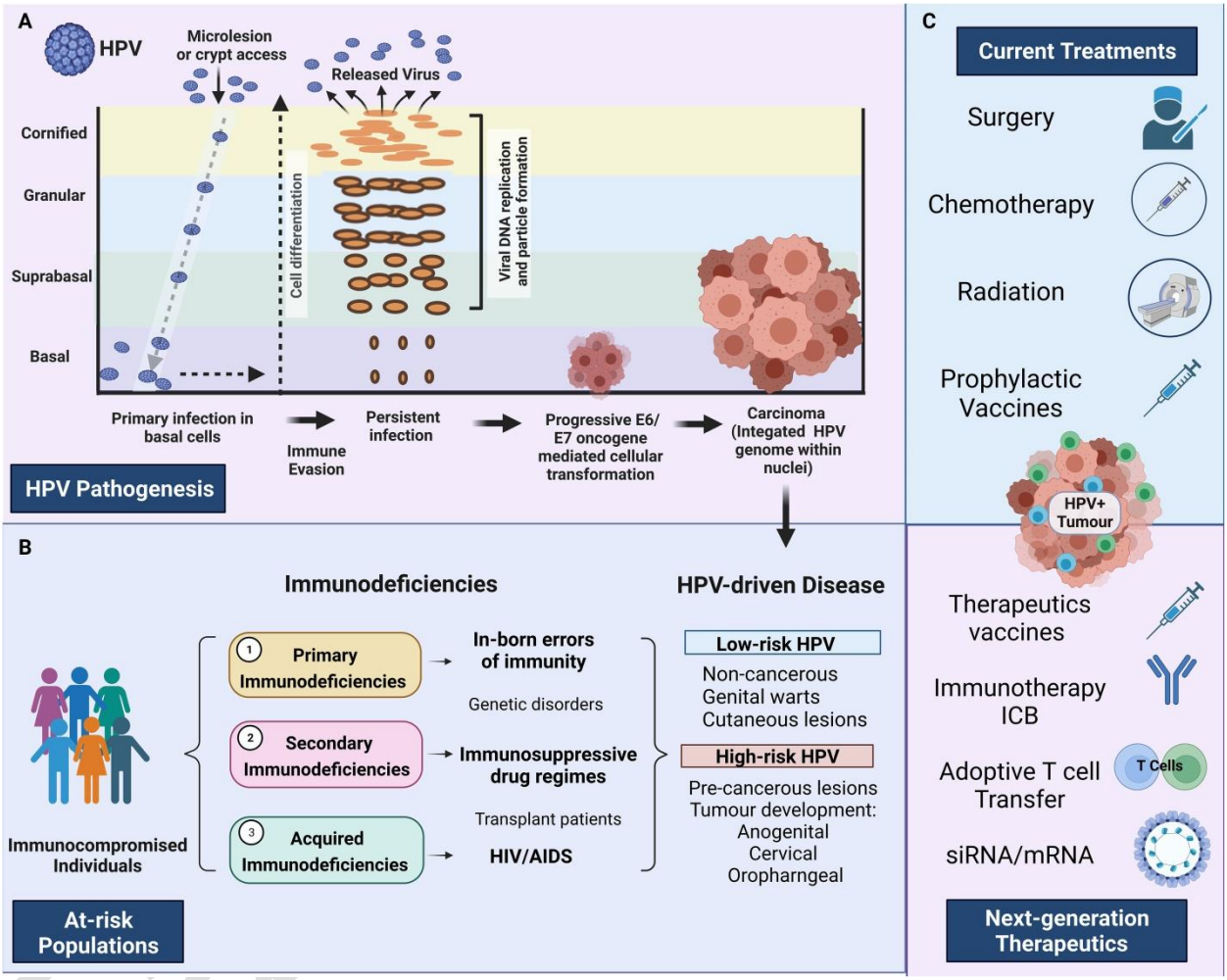

Figure 2. HPV pathogenesis and treatment in at-risk individuals (Created with BioRender.com)

(A) Pathophysiology of HPV, persistence of infection, and development of cancer. When HPV penetrates basal cells through microscopic lesions or skin injury, primary infection takes place. HPV can persist in illness after replicating and evading the immune system. Oncogenes E6 and E7 perturb the cell cycle, leading to cellular transformation, HPV-driven cancer, and chronic illness. (B) lists the three primary immunodeficiencies. First, primary immunodeficiencies caused by inborn mistakes in immunity; second, secondary immunodeficiencies caused by people taking immunosuppressive medications 3) Immunodeficiencies acquired in relation to HIV/AIDS patients. On the extreme right-hand side panel, the main HPV pathologies brought on by high-risk and low-risk HPV strains are identified (HPV-driven disease) (C) identifies the primary therapies that are now being used as well as the next-generation medicines that are being researched.

2.2. Statistics on the global burden of cancers attributable to infectious diseases

An estimated 15-20% of cancer cases globally are thought to be caused by infectious organisms, which accounts for a substantial portion of the global cancer burden. Figure 3 (zur Hausen, 2009) shows an estimate of the present contribution of infectious agents to the global cancer incidence. This corresponds to roughly 2.2 million cancer cases annually that are linked to

infections. The World Health Organization (WHO) and the International Agency for Research on Cancer (IARC) have designated a number of infectious agents as carcinogens, including but not limited to the human papillomavirus (HPV), hepatitis B and C viruses (HBV and HCV), Helicobacter pylori (H. pylori), Epstein-Barr virus (EBV), and human immunodeficiency virus (HIV) (de Martel et al., 2020). With an anticipated 570,000 new instances of cervical cancer worldwide in 2018, HPV is the primary cause of infection-related cancers. Cervical cancer is the fourth most frequent cancer among women. An enormous number of additional anogenital and oropharyngeal malignancies are also caused by HPV. Hepatocellular carcinoma (HCC) is one of the deadliest malignancies, causing about 780,000 deaths yearly. It is mostly caused by chronic HBV and HCV infections. In high-incidence areas like sub-Saharan Africa and East Asia, HBV is thought to be responsible for over 60% of HCC cases, but HCV is a significant risk factor in Japan, Egypt, and other Middle Eastern countries (Van Dyne et al., 2018). A further significant variable in the cancer burden is H. pylori, a bacterium associated with stomach cancer and mucosa-associated lymphoid tissue (MALT) lymphoma. In 2018, gastric cancer accounted for almost 1 million cases and around 783,000 deaths globally. Globally, gastric cancer is the third greatest cause of cancer-related mortality and the fifth most often diagnosed malignancy (Venerito et al., 2018).

The global distribution of infection-related cancers varies widely, reflecting differences in the prevalence of infectious agents, public health policies, vaccination coverage, and access to healthcare services (Figure 3) (zur Hausen, 2009). Countries with low or middle incomes (LMICs) are disproportionately affected by these malignancies due to problems with early detection and care, a higher prevalence of infectious agents, and restricted access to immunizations and medications. (Brown et al., 2019). These figures highlight the urgent need for all-encompassing public health initiatives to stop and manage malignancies linked to infections. To lower the amount of cancer that is caused by infectious diseases worldwide, measures including mass screening and treatment for H. pylori infection, vaccination campaigns against HPV and HBV, and campaigns to stop the spread of HBV, HCV, and HIV are crucial (Eusebi et al., 2020).

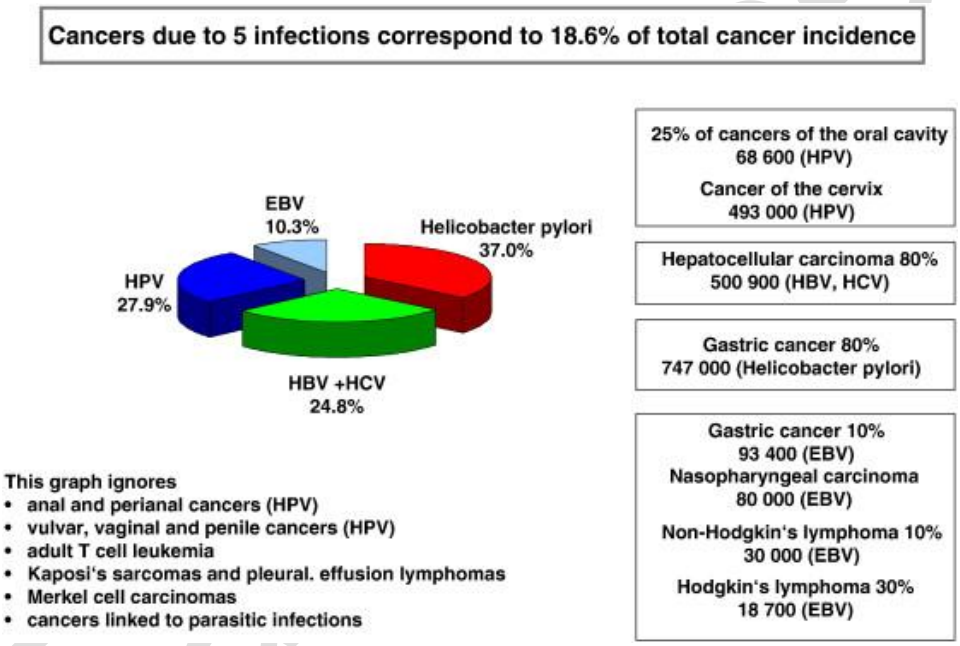

Figure 3. Probable annual global cancer prevalence due to infections

2.3. Exploring how infections trigger cancer: Biological mechanisms

Cancer can result from infections via a number of diverse biological processes. These processes frequently entail both direct and indirect interactions between the infectious agent and hosT-cells, which modify cellular functions and create an environment that is conducive to tumor growth. Comprehending these pathways is crucial to devise focused therapies aimed at preventing and treating malignancies associated with infections (van Elsland & Neefjes, 2018). The primary biological mechanisms by which infections can lead to cancer include:

Chronic Inflammation: A persistent inflammatory condition is brought on by several infectious agents, and this can encourage the development of cancer. When there is ongoing inflammation, chemokines, pro-inflammatory cytokines, and reactive oxygen and nitrogen species are all continually created. These chemicals raise the chance of developing cancer by damaging DNA, encouraging cellular growth, preventing apoptosis, and causing mutations. For example, stomach cancer risk is increased by a chronic Helicobacter pylori-caused gastritis infection. (Greten & Grivennikov, 2019).

Immune Suppression: Some infections, especially those caused by viruses such as HIV, depress the immune system, making a person more vulnerable to other cancer-causing illnesses and less able to detect and eradicate newly developing tumor cells. The

higher likelihood of non-Hodgkin lymphoma and Kaposi's sarcoma in people with acquired immunodeficiency syndrome (AIDS) is indicative of this mechanism (Carbone et al., 2022).

Insertional Mutagenesis: Some viruse has the capacity to incorporate their genetic makeup into the host genome, such as the Human Papillomavirus (HPV). Tumor suppressor gene function may be compromised by this integration, and oncogenes may become active, resulting in unchecked cell proliferation and cancer. For example, HPV integration may interfere with the p53 tumor suppressor gene's ability to function, which may lead to the development of cervical and other anogenital malignancies (Pinatti et al., 2018).

Modulation of Cell Signaling Pathways: The hallmarks of cancer, including cell invasion, multiplication, and survival, can all be enhanced by infectious agents through changes to cell signaling pathways. Hepatitis B and C viruses, can cause hepatocellular carcinoma by activating oncogenic pathways such the Wnt/β-catenin and MAPK pathways (van Senten et al., 2020).

Induction of Epigenetic Changes: Histone modifications, DNA methylation, and the creation of non-coding RNA are examples of epigenetic alterations brought on by infections that can alter gene expression without changing the DNA sequence. These epigenetic alterations can contribute to carcinogenesis by activating oncogenes or silencing tumor suppressor genes. For example, gastric cancer has been linked to DNA methylation in the stomach caused by Helicobacter pylori infection (Bannister et al., 2020).

Researchers and medical professionals can create more potent preventative measures, such as vaccinations against oncogenic infections and targeted medicines that stop the carcinogenic processes brought on by infectious agents, by clarifying the biological mechanisms through which infections cause cancer (Sheweita & Alsamghan, 2020).

3. Case Studies of Infectious Agents and Associated Cancers

3.1 Case Studies: HPV & cervical, H. pylori & gastric, hepatitis B/C & liver cancer

The importance of infections in oncogenesis is shown by the epidemiological connections between infectious agents and the emergence of cancer. This session investigation centers on three well-established correlations: Hepatitis B and C viruses (HBV and HCV) and liver cancer; Helicobacter pylori (H. pylori) and gastric cancer; and Human Papillomavirus (HPV) and cervical cancer. Comprehending these correlations reveals the pathogenic mechanisms implicated and underscores prospects for prevention and remediation (Tornesello et al., 2018).

3.1.1. Human papillomavirus (HPV) and cervical cancer

Sexually transmitted DNA virus (HPV) is the primary cause of cervical cancer (Figure 4) (Modabber et al., 2023), which is the fourth most common cancer among women globally. Approximately 14 of the more than 100 HPV varieties are carcinogenic. Among these, HPV types 16 and 18 are noteworthy because they cause almost 70% of cases of cervical cancer. The virus integrates its DNA into the hosT-cell's genome, causing viral oncoproteins E6 and E7 to become overexpressed. These proteins cause cell cycle regulation to be disrupted and malignant transformation to be promoted by inactivating the tumor suppressor genes p53 and retinoblastoma (RB), respectively (Pal & Kundu, 2020). A key public health approach for preventing cervical cancer is vaccination against HPV, which dramatically lowers the prevalence of HPV infections and precancerous lesions (Ferrall et al., 2021).

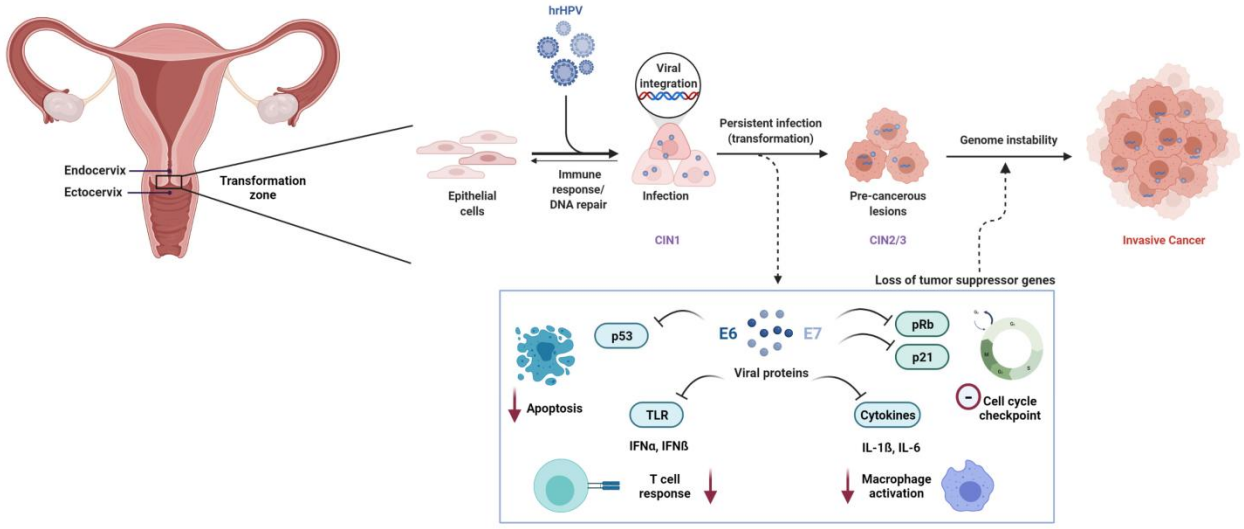

Figure 4. Cervical cancer's pathogenesis

After a prolonged high-risk HPV infection, epithelial cells in the cervix's transformation zone develop lesions (hrHPV). Lesions disappear in some cases, but in others, when the virus integrates, cells change and advance from I to II and III cervical intraepithelial neoplasia (CIN1, CIN2, and CIN3). The released viral proteins E6 and E7 block the actions of TP53-mediated apoptosis, p21-mediated cell cycle checkpoints, toll-like receptors (TLRs)-mediated T-cell responses, and cytokines-mediated macrophage activation. Insufficient immune response, viral replication, unchecked cell division, instability of the genome, and subsequent CIS or invasive cervical cancer (CC) are the results of this.

3.1.2. Helicobacter pylori (H. pylori) and gastric cancer (Figure 5)

The gram-negative bacterium Helicobacter pylori colonize the lining of the stomach and is the main cause of gastric cancer, which includes adenocarcinoma and mucosa-associated lymphoid tissue (MALT) lymphoma. The bacteria cause atrophic gastritis, intestinal metaplasia, and ultimately gastric cancer by inducing chronic gastritis (Guo et al., 2020). CagA and VacA are two examples of H. pylori virulence factors that are essential to carcinogenesis because they cause inflammation, encourage DNA damage, and alter cell signaling pathways. It has been demonstrated that the use of antibiotic medication to eradicate H. pylori lowers the incidence of gastric cancer, underscoring the need of early identification and treatment in high-risk individuals (Ghotaslou et al., 2018).

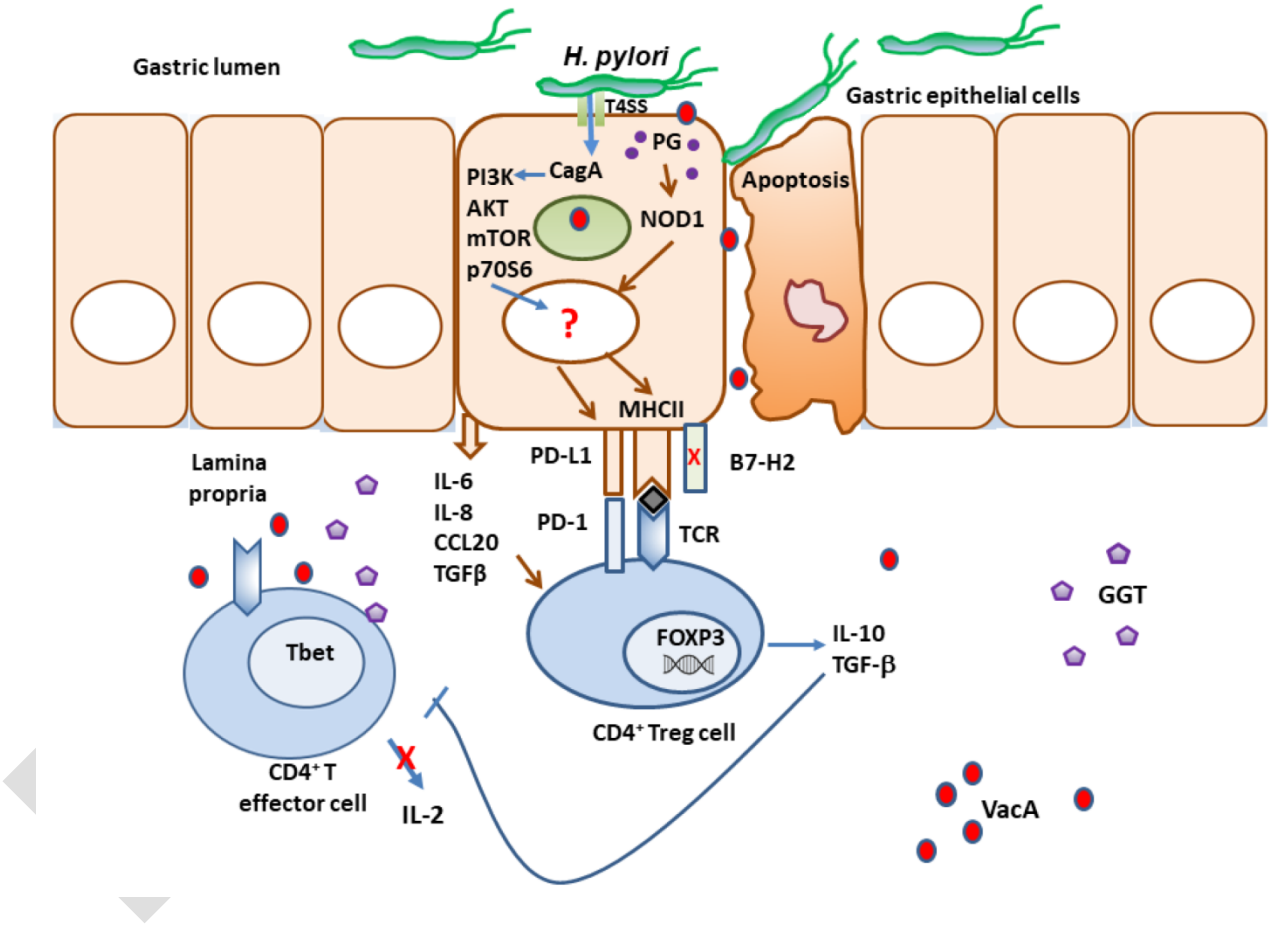

Figure 5. Helicobacter pylori (H. pylori) and gastric cancer

An immunosuppressive environment is set by H. pylori. Using a variety of virulence factors and altering the expression of immunological checkpoint regulatory receptors by the epithelium, H. pylori impede the functions of effector T-cells.

3.1.3. Hepatitis B and C viruses (HBV and HCV) and liver cancer

Persistent HBV and HCV infections are the primary cause of hepatocellular carcinoma (HCC), the most common kind of liver cancer (Figure 6). Through both direct and indirect methods, such as cirrhosis, persistent inflammation, and direct insertion of viral DNA into the host genome (in the case of HBV), these viruses cause carcinogenesis. Genetic alterations, decreased apoptosis, and

enhanced cell proliferation result from the modulation of cell signaling pathways by both viruses (Goto et al., 2020). An important advancement in public health has been the creation of the HBV vaccination, which has significantly decreased HBV transmission and the risk of HCC that follows. Thanks to developments in antiviral therapy, HCV can now be cured, greatly reducing the chance of developing liver cancer (Liu & Liu, 2022).

3.2 Global impact illustrated by epidemiological data

These cases illustrate the crucial role that infectious agents play in the development of cancer as well as the possibility of cancer prevention through focused interventions like vaccinations and antibiotic treatments. In order to develop novel diagnostic, preventative, and therapeutic techniques and ultimately lower the worldwide cancer burden attributed to infectious diseases, more study into these and other infection-cancer links is necessary (Naran et al., 2018).

3.2.1. Human papillomavirus (HPV) and cervical cancer

Cervical cancer, primarily caused by HPV, is the fourth most common disease among women globally, accounting for 311,000 deaths and an anticipated 570,000 new cases in 2018, according to the World Health Organization (WHO). HPV16 and HPV18 are two high-risk HPV strains that account for about 70% of these cases. Cervical cancer is more common in low- and middle-income countries (LMICs), where access to HPV vaccination and cervical screening programs is limited (Brisson et al., 2020).

3.2.2. Helicobacter pylori (H. pylori) and gastric cancer

According to the International Agency for Research on Cancer (IARC), H. pylori infection causes over 89% of non-cardia gastric adenocarcinomas, making it the strongest known risk factor for gastric cancer. In 2018, stomach cancer accounted for over a million new cases and over 783,000 deaths worldwide, making it the third most common cancer overall and the fifth most common cause of cancer-related deaths in general (Sugimoto et al., 2020). East Asia, Eastern Europe, and South America have the greatest incidence rates of H. pylori prevalence.

3.2.3. Hepatitis B and C viruses (HBV and HCV) and liver cancer

Persistent HBV and HCV infections are a major cause of hepatocellular carcinoma (HCC), the most common kind of liver cancer. Estimates from the Global Cancer Observatory (GLOBOCAN) show that in 2018, there were 782,000 liver cancer deaths and 841,000 new instances of the illness; a considerable amount of these deaths was associated with HBV and HCV infections (Zhao et al., 2021). HBV is the main cause of HCC in high-incidence regions like East Asia and sub-Saharan Africa, although HCV is more prevalent in Japan, Egypt, and some regions of Europe. Although there are now effective HBV and HCV vaccinations as well as curative treatments available, these diseases nevertheless pose a serious threat to public health and increase the incidence of liver cancer worldwide (Petruzziello, 2018). These epidemiological data show how infectious pathogens have a major worldwide influence on the incidence and death of cancer.

3.3. Understanding cancer's progression from infection

To comprehend how infections caused by certain agents, such as Helicobacter pylori (H. pylori), Human Papillomavirus (HPV), and the Hepatitis B and C viruses (HBV and HCV), result in the development of cancer,this extensive exploration delves into the current understanding of the pathogenesis and progression of cancer from initial infection to malignancy, emphasizing the complex interplay of viral and bacterial factors with host cellular pathways (Volesky et al., 2019).

3.3.1. Human papillomavirus (HPV) pathogenesis in cervical cancer

The primary way that HPV, a double-stranded DNA virus, causes cancer is by expressing its oncoproteins, E6 and E7 (Figure 4) (Modabber et al., 2023). These proteins attach to the tumor suppressor proteins retinoblastoma (Rb) and p53, respectively, rendering them inactive. Degradation of p53 and Rb impacts DNA repair and cell cycle regulation, leading to genomic instability. (Almeida et al., 2019). Moreover, E6 and E7 have the ability to disrupt other biological pathways, which can lead to chromosomal defects and epigenetic changes. Precancerous tissue must be continuously infected with high-risk HPV strains, particularly HPV16 and HPV18, in order to progress to invasive cervical cancer. The integration of viral DNA into the host genome is a critical step in malignant transformation that speeds up carcinogenesis and boosts the production of E6 and E7. (Pal & Kundu, 2020).

3.3.2. Helicobacter pylori (H. pylori) pathogenesis in gastric cancer

H. pylori is a gram-negative bacterium that colonizes the stomach epithelium, resulting in a chronic inflammatory response that may eventually cause stomach cancer. CagA and VacA, two virulence factors of the bacteria, are essential to this process (figure 5) (Reyes, 2023). When CagA enters its hosT-cells, it becomes phosphorylated and interferes with several signal

transduction pathways, which alters the shape, motility, and proliferation of the cells. Increased mutation rates and epithelial damage are caused by this disturbance (Johnson & Ottemann, 2018). Reactive oxygen and nitrogen species are produced during chronic inflammation brought on by H. pylori infection, which damages DNA and creates a milieu that is favorable to neoplastic transformation. The change from chronic gastritis to atrophic gastritis, intestinal metaplasia, and eventually cancer is mediated by a sequence of genetic and epigenetic modifications triggered by the ongoing inflammatory response. (Díaz et al., 2018).

3.3.3. Hepatitis B and C viruses (HBV and HCV) pathogenesis in liver cancer

Chronic HBV and HCV infections are important risk factors for HCC, or hepatocellular cancer (Figure 6). The DNA virus known as HBV has the ability to integrate its genome into the hepatocytes of its host, resulting in insertional mutagenesis and oncogene transactivation. HBV's regulatory protein HBx influences signal transduction pathways, prevents DNA repair, and encourages cell division and genetic instability, all of which are essential to the pathogenesis of the virus (Campbell et al., 2021). The RNA virus HCV directly interferes with signaling pathways essential to cell survival and proliferation, oxidative stress, and chronic inflammation are all ways that it leads to carcinogenesis. These viruses cause cirrhosis and fibrosis in the liver, which increases cellular turnover, damages DNA, and causes mutations that make HCC more likely to develop (Mahmoudvand et al., 2019). A series of sequential incidents, including the direct effects of bacterial and viral oncoproteins, long-term inflammation, immune evasion, and the accumulation of genetic and epigenetic modifications, characterize the pathogenesis from infection to cancer (Bi et al., 2022).

4. Screening and Prevention Strategies

4.1. Screening approaches for early infection-related cancer detection

A crucial component of minimizing the worldwide cancer burden is the early diagnosis of tumors associated with infectious agents. To enable prompt intervention and enhance the health of patients, screening programs are essential in detecting precancerous diseases and early-stage malignancies (Holcakova et al., 2021). This study examines current screening programs for cancers associated with infections, with a focus on stomach cancer associated with Helicobacter pylori (H. pylori), cervical cancer associated with the Human Papillomavirus (HPV), and liver cancer associated with the Hepatitis B and C viruses (HBV and HCV). (Zhang et al., 2021).

4.1.1. Screening for cervical cancer

With the use of HPV testing and Pap smears, also known as Papanicolaou tests, cervical cancer screening programs have significantly decreased the incidence and death rate of the disease. The Pap smear test finds aberrant cervical cells that could turn into cancer. Cervical cancer is known to be caused by high-risk HPV varieties, which are detected through HPV testing (Greten & Grivennikov, 2019). A complete strategy for the prevention of cervical cancer is provided by the combination of HPV vaccination and screening programs. According to current standards, women between the ages of 21 and 65 should undergo routine screening; the frequency of testing should be determined by the patient's age and test findings. The introduction of self-collected HPV testing kits has become a viable tactic to boost screening rates, especially in areas with poor access to medical care (Brisson et al., 2020).

4.1.2. Screening for liver cancer

Regular screening is essential for early detection in people whose persistent HBV or HCV infection puts them at high risk of liver cancer. The two main ways of screening for hepatocellular carcinoma (HCC) are blood tests that measure the levels of alpha-fetoprotein (AFP) and ultrasound exams. It is advised that high-risk people, such as those with cirrhosis and ongoing HBV or HCV infection, undergo ultrasound screening every six months (Tzartzeva et al., 2018). AFP testing can be useful as a supplementary tool in some clinical settings, while being less sensitive and specific than ultrasonography. Potentially curative procedures like resection, ablation, or transplanting are made possible by early discovery made possible by these screening techniques (Tzartzeva et al., 2018).

4.1.3. Screening for gastric cancer

Populations like South Korea and Japan, where H. pylori infection and stomach cancer are highly prevalent, are the main targets of gastric cancer screening. Barium meals and endoscopy are two screening techniques; endoscopy is a more sensitive modality for identifying precancerous lesions and early stomach malignancies (Venerito et al., 2018). Furthermore, a successful method for preventing stomach cancer is non-invasive testing for H. pylori infection and treatment for those who have the illness. Targeted therapies can be made easier by identifying at-risk populations using breath tests or serological testing for H. pylori antibodies (Elbehiry et al., 2023).

4.2. Evaluation of vaccination programs aimed at preventing infection-related

A vital aspect of public health strategies aimed at lowering the worldwide cancer burden is vaccination campaigns that target illnesses linked to the development of cancer. The vaccinations against Hepatitis B (HBV) and Human Papillomavirus (HPV) are two of the most well-known instances of effective interventions designed to prevent cancers linked to infections, namely hepatocellular carcinoma (HCC) and cervical cancer, respectively (Saco et al., 2018). This review explores these immunization programs' execution, efficacy, difficulties, and potential futures.

4.2.1. Human papillomavirus (HPV) vaccination

The most carcinogenic HPV varieties, mainly HPV16 and HPV18, which account for a sizable fraction of cervical cancer incidence globally, are the targets of HPV vaccinations. The prevalence of these high-risk HPV infections among populations who have received vaccinations has significantly decreased with the advent of HPV vaccines, such as the bivalent, quadrivalent, and nonavalent vaccines (Suresh et al., 2021). Research has indicated a noteworthy decrease in the prevalence of HPV-associated precancerous cervical lesions subsequent to the establishment of nationwide HPV vaccination campaigns. Instances of cervical cancer in the vaccinated population have been reported to have decreased by up to 50% in countries like Australia, which have high vaccination rates. Notwithstanding these achievements, HPV vaccination programs continue to face obstacles such as vaccine hesitancy, differences in vaccine availability between high- and low-income countries (LMICs), and the requirement for comprehensive vaccination of both sexes in order to successfully prevent HPV-related cancers (Cai et al., 2022).

4.2.2. Hepatitis B virus (HBV) vaccination

The first vaccine that has been shown to prevent cancer, specifically HCC, is the HBV vaccine. The prevalence of HBV infections has significantly decreased as a result of catch-up vaccines for unvaccinated children and high-risk adults as well as universal baby vaccination programs. This has also decreased the incidence of HCC. Taiwan and other nations that have made HBV immunization universal have noted a notable drop in the incidence of HCC in the vaccinated cohort, demonstrating the vaccine's long-term preventive benefit against HBV-related liver cancer (Whitford et al., 2018). The management of mother-to-child transmission by timely birth dose administration, the requirement for booster doses in persons with declining immunity, and insufficient vaccine coverage in some locations persist despite the success of HBV immunization programs. Sustained public health initiatives are needed to address these issues; these initiatives should focus on improving surveillance systems, encouraging vaccination among marginalized communities, and incorporating HBV vaccine into larger liver cancer prevention plans (Hou et al., 2019).

5. Public Health Policies and Global Challenges

5.1. Public health policies' role in linking infectious diseases and cancer

To address the intricate relationships between infectious diseases and cancer, public health policies are essential because they provide a framework for the management, early detection, and prevention of infections-related cancers. The examination of the impact these policies have on health outcomes indicates how vital they are in reducing the worldwide cancer burden caused by infectious agents including Helicobacter pylori (H. pylori), Hepatitis B and C viruses, and Human Papillomavirus (HPV) (Green et al., 2019). Vaccination programs are a key component of public health policy in the fight against malignancies linked to infections. Effective immunizations against HPV and HBV have significantly reduced the incidence of cervical cancer and hepatocellular carcinoma (HCC), respectively. Public health initiatives that prioritize the inclusion of these vaccinations in national immunization schedules and ensure their accessibility are crucial, especially in low- and middle-income countries (LMICs). (Mix et al., 2021). Policies that support gender-neutral HPV vaccination also increase its preventive benefits and help prevent other malignancies linked to HPV. Another essential component of public health policy is screening programs, which make it possible to identify malignancies and their precursors early on. By facilitating the early detection and treatment of precancerous lesions, policies that support routine cervical cancer screening, such as Pap smears and HPV tests, have, for instance, significantly reduced the mortality rate from the disease. (Lehtinen et al., 2018).

The incidence of related cancers is directly impacted by public health initiatives targeted at the management and elimination of infectious pathogens. For example, utilizing antibiotics in H. pylori eradication programs can significantly reduce the incidence of stomach cancer. The risk of liver cancer is also decreased by public health initiatives to stop the spread of HBV and HCV, such as safe injection procedures, blood donor screening, and harm reduction programs for drug injectors (Tzartzeva et al., 2018). Understanding and managing the epidemiology of infection-related malignancies requires policy components such as research funding and the establishment of reliable surveillance systems. It is crucial for policies to promote further research into the processes of oncogenesis, the efficacy of preventative and therapeutic measures, and the discovery of novel oncogenic pathogens Systems of surveillance that track cancer incidence, vaccination rates, and infection rates offer important information to guide policy choices and modify plans of action in response to new threats (Deo et al., 2021).

5.2. The challenges of vaccination and screening in low-resource environments

A number of obstacles must be overcome before extensive immunization and screening programs can be implemented, especially in low-resource environments, in order to prevent malignancies linked to infections. The widespread adoption of these preventative interventions is hampered by a number of logistical, financial, and cultural obstacles, despite their shown effectiveness. With an emphasis on enhancing public health outcomes in settings with limited resources, this paper investigates potential solutions to the problems encountered (Shah et al., 2019). A major logistical challenge in low-resource environments is the absence of the healthcare infrastructure required to facilitate extensive immunization and screening programs. Significant barriers include restricted access to medical institutions, weak supply chains for the distribution of vaccines and screening tools, and inadequate cold storage capacity for the preservation of vaccines. These logistical problems are made worse by the lack of qualified medical personnel to do screens and give vaccinations. By delivering care directly to underprivileged communities, mobile clinics and the use of community health workers could help to reduce some of these obstacles (Equils et al., 2019).

High expenses for immunization and screening programs are a significant obstacle in environments with limited resources. Budgetary restrictions have an impact on the ability to maintain long-term program operations as well as the acquisition of vaccinations and screening instruments. Decision-makers in the healthcare industry are frequently forced to put urgent medical demands ahead of preventative measures due to budgetary restrictions (Sagnelli et al., 2020). Economic obstacles can be lessened by international financial assistance, economical vaccine production techniques, and creative funding options like vaccine bonds or pooled procurement plans. Sociocultural variables have a big impact on whether or not vaccination and screening programs are accepted and used. A significant obstacle is vaccine reluctance, which is fostered by false information, cultural norms, and mistrust of healthcare institutions. Stigma and privacy issues may discourage people from participating in screening programs, especially those that deal with STDs and malignancies like cervical cancer (Giannakou & Vachtsioli, 2020). To overcome these obstacles, culturally aware health education initiatives, community involvement, and the support of reputable local leaders are needed to increase acceptance and comprehension of the advantages of immunization and examination (Nganga et al., 2019).

For immunization and screening programs to be implemented successfully, effective governance and policy are essential. However, in many low-resource contexts, program launch and sustainability are hindered by insufficient political will, inconsistent policies, and weak health governance. These programs can be implemented more effectively and efficiently if health governance mechanisms are strengthened, political commitment is encouraged, and clear, evidence-based policies are established (Tatar et al., 2021). Sustaining immunization and screening programs requires effective data collection and surveillance systems to track their development and results. However, the absence of strong health information systems and data management tools can make it more difficult to evaluate and modify programs in low-resource environments (Basu et al., 2021).

6. Therapeutic Strategies and Research Directions

6.1. Treatment approaches for infection-related cancers

Infection-related tumors require an integrated approach that includes novel therapies, novel surgical procedures, and breakthroughs in medical oncology. These malignancies provide special therapeutic prospects and problems since they are frequently the result of long-term infections with certain pathogens including Helicobacter pylori (H. pylori), Hepatitis B and C viruses, and Human Papillomavirus (HPV) (Peng et al., 2020).

6.1.1. Cervical cancer (HPV-related)

The process of treatment for cervical cancer is contingent upon the disease's stage. Surgical procedures such as radical trachelectomy, hysterectomy, or conization may be used to treat early-stage cervical cancer. The goal of these procedures is to remove malignant tissues as much as possible while maintaining fertility (Holman, 2019). Chemotherapy and radiation therapy are frequently combined in advanced stages, with cisplatin-based regimens being the most popular. Patients with recurrent or metastatic illness now have new hope thanks to the approval of targeted treatments and immunotherapies like bevacizumab (a VEGF inhibitor) and pembrolizumab (a PD-1 inhibitor) for advanced cervical cancer (Gupta et al., 2018).

6.1.2. Liver cancer (HBV and HCV-related)

The most common type of liver cancer associated with HBV and HCV infections, hepatocellular carcinoma (HCC), is managed mostly based on the stage of the malignancy and the liver's functional condition. For early-stage HCC, curative measures include liver transplantation, ablative therapy, and surgical resection (Lurje et al., 2019). Patients with more advanced disease have been shown to live longer when receiving systemic therapy such multikinase inhibitors (sorafenib and lenvatinib) and immune checkpoint inhibitors (atezolizumab in conjunction with bevacizumab). Antiviral therapy may also be used in conjunction with HBV or HCV treatment to improve overall outcomes and reduce the risk of recurrence. (Conforti et al., 2018)

6.1.3. Gastric cancer (H. pylori-related)

Usually, a combination of radiation therapy, chemotherapy, and surgery is used to treat stomach cancer. The standard treatment for localized disease remains surgical excision, which aims to remove the tumor along with any nearby lymph nodes. Chemotherapy, which is frequently given both before and after surgery (perioperative chemotherapy), can involve the use of medications such trastuzumab for HER2-positive malignancies, fluorouracil, and platinum agents (Joshi & Badgwell, 2021a). (For advanced gastric cancer, targeted treatments and immunotherapies are becoming more popular. Pembrolizumab and ramucirumab, two VEGFR-2 antagonists, have shown promise in certain patient populations. For individuals with early-stage stomach cancer, eradication of the H. pylori infection is advised in order to avoid recurrence (Zaanan & Taieb, 2019b).

The technology for treating infection-related tumors has advanced significantly, there are still issues to be resolved, such as recurrence, resistance to existing treatments, and the need for less toxic treatments. In order to find new therapeutic targets, ongoing research aims to comprehend the molecular and immunological landscape of these tumors. Future therapies could be facilitated by the development of vaccinations, especially therapeutic vaccines that target malignanT-cells and induce an immune response (Wang et al., 2021b). Furthermore, the incorporation of precision medicine techniques, which make use of proteomic and genomic profiling, presents the possibility of more individualized and successful treatment plans. A plethora of surgical, pharmacological, and immunological therapies have been developed to treat malignancies brought on by infections. Improving patient outcomes requires ongoing research and innovation, highlighting the significance of a multidisciplinary approach in the treatment of these complex diseases (Manzari et al., 2021).

6.2. Advances in immunotherapies and targeted therapy for infection-related cancers

Based on the principle that the immune system can identify aberranT-cells and destroy them while protecting healthy tissues, immunotherapy uses the body's immune system to specifically target and eradicate cancer cells. This strategy makes use of T-cells, natural killer cells, and antibodies, among other immune system components, to generate a potent and targeted attack on tumor cells. Immunotherapy's core tactics include adoptive cell transfer, which involves engineering or expanding immune cells ex vivo before being reintroduced into the patient to more effectively target cancer, cancer vaccines, which stimulate the immune system to recognize and attack specific tumor antigens, and immune checkpoint inhibitors, which block proteins that suppress immune responses, enhancing T-cell activity against cancer cells. Immune checkpoint inhibitors, such as CTLA-4 and PD-1/PD-L1 blockers, have demonstrated notable efficacy in treating a range of tumors in clinical settings by impeding the ability of cancer cells to elude immune surveillance (Zaanan & Taieb, 2019b). The therapy landscape for tumors such as renal cell carcinoma, lung cancer, and melanoma has changed as a result of these inhibitors. Furthermore, adoptive cell transfer in the form of chimeric antigen receptor (CAR) T-cell therapy has produced impressive results in the treatment of hematologic malignancies by genetically altering T-cells to express receptors that specifically target cancer antigens. Oncolytic viruses and cancer vaccines provide additional examples of the various strategies used in immunotherapy, which aims to create a durable immunological memory against cancer. When taken as a whole, these tactics give hope for long-lasting effects and increased chances of survival for cancer patients, thereby representing a paradigm change in oncology (de Martel et al., 2020).

A promising strategy in cancer immunotherapy is to target neoantigens, also known as tumor-specific antigens (TSAs), which are antigens resulting from somatic mutations specific to tumor cells. Since these neoantigens are absent from healthy tissues, the immune system can identify and target cancer cells with precision while causing the least amount of harm to good cells. Using cutting-edge genomic and bioinformatic tools, neoantigens are identified by sequencing tumor DNA and predicting antigenic peptides that major histocompatibility complex (MHC) molecules can present on the surface of tumor cells (Ebrahimi et al., 2022). The specificity and effectiveness of immunotherapeutic treatments are improved by this targeted precision. Adoptive T-cell therapy and tailored cancer vaccines are two examples of neoantigen-based therapeutics in use. In order to create personalized cancer vaccines, peptides that match anticipated neoantigens are synthesized and subsequently given to the patient in order to stimulate a potent T-cell response against the tumor. By altering patient-derived T-cells to express neoantigen-specific receptors, adoptive T-cell therapies—like T-cell receptor (TCR) engineering—increase the capacity of these immune cells to identify and eliminate cancer cells. Neoantigen-targeted treatments have been shown in clinical studies to have the capacity to produce effective anti-tumor responses and enhance patient outcomes, underscoring their significance in the development of precision oncology (Ebrahimi et al., 2022).

Progress in comprehending the molecular and immunological foundations of infection-associated malignancies has enabled the creation of immunotherapies and tailored treatments. These cutting-edge therapies provide hope for more efficient and individualized cancer care by taking advantage of the unique pathways via which infectious pathogens contribute to carcinogenesis (Smith & Khanna, 2018).

Therapeutics targeting HPV-related diseases, especially cervical cancer, have advanced significantly in terms of development. It is known that the E6 and E7 oncoproteins disrupt tumor suppressor pathways, which is why treatment strategies that reduce their activity are being researched. Research is being done on small chemical inhibitors that focus on how these viral oncoproteins interact with hosT-cellular proteins (J. Zhang et al., 2021). For the treatment of advanced cervical cancer, bevacizumab, a monoclonal antibody that inhibits vascular endothelial growth factor (VEGF), has been approved. This is an example of how tailored therapy based on the angiogenic profile of the tumor can be applied successfully. Therapeutics targeting HPV-related diseases, especially cervical cancer, have advanced significantly in terms of development. It is known that the E6 and E7 oncoproteins disrupt tumor suppressor pathways, which is why treatment strategies that reduce their activity are being researched. Research is being done on small chemical inhibitors that focus on how these viral oncoproteins interact with hosT-cellular proteins. (Chellappan et al., 2018). For the treatment of advanced cervical cancer, bevacizumab, a monoclonal antibody that inhibits vascular

endothelial growth factor (VEGF), has been approved. This is an example of how tailored therapy based on the angiogenic profile of the tumor can be applied successfully (Garcia et al., 2020).

Immunotherapy, a novel approach to treating infections-related malignancies, makes use of the immune system's ability to recognize and destroy cancer cells. Promising outcomes have been shown in HPV-associated malignancies and HCC when checkpoint inhibitors, like nivolumab and pembrolizumab, are used to augment anticancer immune responses by blocking PD-1/PD-L1 interactions (Gong et al., 2018). Another cutting-edge strategy is the use of therapeutic vaccinations, which attempt to stimulate the immune system against viral antigens released by cancerous cells. Therapeutic HPV vaccines, for instance, that target the E6 and E7 proteins are presently being studied in clinical settings (Z. S. Guo et al., 2019).

7. Integrating Epidemiological Insights into Public Health Methods

7.1. Integrating epidemiological data into public health strategies

In the fight against disease and to promote population health, the use of epidemiological data into public health initiatives is a vital component. Epidemiological insights are becoming more and more valuable as public health keeps changing to meet new problems. This all-encompassing strategy directs policy choices, resource allocation, and long-term health outcome assessment in addition to helping to create and implement successful public health initiatives (Tarkoma et al., 2020b).

Epidemiological data is the foundation of public health decision-making. It is obtained by the methodical gathering, examination, and interpretation of health-related data. With its ability to paint a precise picture of illness patterns, risk factors, and health-related behaviors within communities, it provides a solid scientific foundation for directing treatments to the most critical areas (Coelho et al., 2022). Health authorities can promptly deploy resources, implement containment techniques, and reduce the spread of disease by detecting infectious disease outbreaks. In a similar vein, information on non-communicable diseases can help guide activities like nutrition education campaigns or smoking cessation programs that target lifestyle variables in an effort to lower the prevalence of disease and enhance community health (Fritz & Fromell, 2022).

Robust monitoring mechanisms and health information technology are necessary for the successful integration of epidemiological data into public health plans. For these systems to react quickly to public health emergencies, real-time data collection is a necessary. Moreover, the application of advanced analytics, such as geographic information systems (GIS) and predictive modeling, improves the capacity to recognize patterns, areas of high disease activity, and populations at risk, enabling focused treatments (Polonsky et al., 2019). Working together across industries and specialties is another essential component of efficiently using epidemiological data. Public health policies that are evidence-based, culturally aware, and community-focused can be created by establishing collaborations between epidemiologists, healthcare professionals, legislators, and community organizations. These cooperative initiatives guarantee that treatments are effectively developed, broadly embraced, and used in communities (D. Kim, 2019).

There are obstacles to overcome when incorporating epidemiological data into public health decision-making, though. It is necessary to handle issues including data privacy concerns, the requirement for consistent data collection procedures, and the possibility of misinterpreting data. The equitable implementation of public health initiatives may also be hampered by regional differences in the quantity and quality of health data. To tackle these obstacles, sustained funding for workforce development, public health infrastructure, and the development of explicit ethical standards for data usage are needed (Cramer et al., 2021).

7.2. Interdisciplinary collaboration: epidemiologists, oncologists, and public health officials

As the primary cause of morbidity and mortality globally, cancer requires thorough study, prevention, and care. Multidisciplinary collaboration between epidemiologists, oncologists, and public health officials is essential to this effort. Because cancer is a complicated disease influenced by genetic, environmental, behavioral, and infectious variables, figuring out its complex epidemiology and putting effective public health interventions in place requires teamwork (White et al., 2019). By using advanced statistical models and surveillance data to detect cancer patterns, trends, and risk factors in communities, epidemiologists provide a valuable contribution. This epidemiological knowledge is essential for directing the creation of focused screening initiatives, public health campaigns, and legislative initiatives for the prevention and management of cancer (Munoz et al., 2018).

Oncologists play a crucial role in converting epidemiological results into clinical practice because of their clinical skills and grasp of cancer biology. They are essential to the creation and use of patient care regimens, therapeutic methods, and diagnostic instruments. When oncologists work with epidemiologists to assess treatment plans and screening initiatives in real-world contexts, they can offer insightful commentary that helps improve public health initiatives and clinical recommendations (Gornick et al., 2018). When creating and implementing health policies and initiatives, public health officials depend on the knowledge of both oncologists and epidemiologists to help guide their choices. Through the integration of clinical outcomes, treatment efficacy, and epidemiology data, public health authorities can efficiently allocate resources, prioritize health initiatives, and promote policy changes that promote cancer prevention, research, and care (Munoz et al., 2018).

The synergy of these disciplines facilitates the development of comprehensive cancer control plans These include palliative care, early identification, treatment, and prevention. The success of vaccination campaigns against the Human Papillomavirus (HPV) to prevent cervical cancer, for instance, has been largely attributed to interdisciplinary teamwork. This illustrates the potential of integrated approaches to lower the burden of infection-related cancers (Ariza-Heredia & Chemaly, 2018). Additionally,

multidisciplinary research projects promote creativity in both cancer prevention and treatment by investigating new therapeutic targets, early detection biomarkers, and ways to reduce cancer risk factors. The cooperative sharing of expertise and knowledge improves the ability to handle the intricate problems that cancer presents, opening the door for developments in targeted medicines, personalized medicine, and public health initiatives (Lu & Zhan, 2018). To make progress in the fight against cancer, epidemiologists, oncologists, and public health authorities must work together transdisciplinary. These partnerships improve our knowledge of cancer and encourage the creation of practical methods for its prevention, detection, and treatment. In the end, they close the gaps between clinical practice, research, and public health policy, enhancing the health and quality of life for cancer patients. (Nipp et al., 2020).

7.3. Successful cancer reduction through integrated approaches

Through integrated projects that combine expertise from multiple domains, such as epidemiology, oncology, and public health policy, the fight against cancer has witnessed noteworthy wins. These cooperative efforts have resulted in notable decreases in the prevalence of particular tumors, demonstrating the effectiveness of multidisciplinary approaches in addressing intricate health issues. In this talk, effective cancer reduction cases are examined, with a focus on the tactics and teamwork that enabled these outcomes (Prabhu Das et al., 2018). Human Papillomavirus (HPV) vaccination campaigns have become a common tool in the battle against cervical cancer, which is one of the most impressive examples of cancer incidence reduction. Since HPV is known to be the main cause of cervical cancer, public health officials have advocated for the use of HPV vaccines alongside oncologists and epidemiologists (Lei et al., 2020). High vaccination rates have been linked to a sharp decline in HPV infections and, as a result, a decline in occurrences of cervical cancer. One such country is Australia. This success story emphasizes the significance of immunization and preventive medicine as the cornerstones of cancer control strategies (Brisson et al., 2020).

Similarly, the inclusion of the Hepatitis B Virus (HBV) vaccination in national immunization regimens has greatly reduced the incidence of hepatocellular carcinoma (HCC), a frequent type of liver cancer. One of the main risk factors for HCC is persistent HBV infection, which has significantly decreased since the HBV vaccination was developed. This has also resulted in a lower incidence of HCC. This accomplishment shows how effective preventive actions can be guided by knowledge of the etiological relationship between an infectious agent and cancer (Wandeler et al., 2019). Campaigns to quit smoking and tobacco control laws are credited with being another significant factor in the decline of cancer. The incidence of lung cancer, which is strongly associated with tobacco use, has decreased in areas where extensive laws and programs for quitting smoking have been strictly enforced. These initiatives highlight how behavioral and policy changes might prevent cancer and frequently entail cooperation between public health officials, legislators, and community organizations (Gredner et al., 2020).

Programs for early identification and screening have also been essential in lowering the incidence and mortality of cancer (Figure 7 & 8). Colorectal cancer rates have decreased as a result of early detection and treatment of precancerous tumors made possible by colorectal cancer screening techniques including colonoscopy and fecal occult blood tests. The accomplishments of these initiatives highlight the necessity of public health campaigns to encourage screening participation and the critical role that early detection plays in cancer control efforts (Dibden et al., 2020).

Globally lowering the incidence of cancer still faces obstacles, notwithstanding these achievements. There are still disparities in access to screening programs and immunizations, for example, especially in low- and middle-income nations. The intricacy of the genesis of cancer and the introduction of novel risk factors also present difficulties for cancer control initiatives. In the long run, effective cancer prevention will depend on strengthening international cooperation, promoting research into cutting-edge prophylactic and therapeutic approaches, and guaranteeing fair access to well-tested measures (Soerjomataram & Bray, 2021). Using digital health tools to increase screening participation and promote health education is one of the promising ways to further reduce the incidence of cancer. Furthermore, maintaining the improvements made and addressing the changing epidemiology of cancer need ongoing investments in public health infrastructure and staff development (Krist et al., 2017).

8. Direction and Future Challenges

As a result of the growing understanding of the intricate interrelationships among genetic, environmental, behavioral, and viral factors in the etiology of cancer, public health interventions and cancer research are moving in the direction of more integration and interdisciplinary approaches. Future cancer prevention and control will mostly depend on the creation of precise and customized interventions based on data science, genetics, immunology, and technological advancements. (Greenlee et al., 2014). There are several obstacles that need to be cleared in order to fully realize the potential of these advancements. The requirement for worldwide fairness in cancer prevention and treatment is one of the main concerns facing society in the future. Disparities in access to cancer care and preventative strategies, such vaccination and screening programs, continue globally despite notable improvements in certain areas, especially in countries with low and moderate incomes (LMICs) (Cortes et al., 2020). International collaboration, financial investments in healthcare facilities, and creative delivery strategies are needed to close this disparity and guarantee that cancer research advances benefit all populations. The quick speed at which technology is developing and the requirement that healthcare systems adjust to these developments present another difficulty. Big data analytics, AI, and machine learning have the potential to significantly improve disease surveillance, risk assessment, and treatment optimization when included into cancer research and public health decision-making (Ngwa et al., 2016). The dynamic nature of cancer etiology, characterised by the emergence of environmental and lifestyle risk factors, demands ongoing investigation and monitoring in order to modify preventive approaches appropriately. It is anticipated that factors such as pollution, shifting food and lifestyle habits, and climate change will

impact the incidence and distribution of cancer. This will make it more difficult for researchers and public health officials to anticipate and reduce future cancer burdens (Schottenfeld et al., 2013). Additionally, there are now more opportunities and challenges for future study and therapy development related to the function of the microbiome in cancer. Innovative research techniques and multidisciplinary collaboration are needed to fully comprehend the intricate relationships between the microbiome and host in the setting of cancer. Although such understanding may open the door to novel approaches to treatment and prevention, such as microbiome-based medicines, it also necessitates careful assessment of the implications for patient care and public health (Raza et al., 2019). Technology innovation and interdisciplinary cooperation will drive major improvements in the field of cancer research and public health intervention in the years to come. To optimize these advances for cancer prevention and control, it will be imperative to tackle the issues of global fairness, technology adaptability, rising risk factors, and the intricate involvement of the microbiome in cancer. It is feasible to foresee a day in the future when patients will benefit from more efficient, individualized treatments and cancer incidence and mortality will be significantly decreased through the combined efforts of researchers, doctors, public health authorities, and lawmakers (Roy & Trinchieri, 2017).

9. Conclusion

In conclusion, this study has outlined the complex epidemiological relationships that exist between infectious disorders and cancer, emphasizing important developments in our knowledge of, ability to prevent, and management of cancers associated with infections. Notable achievements have resulted from the fusion of epidemiological insights with clinical and public health strategies. Two such examples are the creation and administration of vaccines against the human papillomavirus (HPV) and hepatitis B virus (HBV), which have significantly decreased the incidence of hepatocellular carcinoma and cervical cancer, respectively. Global health depends on addressing the epidemiological connections between infectious diseases and cancer, as this provides a direct route to lowering the incidence of malignancies that can be avoided by immunization, screening, and the elimination of infectious agents. Incorporating scientific discoveries into clinical practices and public health policies that can save millions of lives globally requires the cooperation of epidemiologists, oncologists, and public health officials.

Future prospects and challenges in the field of cancer prevention and control are numerous. Focused attention is needed in the areas of global disparities in access to treatment and preventive measures, the quickening speed of technology innovation, new environmental and lifestyle risk factors, and the developing knowledge of the microbiome's role in cancer. The international community must work together to address these issues, which calls for consistent funding of research, creative public health policy, and a dedication to health fairness. Potential new therapeutic approaches could result from the ongoing investigation of the connections between infectious diseases and cancer as well as developments in precision medicine and immunotherapy. The future of public health policies and cancer treatment techniques can be tailored to address the changing difficulties of cancer prevention and control by embracing interdisciplinary collaboration and utilizing technological breakthroughs. This will ultimately improve health outcomes globally.

Acknowledgement

The authors are grateful to Ladoke Akintola University of Technology, Nigeria, Department of Public Health, University of Illinois at Springfield. USA, School of Medicine, University for Development Studies,Ghana, for their moral support and encouragement.

Ethical Statement

This study does not contain any studies with human or animal subjects performed by any of the authors.

Conflicts of Interest

The authors declare that they have no conflicts of interest to this work.

Data Availability Statement

The data that support the findings of this study are openly available in [repository name e.g “figshare”] at http://doi.org/[doi].

Author Contribution Statement

Taiwo Temitope Ogunjobi, Ajayi Oluwagbemileke Rufus, Anegbe Emmanuel, Musa Adnan, Inusah Abdul-Hanan Saani, Agyei-Nkrumah Kenneth Lord, Mufutau Oyewale Kabiru, Aigbagenode Augustine Aiyebor, Afuape Rapheal Akinwunmi, Ahorlu Kwasi Elim, Oyeyemi Nuratullahi Ashade-Ogunfuwa, Stephen Ajuluchukwu Echesi, Temitope Ayinde Ajamu, Daniel Ebubechi Obasi

References

Almeida, A. M., Queiroz, J. A., Sousa, F., & Sousa, Â. (2019). Cervical cancer and HPV infection: ongoing therapeutic research to counteract the action of E6 and E7 oncoproteins. Drug Discovery Today, 24(10), 2044 - 2057. https://doi.org/10.1016/j.drudis.2019.07.011

Anna Szymonowicz, K., & Chen, J. (2020). Biological and clinical aspects of HPV-related cancers. Cancer Biology & Medicine, 17(4), 864-878. https://doi.org/10.20892/j.issn.2095-3941.2020.0370

Ariza-Heredia, E. J., & Chemaly, R. F. (2018). Update on infection control practices in cancer hospitals. CA: A Cancer Journal for Clinicians, 68(5), 340-355. https://doi.org/10.3322/caac.21462

Bannister, S., Messina, N. L., Novakovic, B., & Curtis, N. (2020). The emerging role of epigenetics in the immune response to vaccination and infection: a systematic review. Epigenetics: Official Journal of the DNA Methylation Society, 15(6-7), 555-593. https://doi.org/10.1080/15592294.2020.1712814

Basu, P., Lucas, E., Zhang, L., Muwonge, R., Murillo, R., & Nessa, A. (2021). Leveraging vertical COVID-19 investments to improve monitoring of cancer screening programme - A case study from Bangladesh. Preventive Medicine, 151(106624), 106624. https://doi.org/10.1016/j.ypmed.2021.106624

Bi, Q., Wu, J.-Y., Qiu, X.-M., Zhang, J.-D., Sun, Z.-J., & Wang, W. (2022). Tumor-associated inflammation: The tumor-promoting immunity in the early stages of tumorigenesis. Journal of Immunology Research, 2022, 1 - 13. https://doi.org/10.1155/2022/3128933

Brisson, M., Kim, J. J., Canfell, K., Drolet, M., Gingras, G., Burger, E. A., Martin, D., Simms, K. T., Bénard, É., Boily, M.-C., Sy, S., Regan, C., Keane, A., Caruana, M., Nguyen, D. T. N., Smith, M. A., Laprise, J.-F., Jit, M., Alary, M., ⋯ Hutubessy, R. (2020). Impact of HPV vaccination and cervical screening on cervical cancer elimination: a comparative modelling analysis in 78 low-income and lower-middle-income countries. Lancet, 395(10224), 575 - 590. https://doi.org/10.1016/s0140-6736(20)30068-4

Brown, H. E., Dennis, L. K., Lauro, P., Jain, P., Pelley, E., & Oren, E. (2019). Emerging evidence for infectious causes of cancer in the United States. Epidemiologic Reviews, 41(1), 82-96. https://doi.org/10.1093/epirev/mxz003

Budisan, L., Zanoaga, O., Braicu, C., Pirlog, R., Covaliu, B., Esanu, V., Korban, S., & Berindan-Neagoe, I. (2021). Links between infections, lung cancer, and the immune system. International Journal of Molecular Sciences, 22(17), 9394. https://doi.org/10.3390/ijms22179394

Cai, S., Tan, X., Miao, K., Li, D., Cheng, S., Li, P., Zeng, X., & Sun, F. (2022). Effectiveness and safety of therapeutic vaccines for precancerous cervical lesions: A systematic review and meta-analysis. Frontiers in Oncology, 12. https://doi.org/10.3389/fonc.2022.918331

Campbell, C., Wang, T., McNaughton, A. L., Barnes, E., & Matthews, P. C. (2021). Risk factors for the development of hepatocellular carcinoma (HCC) in chronic hepatitis B virus (HBV) infection: a systematic review and meta - analysis. Journal of Viral Hepatitis, 28(3), 493-507. https://doi.org/10.1111/jvh.13452

Carbone, A., Vaccher, E., & Gloghini, A. (2022). Hematologic cancers in individuals infected by HIV. Blood, 139(7), 995-1012. https://doi.org/10.1182/blood.2020005469

Chellappan, D. K., Leng, K. H., Jia, L. J., Aziz, N. A. B. A., Hoong, W. C., Qian, Y. C., Ling, F. Y., Wei, G. S., Ying, T., Chellian, J., Gupta, G., & Dua, K. (2018). The role of bevacizumab on tumour angiogenesis and in the management of gynaecological cancers: A review. Biomedecine & Pharmacotherapie [Biomedicine & Pharmacotherapy], 102, 1127 - 1144. https://doi.org/10.1016/j.biopha.2018.03.061

Coelho, F. C., Câmara, D., Araújo, E., Bianchi, L., Ogasawara, I., Dalal, J., James, A., Abbate, J. L., Merzouki, A., Reis, I., Nwosu, K., & Keiser, O. (2022). A platform for data-centric, continuous epidemiological analyses. In bioRxiv. https://doi.org/10.1101/2022.04.19.22274026

Conforti, F., Pala, L., Bagnardi, V., De Pas, T., Martinetti, M., Viale, G., Gelber, R. D., & Goldhirsch, A. (2018). Cancer immunotherapy efficacy and patients' sex: a systematic review and meta-analysis. The Lancet Oncology, 19(6), 737-746. https://doi.org/10.1016/s1470-2045(18)30261-4

Cortes, J., Perez-García, J. M., Llombart-Cussac, A., Curigliano, G., El Saghir, N. S., Cardoso, F., Barrios, C. H., Wagle, S., Roman, J., Harbeck, N., Eniu, A., Kaufman, P. A., Tabernero, J., García-Estévez, L., Schmid, P., & Arribas, J. (2020). Enhancing global access to cancer medicines. CA: A Cancer Journal for Clinicians, 70(2), 105-124. https://doi.org/10.3322/caac.21597

Cramer, G. R., Young, G. J., Singh, S., McGuire, J., & Kim, D. (2021). Evidence that collaborative action between local health departments and nonprofit hospitals helps foster healthy behaviors in communities: a multilevel study. BMC Health Services Research, 21(1). https://doi.org/10.1186/s12913-020-05996-8

de Martel, C., Georges, D., Bray, F., Ferlay, J., & Clifford, G. M. (2020). Global burden of cancer attributable to infections in 2018: a worldwide incidence analysis. The Lancet. Global Health, 8(2), e180-e190. https://doi.org/10.1016/s2214-109x(19)30488-7

Deo, S. V. S., Gowda, S. M., & Bhoriwal, S. (2021). Epidemiology of Cancer. In Textbook of Onco-Anesthesiology (pp. 7-12). Springer Singapore.

Díaz, P., Valenzuela Valderrama, M., Bravo, J., & Quest, A. F. G. (2018). Helicobacter pylori and gastric cancer: Adaptive cellular mechanisms involved in disease progression. Frontiers in Microbiology, 9. https://doi.org/10.3389/fmicb.2018.00005

Dibden, A., Offman, J., Duffy, S. W., & Gabe, R. (2020). Worldwide review and meta-analysis of cohort studies measuring the effect of mammography screening programmes on incidence-based breast cancer mortality. Cancers, 12(4), 976. https://doi.org/10.3390/cancers12040976

Ebrahimi, N., Akbari, M., Ghanaatian, M., Roozbahani moghaddam, P., Adelian, S., Borjian Boroujeni, M., Yazdani, E., Ahmadi, A., & Hamblin, M. R. (2022). Development of neoantigens: from identification in cancer cells to application in cancer vaccines. Expert Review of Vaccines, 21(7), 941-955. https://doi.org/10.1080/14760584.2021.1951246

Elbehiry, A., Marzouk, E., Aldubaib, M., Abalkhail, A., Anagreyyah, S., Anajirih, N., Almuzaini, A. M., Rawway, M., Alfadhel, A., Draz, A., & Abu-Okail, A. (2023). Helicobacter pylori infection: Current status and future prospects on diagnostic, therapeutic and control challenges. Antibiotics (Basel, Switzerland), 12(2), 191. https://doi.org/10.3390/antibiotics12020191

Equils, O., Kellogg, C., Baden, L., Berger, W., & Connolly, S. (2019). Logistical and structural challenges are the major obstacles for family medicine physicians' ability to administer adult vaccines. Human Vaccines & Immunotherapeutics, 15(3), 637‐642. https://doi.org/10.1080/21645515.2018.1543524

Eusebi, L. H., Telese, A., Marasco, G., Bazzoli, F., & Zagari, R. M. (2020). Gastric cancer prevention strategies: A global perspective. Journal of Gastroenterology and Hepatology, 35(9), 1495‐1502. https://doi.org/10.1111/jgh.15037

Ferrall, L., Lin, K. Y., Roden, R. B. S., Hung, C.-F., & Wu, T.-C. (2021). Cervical cancer immunotherapy: Facts and hopes. Clinical Cancer Research: An Official Journal of the American Association for Cancer Research, 27(18), 4953‐4973. https://doi.org/10.1158/1078-0432.ccr-20-2833

Fritz, M., & Fromell, H. (2022). How to dampen the surge of non-communicable diseases in Southeast Asia: insights from a systematic review and meta-analysis. Health Policy and Planning, 37(1), 152‐167. https://doi.org/10.1093/heapol/czab138

Gaisa, M. M., Sigel, K. M., Deshmukh, A. A., Lenskaya, V., Chan, C. A., Silvera, R., Winters, J., & Liu, Y. (2021). Comparing anal cancer Screening algorithms using cytology and human Papillomavirus DNA testing in 3 high-risk populations. The Journal of Infectious Diseases, 224(5), 881‐888. https://doi.org/10.1093/infdis/jiaa801

Garcia, J., Hurwitz, H. I., Sandler, A. B., Miles, D., Coleman, R. L., Deurloo, R., & Chinot, O. L. (2020). Bevacizumab (Avastin®) in cancer treatment: A review of 15 years of clinical experience and future outlook. Cancer Treatment Reviews, 86(102017), 102017. https://doi.org/10.1016/j.ctrv.2020.102017

Giannakou, K., & Vachtsioli, E. (2020). Understanding hesitancy around vaccines and vaccination: an umbrella review. European Journal of Public Health, 30(Supplement_5). https://doi.org/10.1093/eurpub/ckaa166.1421

Golrokh Mofrad, M., Taghizadeh Maleki, D., & Faghihloo, E. (2020). The roles of programmed death ligand 1 in virus-associated cancers. Infection, Genetics and Evolution: Journal of Molecular Epidemiology and Evolutionary Genetics in Infectious Diseases, 84(104368), 104368. https://doi.org/10.1016/j.meegid.2020.104368

Gong, J., Chehrazi-Raffle, A., Reddi, S., & Salgia, R. (2018). Development of PD-1 and PD-L1 inhibitors as a form of cancer immunotherapy: a comprehensive review of registration trials and future considerations. Journal for Immunotherapy of Cancer, 6(1). https://doi.org/10.1186/s40425-018-0316-z

Gornick, M. C., Cobain, E., Le, L. Q., Bartnik, N., Stoffel, E., Schuetze, S., Talpaz, M., Chinnaiyan, A., Roberts, J. S., & for the Michigan Oncology Sequencing Study. (2018). Oncologists' use of genomic sequencing data to inform clinical management. JCO Precision Oncology, 2, 1‐13. https://doi.org/10.1200/po.17.00122

Goto, K., Roca Suarez, A. A., Wrensch, F., Baumert, T. F., & Lupberger, J. (2020). Hepatitis C virus and hepatocellular carcinoma: When the host loses its grip. International Journal of Molecular Sciences, 21(9), 3057. https://doi.org/10.3390/ijms21093057

Gredner, T., Niedermaier, T., Brenner, H., & Mons, U. (2020). Impact of tobacco control policies on smoking-related cancer incidence in Germany 2020 to 2050−A simulation study. Cancer Epidemiology, Biomarkers & Prevention: A Publication of the American Association for Cancer Research, Cosponsored by the American Society of Preventive Oncology, 29(7), 1413‐1422. https://doi.org/10.1158/1055-9965.epi-19-1301

Green, R. F., Ari, M., Kolor, K., Dotson, W. D., Bowen, S., Habarta, N., Rodriguez, J. L., Richardson, L. C., & Khoury, M. J. (2019). Evaluating the role of public health in implementation of genomics-related recommendations: a case study of hereditary cancers using the CDC Science Impact Framework. Genetics in Medicine: Official Journal of the American College of Medical Genetics, 21(1), 28‐37. https://doi.org/10.1038/s41436-018-0028-2

Greenlee, H., Balneaves, L. G., Carlson, L. E., Cohen, M., Deng, G., Hershman, D., Mumber, M., Perlmutter, J., Seely, D., Sen, A., Zick, S. M., Tripathy, D., & for the Society for Integrative Oncology Guidelines Working Group. (2014). Clinical practice guidelines on the use of integrative therapies as supportive care in patients treated for breast cancer. Journal of the National Cancer Institute. Monographs, 2014(50), 346‐358. https://doi.org/10.1093/jncimonographs/lgu041

Greten, F. R., & Grivennikov, S. I. (2019). Inflammation and cancer: Triggers, mechanisms, and consequences. Immunity, 51(1), 27‐41. https://doi.org/10.1016/j.immuni.2019.06.025

Guo, Y., Zhang, Y., Gerhard, M., Gao, J.-J., Mejias-Luque, R., Zhang, L., Vieth, M., Ma, J.-L., Bajbouj, M., Suchanek, S., Liu, W.-D., Ulm, K., Quante, M., Li, Z.-X., Zhou, T., Schmid, R., Classen, M., Li, W.-Q., You, W.-C., & Pan, K.-F. (2020). Effect of Helicobacter pylori on gastrointestinal microbiota: a population-based study in Linqu, a high-risk area of gastric cancer. Gut, 69(9), 1598‐1607. https://doi.org/10.1136/gutjnl-2019-319696

Guo, Z. S., Lu, B., Guo, Z., Giehl, E., Feist, M., Dai, E., Liu, W., Storkus, W. J., He, Y., Liu, Z., & Bartlett, D. L. (2019). Vaccinia virus-mediated cancer immunotherapy: cancer vaccines and oncolytics. Journal for Immunotherapy of Cancer, 7(1). https://doi.org/10.1186/s40425-018-0495-7

Gupta, S., Maheshwari, A., Parab, P., Mahantshetty, U., Hawaldar, R., Sastri (Chopra), S., Kerkar, R., Engineer, R., Tongaonkar, H., Ghosh, J., Gulia, S., Kumar, N., Shylasree, T. S., Gawade, R., Kembhavi, Y., Gaikar, M., Menon, S., Thakur, M., Shrivastava, S., & Badwe, R. (2018). Neoadjuvant chemotherapy followed by radical surgery versus concomitant chemotherapy and radiotherapy in patients with stage IB2, IIA, or IIB squamous cervical cancer: A randomized controlled trial. Journal of Clinical Oncology: Official Journal of the American Society of Clinical Oncology, 36(16), 1548‐1555. https://doi.org/10.1200/jco.2017.75.9985

Holcakova, J., Bartosik, M., Anton, M., Minar, L., Hausnerova, J., Bednarikova, M., Weinberger, V., & Hrstka, R. (2021). New trends in the detection of gynecological precancerous lesions and early-stage cancers. Cancers, 13(24), 6339. https://doi.org/10.3390/cancers13246339

Holman, D. A. (2019). Fertility preservation in gynecologic cancer. Seminars in Oncology Nursing, 35(2), 202‐210. https://doi.org/10.1016/j.soncn.2019.02.007

Horn, J., Denecke, A., Luyten, A., Rothe, B., Reinecke-Lüthge, A., Mikolajczyk, R., & Petry, K. U. (2019). Reduction of cervical cancer incidence within a primary HPV screening pilot project (WOLPHSCREEN) in Wolfsburg, Germany. British Journal of Cancer, 120(10), 1015‐1022. https://doi.org/10.1038/s41416-019-0453-2

Hou, J., Cui, F., Ding, Y., Dou, X., Duan, Z., Han, G., Jia, J., Mao, Q., Li, J., Li, Z., Liu, Z., Wei, L., Xie, Q., Yang, X., Zhang, H., & Zhuang, H. (2019). Management algorithm for interrupting mother-to-child transmission of hepatitis B virus. Clinical Gastroenterology and Hepatology: The Official Clinical Practice Journal of the American Gastroenterological Association, 17(10), 1929-1936.e1. https://doi.org/10.1016/j.cgh.2018.10.007

Ishikura, N., Usui, Y., Ito, H., Kasugai, Y., Oze, I., Kato, S., Yatabe, Y., Nakamura, S., & Matsuo, K. (2019). Helicobacter pylori (HP) infection alone, but not HP-induced atrophic gastritis, increases the risk of gastric lymphoma: a case-control study in Japan. Annals of Hematology, 98(8), 1981‐1987. https://doi.org/10.1007/s00277-019-03721-y

Jain, S., Sengupta, M., & Jain, P. (2019b). Non-viral parasites associated with carcinogenesis. Cancer Investigation, 37(9), 453‐462. https://doi.org/10.1080/07357907.2019.1662918

Johnson, K. S., & Ottemann, K. M. (2018). Colonization, localization, and inflammation: the roles of H. pylori chemotaxis in vivo. Current Opinion in Microbiology, 41, 51‐57. https://doi.org/10.1016/j.mib.2017.11.019

Joshi, S. S., & Badgwell, B. D. (2021). Current treatment and recent progress in gastric cancer. CA: A Cancer Journal for Clinicians, 71(3), 264‐279. https://doi.org/10.3322/caac.21657

Kim, D. (2019). Bridging the epidemiology-policy divide: A consequential and evidence-based framework to optimize population health. Preventive Medicine, 129(105781), 105781. https://doi.org/10.1016/j.ypmed.2019.105781

Krist, A. H., Woolf, S. H., Hochheimer, C., Sabo, R. T., Kashiri, P., Jones, R. M., Lafata, J. E., Etz, R. S., & Tu, S.-P. (2017). Harnessing information technology to inform patients facing routine decisions: Cancer screening as a test case. Annals of Family Medicine, 15(3), 217‐224. https://doi.org/10.1370/afm.2063

Lehtinen, M., Söderlund-Strand, A., Vänskä, S., Luostarinen, T., Eriksson, T., Natunen, K., Apter, D., Baussano, I., Harjula, K., Hokkanen, M., Kuortti, M., Palmroth, J., Petäjä, T., Pukkala, E., Rekonen, S., Siitari-Mattila, M., Surcel, H.-M., Tuomivaara, L., Paavonen, J., ⋯ Garnett, G. (2018). Impact of gender ‐ neutral or girls ‐ only vaccination against human papillomavirus–Results of a community ‐ randomized clinical trial (I). International Journal of Cancer. Journal International Du Cancer, 142(5), 949‐958. https://doi.org/10.1002/ijc.31119

Lei, J., Ploner, A., Elfström, K. M., Wang, J., Roth, A., Fang, F., Sundström, K., Dillner, J., & Sparén, P. (2020). HPV vaccination and the risk of invasive cervical cancer. The New England Journal of Medicine, 383(14), 1340 ‐ 1348. https://doi.org/10.1056/nejmoa1917338

Liu, Y., & Liu, L. (2022). Changes in the epidemiology of hepatocellular carcinoma in Asia. Cancers, 14(18), 4473. https://doi.org/10.3390/cancers14184473

Lu, M., & Zhan, X. (2018). The crucial role of multiomic approach in cancer research and clinically relevant outcomes. The EPMA Journal, 9(1), 77‐102. https://doi.org/10.1007/s13167-018-0128-8

Lurje, I., Czigany, Z., Bednarsch, J., Roderburg, C., Isfort, P., Neumann, U. P., & Lurje, G. (2019). Treatment strategies for hepatocellular carcinoma ‐ a multidisciplinary approach. International Journal of Molecular Sciences, 20(6), 1465. https://doi.org/10.3390/ijms20061465

Mahmoudvand, S., Shokri, S., Taherkhani, R., & Farshadpour, F. (2019). Hepatitis C virus core protein modulates several signaling pathways involved in hepatocellular carcinoma. World Journal of Gastroenterology: WJG, 25(1), 42 ‐ 58. https://doi.org/10.3748/wjg.v25.i1.42

Mix, J. M., Van Dyne, E. A., Saraiya, M., Hallowell, B. D., & Thomas, C. C. (2021). Assessing impact of HPV vaccination on cervical cancer incidence among women aged 15‐29 years in the United States, 1999‐2017: An ecologic study. Cancer Epidemiology, Biomarkers & Prevention: A Publication of the American Association for Cancer Research, Cosponsored by the American Society of Preventive Oncology, 30(1), 30‐37. https://doi.org/10.1158/1055-9965.epi-20-0846

Modabber, N., Mahboub, S. S., Khoshravesh, S., Karimpour, F., Karimi, A., & Goodarzi, V. (2023). Evaluation of long non-coding RNA (LncRNA) in the pathogenesis of chemotherapy resistance in cervical cancer: Diagnostic and prognostic approach. Molecular Biotechnology. https://doi.org/10.1007/s12033-023-00909-6

Munoz, D. F., Xu, C., & Plevritis, S. K. (2018). A molecular subtype‐specific stochastic simulation model of US breast cancer incidence, survival, and mortality trends from 1975 to 2010. Medical Decision Making: An International Journal of the Society for Medical Decision Making, 38(1_suppl), 89S-98S. https://doi.org/10.1177/0272989x17737508

Münz, C. (2023). Modulation of Epstein-Barr-virus (EBV)-associated cancers by co-infections. Cancers, 15(24), 5739. https://doi.org/10.3390/cancers15245739

Nacif-Pimenta, R., da Silva Orfanó, A., Mosley, I. A., Karinshak, S. E., Ishida, K., Mann, V. H., Coelho, P. M. Z., da Costa, J. M. C., Hsieh, M. H., Brindley, P. J., & Rinaldi, G. (2019). Differential responses of epithelial cells from urinary and biliary tract to eggs of Schistosoma haematobium and S. mansoni. Scientific Reports, 9(1). https://doi.org/10.1038/s41598-019-46917-y

Naran, K., Nundalall, T., Chetty, S., & Barth, S. (2018). Principles of immunotherapy: Implications for treatment strategies in cancer and infectious diseases. Frontiers in Microbiology, 9. https://doi.org/10.3389/fmicb.2018.03158

Nganga, S. W., Otieno, N. A., Adero, M., Ouma, D., Chaves, S. S., Verani, J. R., Widdowson, M.-A., Wilson, A., Bergenfeld, I., Andrews, C., Fenimore, V. L., Gonzalez-Casanova, I., Frew, P. M., Omer, S. B., & Malik, F. A. (2019). Patient and provider perspectives on how trust influences maternal vaccine acceptance among pregnant women in Kenya. BMC Health Services Research, 19(1). https://doi.org/10.1186/s12913-019-4537-8

Ngwa, W., Ngoma, T., Zietman, A., Mayr, N., Elzawawy, A., Winningham, T. A., Balogun, O., Enwerem-Bromson, N., Ntizimira, C., Olopade, O. I., Oluwole, D., Odedina, F., Williams, M., Flanigan, J., Asana, L., Ngwa, K., Avery, S., Pollard, J. M., Roland, T., ⋯ Nguyen, P. L. (2016). Closing the cancer divide through Ubuntu: Information and communication technology-powered models for global radiation oncology. International Journal of Radiation Oncology, Biology, Physics, 94(3), 440‐449. https://doi.org/10.1016/j.ijrobp.2015.10.063

Nipp, R. D., Temel, B., Fuh, C.-X., Kay, P., Landay, S., Lage, D., Franco-Garcia, E., Scott, E., Stevens, E., O’ Malley, T., Mohile, S., Dale, W., Traeger, L., Jackson, V., Greer, J. A., El-Jawahri, A., & Temel, J. S. (2020). Pilot randomized trial of a transdisciplinary geriatric and palliative care intervention for older adults with cancer. Journal of the National Comprehensive Cancer Network: JNCCN, 18(5), 591‑598. https://doi.org/10.6004/jnccn.2019.7386

Nipp, R. D., & Temel, J. S. (2018). Harnessing the power of Patient-reported outcomes in oncology. Clinical Cancer Research: An Official Journal of the American Association for Cancer Research, 24(8), 1777‑1779. https://doi.org/10.1158/1078-0432.ccr-18-0037

Nwizu, N., Wactawski-Wende, J., & Genco, R. J. (2020). Periodontal disease and cancer: Epidemiologic studies and possible mechanisms. Periodontology 2000, 83(1), 213‑233. https://doi.org/10.1111/prd.12329

Pal, A., & Kundu, R. (2020). Human Papillomavirus E6 and E7: The cervical cancer hallmarks and targets for therapy. Frontiers in Microbiology, 10. https://doi.org/10.3389/fmicb.2019.03116

Peng, Y. Z., Yang, L. J., Lo, H. H., Law, B. Y. K., & Wong, V. K. W. (2020). Tumor Therapeutic Modes. In New Nanomaterials and Techniques for Tumor-targeted Systems (pp. 135‑229). Springer Singapore.

Petruzziello, A. (2018). Epidemiology of Hepatitis B Virus (HBV) and Hepatitis C Virus (HCV) related hepatocellular carcinoma. The Open Virology Journal, 12(1), 26‑32. https://doi.org/10.2174/1874357901812010026

Pinatti, L. M., Walline, H. M., & Carey, T. E. (2018). Human Papillomavirus genome integration and head and neck cancer. Journal of Dental Research, 97(6), 691‑700. https://doi.org/10.1177/0022034517744213

Polonsky, J. A., Baidjoe, A., Kamvar, Z. N., Cori, A., Durski, K., Edmunds, W. J., Eggo, R. M., Funk, S., Kaiser, L., Keating, P., de Waroux, O. le P., Marks, M., Moraga, P., Morgan, O., Nouvellet, P., Ratnayake, R., Roberts, C. H., Whitworth, J., & Jombart, T. (2019). Outbreak analytics: a developing data science for informing the response to emerging pathogens. Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences, 374(1776), 20180276. https://doi.org/10.1098/rstb.2018.0276

Pormohammad, A., Ghotaslou, R., Leylabadlo, H. E., Nasiri, M. J., Dabiri, H., & Hashemi, A. (2018). Risk of gastric cancer in association with Helicobacter pylori different virulence factors: A systematic review and meta-analysis. Microbial Pathogenesis, 118, 214‑219. https://doi.org/10.1016/j.micpath.2018.03.004

Prabhu Das, I., Baker, M., Altice, C., Castro, K. M., Brandys, B., & Mitchell, S. A. (2018). Outcomes of multidisciplinary treatment planning in US cancer care settings. Cancer, 124(18), 3656‑3667. https://doi.org/10.1002/cncr.31394

Rapado-González, Ó., Martínez-Reglero, C., Salgado-Barreira, Á., Rodríguez-Fernández, A., Aguín-Losada, S., León-Mateos, L., Muinelo-Romay, L., López-López, R., & Suarez-Cunqueiro, M. M. (2020). Association of salivary human Papillomavirus infection and oral and oropharyngeal cancer: A meta-analysis. Journal of Clinical Medicine, 9(5), 1305. https://doi.org/10.3390/jcm9051305

Raza, M. H., Gul, K., Arshad, A., Riaz, N., Waheed, U., Rauf, A., Aldakheel, F., Alduraywish, S., Rehman, M. U., Abdullah, M., & Arshad, M. (2019). Microbiota in cancer development and treatment. Journal of Cancer Research and Clinical Oncology, 145(1), 49‑63. https://doi.org/10.1007/s00432-018-2816-0

Reyes, V. E. (2023). Helicobacter pylori and Its Role in Gastric Cancer. Microorganisms, 11(5), 1312. https://doi.org/10.3390/microorganisms11051312 Reyes, V. E. (2023). Helicobacter pylori and Its Role in Gastric Cancer. Microorganisms, 11(5), 1312. https://doi.org/10.3390/microorganisms11051312

Roy, S., & Trinchieri, G. (2017). Microbiota: a key orchestrator of cancer therapy. Nature Reviews. Cancer, 17(5), 271‑285. https://doi.org/10.1038/nrc.2017.13

Saco, T. V., Strauss, A. T., & Ledford, D. K. (2018). Hepatitis B vaccine nonresponders. Annals of Allergy, Asthma & Immunology: Official Publication of the American College of Allergy, Asthma, & Immunology, 121(3), 320 ‑ 327. https://doi.org/10.1016/j.anai.2018.03.017

Schottenfeld, D., Beebe-Dimmer, J. L., Buffler, P. A., & Omenn, G. S. (2013). Current perspective on the global and United States cancer burden attributable to lifestyle and environmental risk factors. Annual Review of Public Health, 34(1), 97‑117. https://doi.org/10.1146/annurev-publhealth-031912-114350

Sell, H., Assi, A., Driedger, S. M., Dubé, È., Gagneur, A., Meyer, S. B., Robinson, J., Sadarangani, M., Tunis, M., & MacDonald, S. E. (2021). Continuity of routine immunization programs in Canada during the COVID-19 pandemic. Vaccine, 39(39), 5532‑5537. https://doi.org/10.1016/j.vaccine.2021.08.044

Sexton, R. E., Al Hallak, M. N., Diab, M., & Azmi, A. S. (2020). Gastric cancer: a comprehensive review of current and future treatment strategies. Cancer Metastasis Reviews, 39(4), 1179‑1203. https://doi.org/10.1007/s10555-020-09925-3

Shah, S. C., Kayamba, V., Peek, R. M., Jr, & Heimburger, D. (2019). Cancer control in low- and middle-income countries: Is it time to consider screening? Journal of Global Oncology, 5, 1‑8. https://doi.org/10.1200/jgo.18.00200

Sheweita, S. A., & Alsamghan, A. S. (2020). Molecular mechanisms contributing bacterial infections to the incidence of various types of cancer. Mediators of Inflammation, 2020, 1‑10. https://doi.org/10.1155/2020/4070419

Shen, C., Jiang, X., Li, M., & Luo, Y. (2023). Hepatitis virus and hepatocellular carcinoma: Recent advances. Cancers, 15(2), 533. https://doi.org/10.3390/cancers15020533

Siegel, R. L., Miller, K. D., & Jemal, A. (2019). Cancer statistics, 2019. CA: A Cancer Journal for Clinicians, 69(1), 7‑34. https://doi.org/10.3322/caac.21551

Smith, C., & Khanna, R. (2018). Immune-based therapeutic approaches to virus-associated cancers. Current Opinion in Virology, 32, 24‑29. https://doi.org/10.1016/j.coviro.2018.08.010

Soerjomataram, I., & Bray, F. (2021). Planning for tomorrow: global cancer incidence and the role of prevention 2020‑2070. Nature Reviews. Clinical Oncology, 18(10), 663‑672. https://doi.org/10.1038/s41571-021-00514-z

Stewart, O. A., Wu, F., & Chen, Y. (2020). The role of gastric microbiota in gastric cancer. Gut Microbes, 11(5), 1220‑1230. https://doi.org/10.1080/19490976.2020.1762520

Sugimoto, M., Murata, M., & Yamaoka, Y. (2020). Chemoprevention of gastric cancer development after Helicobacter pylori eradication therapy in an East Asian population: Meta-analysis. World Journal of Gastroenterology: WJG, 26(15), 1820‐1840. https://doi.org/10.3748/wjg.v26.i15.1820

Suresh, A., Suresh, P., Biswas, R., Rajanbabu, A., Sreedhar, S., & Biswas, L. (2021). Prevalence of high‐risk HPV and its genotypes−Implications in the choice of prophylactic HPV vaccine. Journal of Medical Virology, 93(8), 5188‐5192. https://doi.org/10.1002/jmv.27015

Tarkoma, S., Alghnam, S., & Howell, M. D. (2020). Fighting pandemics with digital epidemiology. EClinicalMedicine, 26(100512), 100512. https://doi.org/10.1016/j.eclinm.2020.100512

Tatar, M., Faraji, M. R., Montazeri Shoorekchali, J., Pagán, J. A., & Wilson, F. A. (2021). The role of good governance in the race for global vaccination during the COVID-19 pandemic. Scientific Reports, 11(1). https://doi.org/10.1038/s41598-021-01831-0

The Microbiome and Cancer. (2021). In Gut Feelings (pp. 273‐290). The MIT Press.

Tian, T., Song, C., Jiang, L., Dai, J., Lin, Y., Xu, X., Yu, C., Ge, Z., Ding, Y., Wen, Y., Liu, B., Shao, Y., Shi, P., Zhu, C., Liu, Y., Jing, S., Wang, Z., Hu, Z., & Li, J. (2020). Hepatitis B virus infection and the risk of cancer among the Chinese population. International Journal of Cancer. Journal International Du Cancer, 147(11), 3075‐3084. https://doi.org/10.1002/ijc.33130

Tornesello, M. L., Annunziata, C., Tornesello, A. L., Buonaguro, L., & Buonaguro, F. M. (2018). Human oncoviruses and p53 tumor suppressor pathway deregulation at the origin of human cancers. Cancers, 10(7), 213. https://doi.org/10.3390/cancers10070213

Tsujimoto, H., Kobayashi, M., Sugasawa, H., Ono, S., Kishi, Y., & Ueno, H. (2021). Potential mechanisms of tumor progression associated with postoperative infectious complications. Cancer Metastasis Reviews, 40(1), 285‐296. https://doi.org/10.1007/s10555-020-09945-z

Tzartzeva, K., Obi, J., Rich, N. E., Parikh, N. D., Marrero, J. A., Yopp, A., Waljee, A. K., & Singal, A. G. (2018). Surveillance imaging and alpha fetoprotein for early detection of hepatocellular carcinoma in patients with cirrhosis: A meta-analysis. Gastroenterology, 154(6), 1706-1718.e1. https://doi.org/10.1053/j.gastro.2018.01.064

Van Dyne, E. A., Henley, S. J., Saraiya, M., Thomas, C. C., Markowitz, L. E., & Benard, V. B. (2018). Trends in human Papillomavirus‐associated cancers − United States, 1999‐2015. MMWR. Morbidity and Mortality Weekly Report, 67(33), 918‐924. https://doi.org/10.15585/mmwr.mm6733a2

van Elsland, D., & Neefjes, J. (2018). Bacterial infections and cancer. EMBO Reports, 19(11). https://doi.org/10.15252/embr.201846632

van Senten, J. R., Fan, T. S., Siderius, M., & Smit, M. J. (2020). Viral G protein-coupled receptors as modulators of cancer hallmarks. Pharmacological Research: The Official Journal of the Italian Pharmacological Society, 156(104804), 104804. https://doi.org/10.1016/j.phrs.2020.104804

Venerito, M., Vasapolli, R., Rokkas, T., & Malfertheiner, P. (2018). Gastric cancer: epidemiology, prevention, and therapy. Helicobacter, 23(S1). https://doi.org/10.1111/hel.12518

Volesky, K. D., El-Zein, M., Franco, E. L., Brenner, D. R., Friedenreich, C. M., & Ruan, Y. (2019). Cancers attributable to infections in Canada. Preventive Medicine, 122, 109‐117. https://doi.org/10.1016/j.ypmed.2019.03.035

Wandeler, G., Mauron, E., Atkinson, A., Dufour, J.-F., Kraus, D., Reiss, P., Peters, L., Dabis, F., Fehr, J., Bernasconi, E., van der Valk, M., Smit, C., Gjærde, L. K., Rockstroh, J., Neau, D., Bonnet, F., & Rauch, A. (2019). Incidence of hepatocellular carcinoma in HIV/HBV-coinfected patients on tenofovir therapy: Relevance for screening strategies. Journal of Hepatology, 71(2), 274‐280. https://doi.org/10.1016/j.jhep.2019.03.032

Wang, Y., Wang, M., Wu, H.-X., & Xu, R.-H. (2021). Advancing to the era of cancer immunotherapy. Cancer Communications (London, England), 41(9), 803‐829. https://doi.org/10.1002/cac2.12178

Whitford, K., Liu, B., Micallef, J., Yin, J. K., Macartney, K., Van Damme, P., & Kaldor, J. M. (2018). Long-term impact of infant immunization on hepatitis B prevalence: a systematic review and meta-analysis. Bulletin of the World Health Organization, 96(7), 484‐497. https://doi.org/10.2471/blt.17.205153

Zaanan, A., & Taieb, J. (2019). How to better select patients with advanced gastric cancer for immunotherapy. Translational Gastroenterology and Hepatology, 4, 6‐6. https://doi.org/10.21037/tgh.2019.01.06

Zhang, J., Zhao, Y., Dai, Y., Dang, L., Ma, L., Yang, C., Li, Y., Kong, L., Wei, L., Zhang, S., Liu, J., Xi, M., Chen, L., Duan, X., Xiao, Q., Abulizi, G., Zhang, G., Hong, Y., Gao, X., … Lang, J. (2021). Effectiveness of high-risk human Papillomavirus testing for cervical cancer screening in China: A multicenter, open-label, randomized clinical trial. JAMA Oncology, 7(2), 263. https://doi.org/10.1001/jamaoncol.2020.6575

Zhang, L., Zhao, Y., Tu, Q., Xue, X., Zhu, X., & Zhao, K.-N. (2021). The roles of programmed cell death ligand-1/ programmed cell death-1 (PD-L1/PD-1) in HPV-induced cervical cancer and potential for their use in blockade therapy. Current Medicinal Chemistry, 28(5), 893‐909. https://doi.org/10.2174/0929867327666200128105459

Zhang, X., Guan, L., Tian, H., Zeng, Z., Chen, J., Huang, D., Sun, J., Guo, J., Cui, H., & Li, Y. (2021). Risk factors and prevention of viral hepatitis-related hepatocellular carcinoma. Frontiers in Oncology, 11. https://doi.org/10.3389/fonc.2021.686962

Zhao, P., Malik, S., & Xing, S. (2021). Epigenetic Mechanisms Involved in HCV-Induced Hepatocellular Carcinoma (HCC). Frontiers in Oncology, 11. https://doi.org/10.3389/fonc.2021.677926

zur Hausen, H. (2009). The search for infectious causes of human cancers: Where and why. Virology, 392(1), 1‐10. https://doi.org/10.1016/j.virol.2009.06.001