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Dendritic Cell Therapy to Improve Cancer Outcomes. Recent Insights: A Narrative Review

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Abstract

Since long surgical excision of the tumors, followed by anti-cancer therapy, and irradiation were the basic tenets of management of all malignancies. Recently, Dendritic Cells (DCs) therapy has appeared on the horizon as a sparkling star in the management of cancer by way of Immunotherapy. DCs are essential cells that protect the human body through effective T cell actions against tumor antigens. All electronic databases for English language literature were searched which included Pub Med, Scopus, Web of Science, EBSCO Cumulative Index to Allied Health Literature, and Cochrane Central with key words of cancer, immunotherapy, dendritic cell vaccines. Our review scrutinizes salient features of how DCs form the basis of the adaptive natural immunity and play a central role in neutralizing cancer cells through T-cell responses against cancer antigens. Reports indicate that DCs actively limit tumor growth and are also involved in interfering with metastasis growth. This review aims to elucidate the benefits of DC therapy in various tumors critically.

Keywords

Dendritic Cells, Dendritic Cell Vaccine, Cancer Immunotherapy, Outcome

1. Introduction

The most common malignancies in Indian women is reported to be of breast, cervical, and ovarian tissue. Breast and cervical cancers make up 40% of female cases.

While cervical cancer is largely linked to infections such as human papillomavirus (HPV), breast and ovarian cancers are often influenced by hormonal factors. Rising cases of these hormone-related cancers are also associated with lifestyle shifts, including later pregnancies, reduced breastfeeding, obesity, and sedentary habits.

For men, oral, lung, and prostate cancers dominate. Tobacco drives 40% of preventable cancers, mainly oral and lung. So what is going on in India? Is it an earlier diagnosis for women? Are men's cancers more aggressive, or is it that habits such as smoking and chewing tobacco drag down their outcomes? Or does the answer lie in differences in access, awareness, and treatment between genders?

Cancer mortality in India is a significant public health issue, with around 916,827 deaths estimated in 2022, or approximately 3 out of 5 people diagnosed. The age-standardized cancer mortality rate in India is lower than the global average, but the rate of mortality is increasing due to factors like lifestyle changes, Westernization, and late-stage diagnosis resulting from poor awareness and screening rates. The highest cancer mortalities in men include tongue, lung, and oral cancers, while in women, the most fatal cancers are typically breast, cervical, and esophageal cancers. While doing his fellowship at Rockefeller University, Ralph M Steinman in 1973 discovered Dendritic cells (DCs) and observed these rare, star-like cells in mouse spleen cultures [1]. Dr Steinman called these cells as dendritic cells and reported that DCs capture and deliver the tumor antigens to T-lymphocytes for neutralization [2]. Immunotherapy and individualized treatment based on DCs have increasing important role in oncology treatments and has become, important type of therapy in recent years [3].

The objective of this review is to provide recent insights in the development of DCs and the role they play in the treatment of common cancers.

2. Material and Methods

The relevent electronic databases for English language literature was searched between January 2010 and July 2025 which included Pub Med, Scopus, Web of Science, EBSCO Cumulative Index, Web of Science, and Cochrane Central with key words of cancer, immunotherapy, dendritic cell vaccines. Only full papers were included for the study and excluded from the analysis were all other publications. Data was extracted based on the inclusion criteria related to the six common tumors (**Figure 1**).

3. Perception of Dendritic Cell Vaccines

Even though DCs were identified in 1973 but the first clinical trial was reported in 1995, and since then, many clinical trials have been conducted and DCs have been shown to be very effective in presenting the cancer antigens to T cells to neutralize them. By 2024, ninety-eight studies were conducted, indicating the use of more than one thousand DC vaccines in over 12 different malignant tumors. Different methodologies were used to isolate, mature DCs in vitro using patients'

autologous peripheral blood. No serious complications were reported, and efficacy in the majority of the human trials was reported.

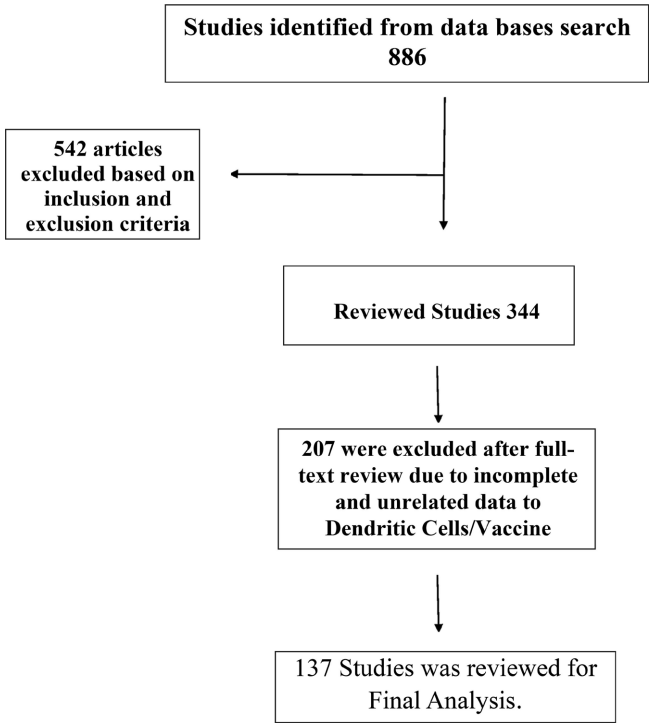

Figure 1. PRISMA flow chart of the review.

3.1. Sources of DCs

The origin of Dendritic cells (DCs) is progenitors from the bone marrow through hematopoiesis, a highly regulated, organized process involving multiple cellular and molecular levels. And are released into the blood and tissues, as immature dendritic cells, which differentiate into various DC progenitor cells. The main source of hematopoietic stem cells (HSCs) and common myeloid progenitors (CMPs), which are the ultimate precursors to all dendritic cells [4]. Three different subsets of DCs have been described: Conventional Type I cDC (cDC1), type 2 cDC (cDC2), and plasmacytoid DC (pDC) [5]-[7].

Immature DCs are released from bone marrow through hematopoiesis, a highly regulated, process involving multiple cellular and molecular levels, and they are released which later differentiate into various DC progenitor cells. The main source of hematopoietic stem cells (HSCs) and common myeloid progenitors (CMPs), which are the ultimate precursors to all dendritic cells [3]. DCs are also derived from monocyte precursors and are found in many peripheral tissues, especially those exposed to the external surroundings. The released DCs are first immature cells and develop into mature cells to settle in the bloodstream and various tissues. Dendritic cells (DCs) require 24 to 48 hours to mature, but under some circumstances, dendritic cells are believed to circulate and replenish over a period of days to weeks.

3.2. Mechanism of Action

DCs are very important in the protection of the human body from external sources, such as microbes like viruses, bacteria, and fungi, which are transmitted from contaminated air, water, food, surfaces, or direct contact with an infected person, and internal sources, like cancer antigens. In the first instance, DCs identify the tumor antigens and produce cytokines to alert the immune system and trigger other innate cells to confer protection. Secondly, equipped with distinctive cellular features, DCs effectively capture, process, and present antigens to T cells and, at the same time, provide costimulatory signals and secrete cytokines, which thereby direct naive T cells to either reproduce and transform into active cells. Under the influence of DCs, T lymphocytes trigger specific immune reactions [8]. In the innate immunity, Plasmacytoid dendritic cells (pDCs), which also originate from in the bone marrow, with their development involving both myeloid and lymphoid progenitors. Once in contact, viral nucleic acids produce enormous quantity of type I interferon (IFN-I), which inhibits viral replication and activates other immune cells, providing a rapid initial barrier [9]. Activated pDCs produce Type I IFN which activates Natural Killer (NK), B cells, and cDCs [10]. DCs initiate an immune response against cancer by capturing tumor antigens and presenting them to T cells in lymph nodes, activating them to kill cancer cells [11]. DCs play a paramount role in the identification of tumor antigens and their capture from the CD8, T cell activity against tumors [12] [13]. Immature DCs penetrate the tumor microenvironment, where they capture or stress tumor cells. It was suggested that dying cancer cells, which release ATP and heat-shock proteins (HSPs), activate the DCs. Mature DCs with the tumor antigens move to the regional lymph nodes, where the T cells terminate the cancer cells. The DCs are not always active against tumor antigens, as the tumor microenvironment (TME) can impair DCs' function by inhibiting their maturation, which allows tumors to progress. This is achieved by tumor cells by secreting inhibitory molecules, cytokines that inhibit DCs' activity. Secondly, the TME can recruit immunosuppressive cells, which in turn will inhibit activity, and lastly, pro-inflammatory cytokines may be absent in the TME, which is essential for DCs maturation and activation.

3.3. Therapeutic Strategies using DCs

As DCs stimulate the body's defense mechanism by starting the action of natural immunity to neutralize cancer cells, this is a good option for enhancing immunotherapy. The strategy to restore anti-tumor immunity is either to stimulate the DCs present in the body to early mature, or provide mature DCs cultured in vitro and inject them. A Dendritic cell vaccine is developed in vitro by collecting a patient's blood, isolating monocytes (immature immune cells), and culturing them to become mature dendritic cells. After maturation the activated DCs which are the antigen-loaded are infused back into the circulation which stimulates T-cell response to cancer cells and kills the tumor cells [14]-[17] (**Figure 2**). In spite of many clinical trials, the treatment using the approach of DCs remains to be stand-

ardized as an adjuvant therapy in many malignant tumors. Moreover, the dosage also needs to be assimilated. At present, DCs (0.3 × 1 million cells to 200 × million cells per injection), the vaccination is given every 3 weeks up to 10 injections. The route of injection varies from accessible intra-tumoral and lymph nodes to achieve the most robust and immune response. The other routes are subcutaneous and intravenous [18].

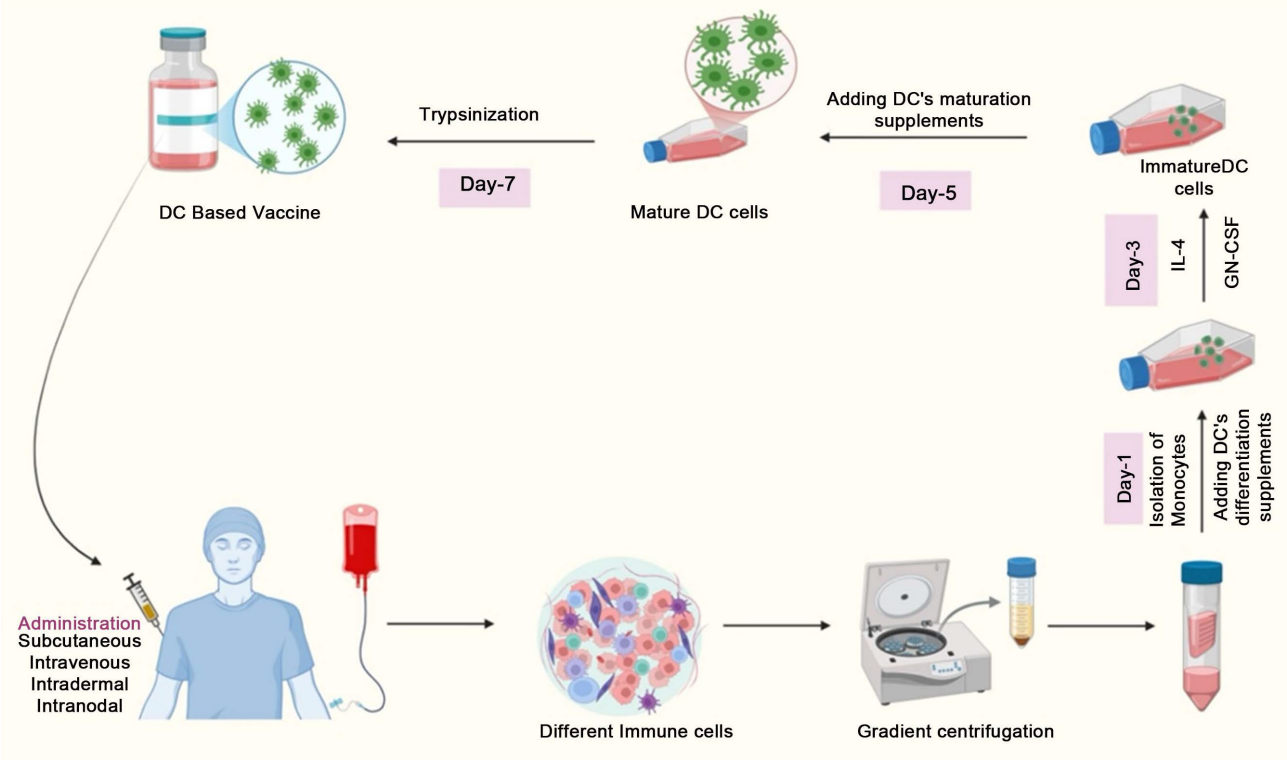

Figure 2. DCs vaccination is prepared using different methods. One by isolating the monocytes from the peripheral blood samples using gradient centrifugation. DC differentiation supplement is added on day 1 and placed in culture in polystyrene flasks at 1×10^6 cells/mL at 37˚C, with 5% CO_2. On day 3, IL-4 and GM-CS were added to develop immature DCs. On day 5, DC mature supplements are added. On day 7, DCs are mature and tryptinized and frozen at −80 degrees C till ready for injection.

4. DCs Vaccine as Current Adjuvant Therapy for Cancer

4.1. Prostate Cancer (PC)

The therapy for patients with prostate cancer is surgical removal of the prostate, irradiation, and chemotherapies like hormone therapy and chemotherapy. Early diagnosis and anti-androgen therapy give good results, but for advanced prostatic cancer, the results are usually not favorable. In 2010, the US FDA approved the first DCs vaccine therapy as Immunotherapy. Immunotherapy using DCs is for tumors that are asymptomatic or minimally symptomatic metastatic post removal of testes-resistant prostate cancer. Over 43.0% of all prostatic cancers are diagnosed late, once they are at the metastatic stage, making treatment difficult and palliative. The DC vaccine marketed as Sipuleucel-T works by trigger the patient's own immune mechanism to attack prostate cancer cells. Cancer of the prostate is

the second most common cancer in men with a high morbidity and mortality [19]. It is expected that in South America, prostate cancer will rise by 82.3% by 2040 [20]. The highest incidence of prostate cancers in India is around 11.8 per 100,000 and is on the rise yearly [21]. The standard of care for metastatic prostate cancer is anti-androgen therapy (ADT), also called androgen ablation therapy or androgen suppression therapy, which reduces the levels of androgen hormones by using drugs or surgery [22]. With this aggressive therapy, many patients relapse and become incurable with a bad prognosis [23]. In these patients, there are no other options but to institute Immunotherapy in the form of DCs. Westdorp *et al.* (2019) [24] used DCs in patients with post testicular removal resistant prostate cancer. The primary endpoint was the response to immunotherapy after DC vaccination, which was monitored in peripheral blood and in T cell cultures of biopsies. The secondary endpoints were safety, feasibility, radiographic progression-free survival (rPFS), and overall survival. Stable disease that persisted for >6 months was seen in 57%. Median rPFS for all patients was 9.5 months (range: 3.2 - 24.8 months). It was concluded that immune system activation with peripheral blood derived DCs was safe and feasible to induce T cells response to neutralize cancer antigens, thereby preventing progression. In 2022, another Phase II study with an adjuvant dendritic cell vaccine was given 12 weeks post prostatectomy, high-risk PC, and undetectable PSA received DC vaccinations for 3 years or until biochemical relapse (BCR). DCs were given, including an additional booster dose monthly during the first year, and every third month for the next 24 months. Fifty-five percent of patients were BCR-free over a median of 96 months (range: 84 - 99). Four patients developed BCR during DCs treatment, and five after the vaccination period. Patients who developed BCR remained stable disease within a median of 99 months [25]. Recently, He *et al.* (2024) [26] found the DC vaccines gave favorable safety profiles with good clinical outcomes, BCR (42% - 73%), overall survival durations (17.7 - 33.8 months), and a reduced two-year mortality rate of 0% - 12.5%.

4.2. Conclusion

DC vaccines for prostate cancer have shown great promise in improved disease-free survival. The DC Vaccine has proved to be an efficacious immunotherapy, demonstrating the safety of the vaccine with minimal side effects. Reports have shown that in subjects with high risk of PC, the adjuvant DC vaccines after prostatectomy with or without chemotherapy are safe and efficacious in terms of limited adverse effects, reducing PSA levels by 50%, BCR-free survival, which reduces the morbidity, and overall survival durations, and reduced mortality rate. Standardized protocols, doses, and routes are needed to adjust for individual patients, aiming for a lasting antitumor activity.

5. Breast Cancer (BC)

Breast cancer is the most common cancer in women worldwide, with approxi-

mately 2.3 million (11.7%) cases diagnosed in 2022, and it is commoner than lung (11.4%) and prostate (7.3%). Breast cancer is rising in the World, with cases in America is expected to reach 400,000 by the year 2040 [26]. The recommended treatment of BC is excision of the tumor, radiotherapy, and chemotherapy as required [27]. Breast cancer caused an estimated 670,000 deaths globally in 2022 [28]. In India, the incidence is not low, and it is reaching 14% of all cancer cases and about 11% of all deaths [29].

Dendritic cell vaccines has been reported to be effective in regulating the immune response of BC. A comparative phase I/II trial was performed with BC patients treated with neoadjuvant chemotherapy, with one control group, and the second group received DCs to assess the safety and efficacy of DCs administered to BC patients [30]. The results showed that the DC vaccine along with chemotherapy was effective. Santisteban *et al.* (2021) [31] evaluated all the parameters of the DC vaccine to Neoadjuvant Chemotherapy (NAC) in HER2-negative BC patients. The study compared subjects with the DC Vaccine with the control group. The study confirmed that this combination increases the pathologic complete response (pCR) rate. Other relevant studies have confirmed that DC vaccine when given early can reduce the size of the tumor, thus decreasing the morbidity and mortality [32]-[36].

Conclusion

In the BC ecology, the internal body habitat inhibits differentiation of DC precursors by factors that are released by tumor cells, preventing the DCs from normally maturing and becoming active. External mature DC vaccines are the only way to provide DCs, is a safe and effective Immuno-therapy for BC. Additional treatment with DCs prolongs the survival of patients.

6. Glioblastoma (GBM)

Glioblastoma, previously called glioblastoma multiforme (GBM), is one of the most truculent and common malignant tumors of the central nervous system with a poor prognosis [37]-[39]. The incidence reaches up to 50 per million persons, and the incidence is increasing in the world [40]. Glioblastomas are thought to arise from astrocytes [41] and are the commonest malignancy of making up over 50% of all gliomas and 17% of all primary tumors of the central nervous system [42]. Recommended treatment usually includes all the facets of cancer therapy [43]. With chemotherapy, many drugs are tried, but the cancer almost always recurs as tumor cells are resistant to standard therapies. The average time of survival after diagnosis is less than a year, and only <10% of patients survive not more than 5 years.

Immunotherapy using DC vaccine brought some change in the morbidity and mortality of patients with GBM. By March 2023, over 75 studies were performed using DCs for patients with GBM, and six meta-analyses reported notable recovery in survival due to DC vaccines. Another report of 3619 patients treated with

recommended care and DCs, found patients living statistically longer [44]-[47]. Moreover, in newly diagnosed glioblastoma, the used of DCs showed better progression-free survival [48]. These studies represent a new breakthrough in the management using Immunotherapy in the treatment of GBM, even though more studies will be required in the future to standardize DC treatment.

7. Lung Cancer (LC)

Lung cancer is a crucial healthcare in India, with increasing incidence, delay in diagnosis, and a high mortality rate. It appears the incidence of LC is on the rise in India from 63,708 cases (2015) to 81,219 cases (2025) [49]. The compounding factors are driven by the same factors as smoking tobacco. (cigarettes, bidis, hookahs), air pollution, household smoke from biomass fuel, and occupational exposure to substances like asbestos. For non-smokers, the risk is significantly increased by passive smoking as well. In India, patients present with LC usually with metastasis in 44% of males and 47.6% of women [50]. In US it is estimated that lung cancer for 2025 are about quarter a million new cases of lung cancer with similar frequency in both sexes and approximately mortality of (64,000 in men and 60,000 in women). Lung cancer treatment options are usually multi-modality which include from surgery, chemo, cyotherapy to electrotherapy.

The mortality rate for lung cancer with metastasis is abysmal, with a 30-month chance of survival of 27% for Stage IV (distant metastasis) lung cancer patients [51]. At present the poor survival rates, is due to different methods of treatment practiced. Dendritic cell vaccines have appeared as an emerging therapy for advanced non-small cell lung cancer (NSCLC). With present improvements in the treatment, the prognosis remains bleak. Some chemotherapy drugs do induce immune induced cell death and cause lymphoablation, decrease immune suppressor cells, thereby increasing T-cell response to the tumor cells. Drugs like immune checkpoint inhibitors, such as pembrolizumab, nivolumab, bevacizumab, and tarlatamab, help the body's innate immunity to fight cancer cells. Even with these drugs in use, the long-term survival is dismal. At present, DC vaccines are recommended as adjuvant treatment of NSCLC [52]-[54].

Hu *et al.* (2014) [55] studied all the parameters of DCs isolated from patients as salvage therapy with adenocarcinoma and showed promising results of overall survival. Takahashi *et al.* (2016) [56] reported after a multi-site clinical trial in which they administered subcutaneous DCs every two weeks, at multiple sites of adenopathy and DC vaccines provided clinical benefit for patients with breast carcinoma. Zemanova *et al.* (2021) [57] DCVAC/LuCa was given intradermally at 21 - 40 days gap, with a maximal of fifteen injections. The combination of carboplatin, paclitaxel, and DCVAC/LuCa exhibited an overall survival of 16 months, compared to 12 months in the carboplatin, paclitaxel arm. Zhong *et al.* (2022) [58] after evaluating the safety and efficacy of dendritic cell vaccines for lung cancer (DCVAC/LuCa), human non-small cell lung cancer cells, derived from a lung cancer obtained from a patient prior to therapy (H522 cell lines), combined with

chemotherapy for advanced non-squamous cell carcinoma. After receiving 2 doses of chemotherapy, patients received 15 injections by subcutaneous route of DCs. At 2 years, 52.57% patients survived and disease-free survival was 8.0 months, suggesting encouraging effectiveness.

Conclusion

In the past decade DC vaccines has positioned itself as an important treatment modality in malignancies and current immunotherapy approaches support DC vaccines as an important way of giving supportive therapy to standard of care in improving clinical performance of DC-based treatments and providing increased overall survival patients. The future of cancer therapy using DCs depends on improving patients survival by combining the standard of care. DC vaccine based treatment has already been integrated with other methods of cancer treatments, such as chemotherapy, radiotherapy, and immune checkpoint inhibitors.

8. Leukemias

Leukemia is a serious global malignant condition, with over 474,000 new patients in 2020 and approximately 311,000 deaths worldwide, making it the within the top 15 most common cancer globally. The World frequency of leukemia is rising, It is the most prevalent cancer in children under five but also affects adults, particularly in their 60s and 70s [59]. Leukemia is a significant healthcare issue in India, ranking as the country's most common type of blood cancer, with an estimated 100,000 people diagnosed annually. In the United States, leukemia became the 6th most common cause of cancer deaths in males between 2018 and 2022 and in the last 30 years, making up around seven percent of all cancers [60]. The management of leukemia depends on leukemia type, stage, patient's age, and overall health. Leukemia management involves a multidisciplinary approach and includes treatments such as therapy, targeted therato radiation and bone marrow transplants, often in combination. In the context of achieving complete hematologic remission (CR), in the last 40 years, the prognosis for this traditional upfront treatment has remained distressing, even though many new drugs have been studied in clinical trials. The current treatment includes regular chemotherapy, anthracyclines, and cytarabine [61]. Currently, drug induced immunotherapy in vogue but the main disadvantage of these targeted therapies is that they cause hematological toxicity, thereby terminating the treatment [62] [63].

Lau *et al.* (2016) [64] reported that maturation of cDC is inhibited in active AML due to cytogenetic aberrations, which may induce an MDSC-like phenotype in DC precursors and prevent the DCs to mature. Some other studies confirmed this dysfunction of DCs in CML in vitro studies [65] [66]. But providing externally mature DCs will override the maturation of the circulating immature DCs. Clinical trials have shown that in vitro activation of DCs and injection have improved the survival of patients [67].

Conclusion

Twenty-five years ago, Fujii *et al.* (1999) [68] injected a DC vaccine in a leukemic patient, and reported autologous leukemic DCs, isolated from peripheral blood was successful in treating CML. Since that case, clinical trials have given strong evidence that in patients with leukemia, DC vaccination can avert or hinder relapse in AML [69]-[71], and Immunotherapy using DC vaccine has emerged as an potent modality to stimulate patients' own immune systems, which is inhibited due to cancer antigens [72]-[74]. At present, DC vaccines have assumed an important role in stopping disease p rogression in advanced stages [75]. DCs have been recommended a favourable way to treat as DCs stimulate CD8+ T lymphocytes, NK, and NKT cells, which are responsible for the elimination of cancer cells and as an adjunct to boost T cells in AML [70] [76]-[78]. Another recommendation is to combine DCs with CAR-T cell therapy. We need clinical trials to confirm this double strategy, as the evidence suggests that DCs improves the prognosis of these patients in the prevention of relapses and overall survival.

9. Cervical Cancer

Cervical cancer remains in the top 5 common malignancy to affect women universally and in India, ranking as the second most common cancer among women. The reported incidence of cervical cancer is 11.2 per 100,000 which is higher than the rest of the world [79]. Human Papillomavirus (HPV) vaccination and enthusiastic screening programs are required to decrease the occurrence of cervical cancer. However, challenges remain in determining whether the benefits of the available HPV vaccines outweigh the risks. Many physicians and healthcare professionals are concerned with the safety [80]. The standard of care for cervical cancer treatment varies depending on the stage at which the patients present. The principle is that surgery is the option in early stages, and chemotherapy and radiation will follow patients who present late. Immunotherapy offers hope in advanced recurrent disease or metastatic disease. With the recent treatment recommendations in the treatment of cervical cancer in patients with locally advanced stage, 50% present with recurrence within the 1st two years [81]. Added to that, the prognosis of node-positive cervical cancers is poor and requires aggressive management, which may improve the outcome. Even after successful surgery, cervical cancer can return in 20% of patients within five years when lymph nodes appear clear, rising to 50% when cancer has spread to distant lymph nodes.

The initial study of Cervical cancer and DCs using patients' monocyte-derived DCs were pulsed with recombinant HPV16 E7 or HPV18 E7 oncoproteins [82]. The treatment was well-tolerated in all patients, and seventy-five percent of patients were found to be significantly immunocompromised. In patients in the early stage of cervical cancer (stages 1B and IIA) after surgery and chemotherapy, the DC vaccine can prevent recurrence and protect patients for the long term by increasing the body's immune mechanism against cancer antigens. The importance of DC vaccines is that they are safe with no untoward effects. Satin *et al.*

(2008) [83] reported after a Phase I trial in subjects who received mature autologous DCs treated with human papillomavirus 16/18 E7 oncoprotein. Patients who received Dendritic cell vaccines after radical surgery remained cancer-free during follow-up. They concluded that HPV E7-loaded DC vaccine is safe for early stages of cervical cancer sufferers and should be used in patients who are at serious risk of relapse.

At present, the management of cervical cancer depends on which stage the patients present. Based on surgery, radiotherapy/and chemotherapy, the recurrence of advanced tumors with present protocols of management reaches over 20%. The combination chemotherapy currently practiced for advanced cervical cancer, is only used for remission purposes [84]-[86]. Many immunomodulatory therapies are undergoing clinical trials [87]-[89]. Under this conundrum new therapies are required for all types and stages of cervical cancer. At this point, the DC vaccine enters the management of cervical cancer which shows improved outcome. DC vaccines are effective in all stages and also could stop the recurrences in the advanced stage of cervical cancer [90].

Conclusion

The DC-based HPV vaccine has surfaced as a prospective agent for cancer caused by HPV. DC vaccines work as natural adjuvants to increase the potency of specific therapies against all malignancies, but they also activate T-cells to counteract the cancer antigens. Autologous DC vaccines have emerged as a major breakthrough in the era of personalized medicine, where an individualized procedure is used to neutralize cancer cells by activating tumor-infiltrating lymphocytes (TILs) that penetrate all malignant tissues thereby stopping further tumor growth. With the new era of using immune therapy in cancer, DC vaccines have proved to be powerful method of treating cervical cancer, with long period of patient progression-free survival. DC vaccines are ideal for use in cervical cancer in stages 0 to 4. Large number of patients with advanced cervical cancer fail to respond to the combination therapy of surgery and chemotherapy or have limited benefits; such patients need to further enhance the survival by using DC vaccines.

10. Colorectal Cancer

Colorectal cancer (CRC)is a cancer of the colon and rectum that starts as uncontrolled cell growth, often from non-cancerous polyps, and can spread to other parts of the body. Early cases can begin as non-cancerous polyps. It is suggested that about 80% of colorectal cancer occur in people without genetic risk [91] [92]. Older age, male sex, lifestyle, a diet high in fats, elevated levels of bile acids, alcohol consumption, obesity, and smoking, which have been reported to increase the risk. It was reported that a family history of first-degree relatives has an increased risk of this malignancy. People suffering from inflammatory diseases like Crohn's disease and Ulcerative colitis are at heightened risk of developing colon cancer [93] [94]. CRC is the third leading cause of cancer death in the world, and its

incidence appears on the rise in industrialized nations. In India in 2022, 64,863 patients were diagnosed with CRC, with more than 50% of mortality, and it was suggested that the incidence of CRC is on the rise [95]. The mortality in developed countries is reported to be 12.8/100,000 among males and about 8.5/100,000 in females [96].

Surgery remains the first line of treatment in patients presenting at an early stage, but 25% of patients present when they already have metastasis [97]. Once metastasis is present, the treatment becomes multidisciplinary, with chemotherapy, targeted therapies, and radiotherapy [98]. Although cures are out of the ordinary in metastatic CRC, less than 20% beyond 5 years from diagnosis [99]. DC therapy is an emerging immunotherapy for colon cancer, as the DCs target and destroy cancer cells. DCs have a two-way action on the progression of CRC by acting as facilitators of T-cell commencement of immune responses against the tumour cells while also stopping cancer antigens, in the progression of the disease [100].

Conclusion

Present evidence supports the view that when matured DCs are injected in CRC causes increase in the 5-year survival rates [101]. Recently, Immune checkpoint inhibitors (ICI) came on the horizon, which is a type of immunotherapy. ICI blocks off signals on checkpoint proteins on T-cells, which enables T-cells to more efficaciously identify tumor cells and neutralize them. ICI drugs like Atezolizumab, Avelumab, Durvalumab, Ipilimumab, Nivolumab, and Relatlimab act by blocking signals that suppress the immune system and enhance the activity of DC vaccines and T-Cells to effectively eliminate cancer cells, thus improving the response to tumor tissue, thereby triggering a robust clinical outcome [71]. It is paramount to consider the timing of ICI infusions, as this can modify actions of DC vaccines. Santos *et al.* (2020) [102] showed that ICIs given prior to DC vaccination did not improve the expected cytotoxic T cell responses. Hence, DC vaccines should be given before any ICI treatment to get optimum results.

11. Tumor Microenvironment on DC Efficacy

Tumors have their own microenvironment (TME) made up of many cellular types such as fibroblasts, endothelial cells, and infiltrating leukocytes. Recent studies have shown that DCs can inhibit tumor growth and improve the quality of life and life span but on the other side tumor-associated leukocytes such as regulatory T cells or myeloid-derived suppressor cells (MDSCs), inhibitory molecules (PD-L1), promotes tumor growth by three known methods one by promoting angiogensis, second by inhibiting innate antitumor immune response and lastly by releasing immunosuppressive cytokines (IL-10) and metabolic factors which impairs DC function and prevents effective antigen presentation to T cells. The efficacy of DCs is also hindered by TME by suppressing the recruitment and maturation of the immature DCs released by the bone marrow, hence external sources

of mature DCs are more viable in suppressing the tumor growth and spread.

To overcome the TME effect of the DCs actions it was recommended that DC vaccines should be an adjuvant to the chemotherapy, radio, or targeted therapies which decreases the tumor buden and also to eliminate TME's immunosuppressive shield which act on DCs. Another recommended method is to modify DCs to resist cells of the TME.

This review has limitations, as we have looked into the most common tumors in the Indian subcontinent, but we have put forward the benefits of the DC vaccines in these common malignancies. DC vaccines are now available to be used in many cancers, which improve the disease-free survival and improve the quality of life. In conclusion, during the present era, cancer immunotherapies have increasingly become vital treatment options in support of the standard of care of surgery, chemotherapy, and radiotherapy treatment. DC cancer vaccines are an encouraging treatment method, using the patients' own immune system to fight tumors. These vaccines have the propensity to convey tumor-associated antigens to T cells, and in turn, T-cells can kill the cancer antigens. Infused DCs also stimulate Natural Killer (NK) cells, and the immune response is further enhanced. NK cells which are activated exudate cytokines that promote DCs' maturation, and matured DCs draw further DC progenitors and stimulate NK cells further, which in turn recruit naive T cells to act on cancer cells. The DC vaccine development has passed through different stages of development and reached the present stage where blood-derived DCs show stronger and better immune response, easier to isolate and culture with less toxicity than traditional cytotoxic therapies. To get better responses to DC vaccines, combining DC vaccines with ICIs has shown great promise in responses and improving clinical outcomes. While the results are promising, the application of DC-based vaccines should be a personalized, patient-based, and customized immunotherapy.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Steinman, R.M. and Cohn, Z.A. (1973) Identification of a Novel Cell Type in Peripheral Lymphoid Organs of Mice. *The Journal of Experimental Medicine*, **137**, 1142-1162. https://doi.org/10.1084/jem.137.5.1142

[2] Steinman, R.M. and Nussenzweig, M.C. (2002) Avoiding Horror Autotoxicus: The Importance of Dendritic Cells in Peripheral T Cell Tolerance. *Proceedings of the National Academy of Sciences*, **99**, 351-358. https://doi.org/10.1073/pnas.231606698

[3] Horn, L., Spigel, D.R., Vokes, E.E., Holgado, E., Ready, N., Steins, M., *et al.* (2017)

Nivolumab versus Docetaxel in Previously Treated Patients with Advanced Non–small-Cell Lung Cancer: Two-Year Outcomes from Two Randomized, Open-Label, Phase III Trials (CheckMate 017 and CheckMate 057). *Journal of Clinical Oncology*, **35**, 3924-3933. https://doi.org/10.1200/jco.2017.74.3062

[4] Steinman, R.M. and Witmer, M.D. (1978) Lymphoid Dendritic Cells Are Potent Stimulators of the Primary Mixed Leukocyte Reaction in Mice. *Proceedings of the National Academy of Sciences*, **75**, 5132-5136. https://doi.org/10.1073/pnas.75.10.5132

[5] Collin, M., McGovern, N. and Haniffa, M. (2013) Human Dendritic Cell Subsets. *Immunology*, **140**, 22-30. https://doi.org/10.1111/imm.12117

[6] See, P., Dutertre, C., Chen, J., Günther, P., McGovern, N., Irac, S.E., *et al.* (2017) Mapping the Human DC Lineage through the Integration of High-Dimensional Techniques. *Science*, **356**, eaag3009. https://doi.org/10.1126/science.aag3009

[7] Brown, C.C., Gudjonson, H., Pritykin, Y., Deep, D., Lavallée, V., Mendoza, A., *et al.* (2019) Transcriptional Basis of Mouse and Human Dendritic Cell Heterogeneity. *Cell*, **179**, 846-863.e24. https://doi.org/10.1016/j.cell.2019.09.035

[8] Gerhard, G.M., Bill, R., Messemaker, M., Klein, A.M. and Pittet, M.J. (2020) Tumor-infiltrating Dendritic Cell States Are Conserved across Solid Human Cancers. *Journal of Experimental Medicine*, **218**, e20200264. https://doi.org/10.1084/jem.20200264

[9] Chudnovskiy, A., Pasqual, G. and Victora, G.D. (2019) Studying Interactions between Dendritic Cells and T Cells *in Vivo*. *Current Opinion in Immunology*, **58**, 24-30. https://doi.org/10.1016/j.coi.2019.02.002

[10] Liu, K. (2016) Dendritic Cells. In: *Encyclopedia of Cell Biology*, Elsevier, 741-749. https://doi.org/10.1016/b978-0-12-394447-4.30111-0

[11] Merad, M., Sathe, P., Helft, J., Miller, J. and Mortha, A. (2013) The Dendritic Cell Lineage: Ontogeny and Function of Dendritic Cells and Their Subsets in the Steady State and the Inflamed Setting. *Annual Review of Immunology*, **31**, 563-604. https://doi.org/10.1146/annurev-immunol-020711-074950

[12] Chen, D.S. and Mellman, I. (2013) Oncology Meets Immunology: The Cancer-Immunity Cycle. *Immunity*, **39**, 1-10. https://doi.org/10.1016/j.immuni.2013.07.012

[13] Wu, R. and Murphy, K.M. (2022) DCs at the Center of Help: Origins and Evolution of the Three-Cell-Type Hypothesis. *Journal of Experimental Medicine*, **219**, e20211519. https://doi.org/10.1084/jem.20211519

[14] Mehrani, Y., Morovati, S., Keivan, F., Sarmadi, S., Shojaei, S., Forouzanpour, D., *et al.* (2025) Dendritic Cell-Based Cancer Vaccines: The Impact of Modulating Innate Lymphoid Cells on Anti-Tumor Efficacy. *Cells*, **14**, Article No. 812. https://doi.org/10.3390/cells14110812

[15] Duarte, A.d.S.S., Zangirolami, A.B., Santos, I., Niemann, F.S., Honma, H.N., Amaro, E.C., *et al.* (2024) Production of Dendritic Cell Vaccines Using Different Methods with Equivalent Results: Implications for Emerging Centers. *Hematology, Transfusion and Cell Therapy*, **46**, 30-35. https://doi.org/10.1016/j.htct.2022.11.006

[16] Palomares, F., Pina, A., Dakhaoui, H., Leiva-Castro, C., Munera-Rodriguez, A.M., Cejudo-Guillen, M., *et al.* (2024) Dendritic Cells as a Therapeutic Strategy in Acute Myeloid Leukemia: Vaccines. *Vaccines*, **12**, Article No. 165. https://doi.org/10.3390/vaccines12020165

[17] Kowalewicz-Kulbat, M., Ograczyk, E., Krawczyk, K., Rudnicka, W. and Fol, M. (2016) Type of Monocyte Immunomagnetic Separation Affects the Morphology of Monocyte-Derived Dendritic Cells, as Investigated by Scanning Electron Microscopy. *Jour-*

nal of Immunological Methods, **439**, 79-82. https://doi.org/10.1016/j.jim.2016.10.004

[18] Sosa Cuevas, E., Saas, P. and Aspord, C. (2023) Dendritic Cell Subsets in Melanoma: Pathophysiology, Clinical Prognosis and Therapeutic Exploitation. *Cancers*, **15**, Article No. 2206. https://doi.org/10.3390/cancers15082206

[19] Bergengren, O., Pekala, K.R., Matsoukas, K., Fainberg, J., Mungovan, S.F., Bratt, O., *et al.* (2023) 2022 Update on Prostate Cancer Epidemiology and Risk Factors—A Systematic Review. *European Urology*, **84**, 191-206. https://doi.org/10.1016/j.eururo.2023.04.021

[20] World Health Organization (2022) Global Health Estimates.

[21] Sankarapillai, J., Krishnan, S., Ramamoorthy, T., Sudarshan, K.L. and Mathur, P. (2024) Descriptive Epidemiology of Prostate Cancer in India, 2012-2019: Insights from the National Cancer Registry Programme. *Indian Journal of Urology*, **40**, 167-173. https://doi.org/10.4103/iju.iju_27_24

[22] Steinbach, C., Merchant, A., Zaharie, A., Horak, P., Marhold, M. and Krainer, M. (2022) Current Developments in Cellular Therapy for Castration Resistant Prostate Cancer: A Systematic Review of Clinical Studies. *Cancers*, **14**, Article No. 5719. https://doi.org/10.3390/cancers14225719

[23] Huang, F., Li, K., Shevach, J.W. and Wang, Q. (2025) Emerging Therapies to Overcome Antiandrogen Resistance and Beyond in Lethal Prostate Cancer. *Journal of the National Cancer Center*. https://doi.org/10.1016/j.jncc.2025.04.004

[24] Westdorp, H., Creemers, J.H.A., van Oort, I.M., Schreibelt, G., Gorris, M.A.J., Mehra, N., *et al.* (2019) Blood-Derived Dendritic Cell Vaccinations Induce Immune Responses That Correlate with Clinical Outcome in Patients with Chemo-Naive Castration-Resistant Prostate Cancer. *Journal for ImmunoTherapy of Cancer*, **7**, Article No. 302. https://doi.org/10.1186/s40425-019-0787-6

[25] Tryggestad, A.M.A., Axcrona, K., Axcrona, U., Bigalke, I., Brennhovd, B., Inderberg, E.M., *et al.* (2021) Long-Term First-in-Man Phase I/II Study of an Adjuvant Dendritic Cell Vaccine in Patients with High-risk Prostate Cancer after Radical Prostatectomy. *The Prostate*, **82**, 245-253. https://doi.org/10.1002/pros.24267

[26] Arzanova, E. and Mayrovitz, H.N. (2022) The Epidemiology of Breast Cancer. In: Mayrovitz, H.N., Ed., *Breast Cancer*, Exon Publications, 1-20. https://doi.org/10.36255/exon-publications-breast-cancer-epidemiology

[27] Ishiba, T., Aruga, T., Miyamoto, H., Ishihara, S., Nara, M., Adachi, M., *et al.* (2021) Short- and Long-Term Outcomes of Immediate Breast Reconstruction Surgery after Neoadjuvant Chemotherapy. *Surgery Today*, **52**, 129-136. https://doi.org/10.1007/s00595-021-02316-3

[28] Breast Cancer. https://www.who.int/news-room/fact-sheets/detail/breast-cancer

[29] International Agency for Research on Cancer. India Source: Globocan 2020. https://gco.iarc.fr/today/data/factsheets/populations/356-india-fact-sheets.pdf

[30] Bernal-Estévez, D.A., Ortíz Barbosa, M.A., Ortíz-Montero, P., Cifuentes, C., Sánchez, R. and Parra-López, C.A. (2021) Autologous Dendritic Cells in Combination with Chemotherapy Restore Responsiveness of T Cells in Breast Cancer Patients: A Single-Arm Phase I/II Trial. *Frontiers in Immunology*, **12**, Article ID: 669965. https://doi.org/10.3389/fimmu.2021.669965

[31] Santisteban, M., Solans, B.P., Hato, L., Urrizola, A., Mejías, L.D., Salgado, E., *et al.* (2021) Final Results Regarding the Addition of Dendritic Cell Vaccines to Neoadjuvant Chemotherapy in Early HER2-Negative Breast Cancer Patients: Clinical and Translational Analysis. *Therapeutic Advances in Medical Oncology*, **13**. https://doi.org/10.1177/17588359211064653

[32] Soliman, H., Aldrich, A., Abdo, N., Han, H., Soyano, A., Costa, R., *et al.* (2025) A Pilot Study Incorporating HER2-Directed Dendritic Cells into Neoadjuvant Therapy of Early Stage HER2+ER-Breast Cancer. *NPJ Breast Cancer*, **11**, Article No. 29. https://doi.org/10.1038/s41523-025-00742-x

[33] Kodumudi, K.N., Ramamoorthi, G., Snyder, C., Basu, A., Jia, Y., Awshah, S., *et al.* (2019) Sequential Anti-PD1 Therapy Following Dendritic Cell Vaccination Improves Survival in a HER2 Mammary Carcinoma Model and Identifies a Critical Role for CD4 T Cells in Mediating the Response. *Frontiers in Immunology*, **10**, Article No. 1939. https://doi.org/10.3389/fimmu.2019.01939

[34] Maeng, H.M., Moore, B.N., Bagheri, H., Steinberg, S.M., Inglefield, J., Dunham, K., *et al.* (2021) Phase I Clinical Trial of an Autologous Dendritic Cell Vaccine against HER2 Shows Safety and Preliminary Clinical Efficacy. *Frontiers in Oncology*, **11**, Article ID: 789078. https://doi.org/10.3389/fonc.2021.789078

[35] Lowenfeld, L., Mick, R., Datta, J., Xu, S., Fitzpatrick, E., Fisher, C.S., *et al.* (2017) Dendritic Cell Vaccination Enhances Immune Responses and Induces Regression of Her2pos DCIS Independent of Route: Results of Randomized Selection Design Trial. *Clinical Cancer Research*, **23**, 2961-2971. https://doi.org/10.1158/1078-0432.ccr-16-1924

[36] Lowenfeld, L., Zaheer, S., Oechsle, C., Fracol, M., Datta, J., Xu, S., *et al.* (2016) Addition of Anti-Estrogen Therapy to Anti-HER2 Dendritic Cell Vaccination Improves Regional Nodal Immune Response and Pathologic Complete Response Rate in Patients with ER^{pos}/$HER2^{pos}$ Early Breast Cancer. *OncoImmunology*, **6**, e1207032. https://doi.org/10.1080/2162402x.2016.1207032

[37] Delgado-Martín, B. and Medina, M.Á. (2020) Advances in the Knowledge of the Molecular Biology of Glioblastoma and Its Impact in Patient Diagnosis, Stratification, and Treatment. *Advanced Science*, **7**, Article ID: 1902971. https://doi.org/10.1002/advs.201902971

[38] Tan, A.C., Ashley, D.M., López, G.Y., Malinzak, M., Friedman, H.S. and Khasraw, M. (2020) Management of Glioblastoma: State of the Art and Future Directions. *CA*: *A Cancer Journal for Clinicians*, **70**, 299-312. https://doi.org/10.3322/caac.21613

[39] Grochans, S., Cybulska, A.M., Simińska, D., Korbecki, J., Kojder, K., Chlubek, D., *et al.* (2022) Epidemiology of Glioblastoma Multiforme-Literature Review. *Cancers*, **14**, Article No. 2412. https://doi.org/10.3390/cancers14102412

[40] Grech, N., Dalli, T., Mizzi, S., Meilak, L., Calleja, N. and Zrinzo, A. (2020) Rising Incidence of Glioblastoma Multiforme in a Well-Defined Population. *Cureus*, **12**, e8195. https://doi.org/10.7759/cureus.8195

[41] Faust Akl, C., Andersen, B.M., Li, Z., Giovannoni, F., Diebold, M., Sanmarco, L.M., *et al.* (2025) Glioblastoma-Instructed Astrocytes Suppress Tumour-Specific T Cell Immunity. *Nature*, **643**, 219-229. https://doi.org/10.1038/s41586-025-08997-x

[42] Ostrom, Q.T., Price, M., Neff, C., Cioffi, G., Waite, K.A., Kruchko, C., *et al.* (2023) CBTRUS Statistical Report: Primary Brain and Other Central Nervous System Tumors Diagnosed in the United States in 2016-2020. *Neuro-Oncology*, **25**, iv1-iv99. https://doi.org/10.1093/neuonc/noad149

[43] van Opijnen, M.P., Nabuurs, R.J.A., de Vos, F.Y.F., Ramsoedh, M.T.R., Verhoeff, J.J.C., Geurts, M., *et al.* (2024) Recurrent Glioblastoma in National Guidelines on the Diagnosis and Treatment of Gliomas: A Matter of European Practice Variation. *Brain and Spine*, **4**, Article ID: 103923. https://doi.org/10.1016/j.bas.2024.103923

[44] Zhou, J., Li, L., Jia, M., Liao, Q., Peng, G., Luo, G., *et al.* (2022) Dendritic Cell Vaccines Improve the Glioma Microenvironment: Influence, Challenges, and Future Direc-

tions. *Cancer Medicine*, **12**, 7207-7221. https://doi.org/10.1002/cam4.5511

[45] Eagles, M., Nassiri, F., Badhiwala, J., Suppiah, S., Almenawer, S., Zadeh, G., *et al.* (2018) Dendritic Cell Vaccines for High-Grade Gliomas. *Therapeutics and Clinical Risk Management*, **14**, 1299-1313. https://doi.org/10.2147/tcrm.s135865

[46] Lv, L., Huang, J., Xi, H. and Zhou, X. (2020) Efficacy and Safety of Dendritic Cell Vaccines for Patients with Glioblastoma: A Meta-Analysis of Randomized Controlled Trials. *International Immunopharmacology*, **83**, Article ID: 106336. https://doi.org/10.1016/j.intimp.2020.106336

[47] Cozzi, S., Najafi, M., Gomar, M., Ciammella, P., Iotti, C., Iaccarino, C., *et al.* (2022) Delayed Effect of Dendritic Cells Vaccination on Survival in Glioblastoma: A Systematic Review and Meta-Analysis. *Current Oncology*, **29**, 881-891. https://doi.org/10.3390/curroncol29020075

[48] Wong, C., Chang, Y., Chen, P., Huang, Y., Chang, Y., Chiang, C., *et al.* (2024) Dendritic Cell Vaccine for Glioblastoma: An Updated Meta-Analysis and Trial Sequential Analysis. *Journal of Neuro-Oncology*, **170**, 253-263. https://doi.org/10.1007/s11060-024-04798-w

[49] Ramnath, N., Ganesan, P., Penumadu, P., Arenberg, D. and Bryant, A. (2025) Lung Cancer Screening in India: Preparing for the Future Using Smart Tools & Biomarkers to Identify Highest Risk Individuals. *The Indian Journal of Medical Research*, **160**, 561-569. https://doi.org/10.25259/ijmr_118_24

[50] Nath, A., Sathishkumar, K., Das, P., Sudarshan, K.L. and Mathur, P. (2022) A Clinicoepidemiological Profile of Lung Cancers in India—Results from the National Cancer Registry Programme. *Indian Journal of Medical Research*, **155**, 264-272. https://doi.org/10.4103/ijmr.ijmr_1364_21

[51] Garg, A., Iyer, H., Jindal, V., Vashistha, V., Ali, A., Jain, D., *et al.* (2022) Prognostic Factors for Treatment Response and Survival Outcomes after First-Line Management of Stage 4 Non-Small Cell Lung Cancer: A Real-World Indian Perspective. *Lung India*, **39**, 102-109. https://doi.org/10.4103/lungindia.lungindia_408_21

[52] Punekar, S.R., Shum, E., Grello, C.M., Lau, S.C. and Velcheti, V. (2022) Immunotherapy in Non-Small Cell Lung Cancer: Past, Present, and Future Directions. *Frontiers in Oncology*, **12**, Article ID: 877594. https://doi.org/10.3389/fonc.2022.877594

[53] Reck, M., Rodríguez-Abreu, D., Robinson, A.G., Hui, R., Csőszi, T., Fülöp, A., *et al.* (2021) Five-Year Outcomes with Pembrolizumab versus Chemotherapy for Metastatic Non-Small-Cell Lung Cancer with PD-L1 Tumor Proportion Score ≥ 50%. *Journal of Clinical Oncology*, **39**, 2339-2349. https://doi.org/10.1200/jco.21.00174

[54] Shields, M.D., Marin-Acevedo, J.A. and Pellini, B. (2021) Immunotherapy for Advanced Non-Small Cell Lung Cancer: A Decade of Progress. *American Society of Clinical Oncology Educational Book*, **41**, e105-e127. https://doi.org/10.1200/edbk_321483

[55] Hu, R.H. Shi, S.B., Qi, J.L., Tian, J., Tang, X., Liu, G., *et al.* (2014) Pemetrexed Plus Dendritic Cells as Second-Line Treatment for Patients with Stage IIIB/IV Non-Small Cell Lung Cancer Who Had Treatment with TKI. *Medical Oncology*, **31**, Article No. 63. https://doi.org/10.1007/s12032-014-0063-z

[56] Takahashi, H., Shimodaira, S., Ogasawara, M., Ota, S., Kobayashi, M., Abe, H., *et al.* (2016) Lung Adenocarcinoma May Be a More Susceptive Subtype to a Dendritic Cell-Based Cancer Vaccine than Other Subtypes of Non-Small Cell Lung Cancers: A Multicenter Retrospective Analysis. *Cancer Immunology, Immunotherapy*, **65**, 1099-1111. https://doi.org/10.1007/s00262-016-1872-z

[57] Zemanova, M., Cernovska, M., Havel, L., Bartek, T., Lukesova, S., Jakesova, J., *et al.*

(2021) Autologous Dendritic Cell-Based Immunotherapy (DCVAC/LuCa) and Carboplatin/Paclitaxel in Advanced Non-Small Cell Lung Cancer: A Randomized, Open-Label, Phase I/II Trial. *Cancer Treatment and Research Communications*, **28**, Article ID: 100427. https://doi.org/10.1016/j.ctarc.2021.100427

[58] Zhong, R., Ling, X., Cao, S., Xu, J., Zhang, B., Zhang, X., *et al.* (2022) Safety and Efficacy of Dendritic Cell-Based Immunotherapy (DCVAC/LuCa) Combined with Carboplatin/Pemetrexed for Patients with Advanced Non-Squamous Non-Small-Cell Lung Cancer without Oncogenic Drivers. *ESMO Open*, **7**, Article ID: 100334. https://doi.org/10.1016/j.esmoop.2021.100334

[59] Huang, J., Chan, S.C., Ngai, C.H., Lok, V., Zhang, L., Lucero-Prisno, D.E., *et al.* (2022) Disease Burden, Risk Factors, and Trends of Leukaemia: A Global Analysis. *Frontiers in Oncology*, **12**, Article ID: 904292. https://doi.org/10.3389/fonc.2022.904292

[60] Nalage, D.N., Kudnar, P.S., Langhe, R., Ughade, B., Sontakke, T. and Biradar, A. (2024) Leukemia in India: Insights into Incidence, Prevalence, Mortality, and Disability-Adjusted Life Years. *Cureus*, **16**, e62557. https://doi.org/10.7759/cureus.62557

[61] Döhner, H., Wei, A.H., Appelbaum, F.R., Craddock, C., DiNardo, C.D., Dombret, H., *et al.* (2022) Diagnosis and Management of AML in Adults: 2022 Recommendations from an International Expert Panel on Behalf of the ELN. *Blood*, **140**, 1345-1377. https://doi.org/10.1182/blood.2022016867

[62] Vago, L. and Gojo, I. (2020) Immune Escape and Immunotherapy of Acute Myeloid Leukemia. *Journal of Clinical Investigation*, **130**, 1552-1564. https://doi.org/10.1172/jci129204

[63] Abadir, E., Gasiorowski, R.E., Silveira, P.A., Larsen, S. and Clark, G.J. (2020) Is Hematopoietic Stem Cell Transplantation Required to Unleash the Full Potential of Immunotherapy in Acute Myeloid Leukemia? *Journal of Clinical Medicine*, **9**, Article No. 554. https://doi.org/10.3390/jcm9020554

[64] Lau, C.M., Nish, S.A., Yogev, N., Waisman, A., Reiner, S.L. and Reizis, B. (2016) Leukemia-Associated Activating Mutation of Flt3 Expands Dendritic Cells and Alters T Cell Responses. *Journal of Experimental Medicine*, **213**, 415-431. https://doi.org/10.1084/jem.20150642

[65] Gaafar, A., Al-Omar, H.M., Manogaran, P.S., Almohareb, F. and Alhussein, K. (2023) Prevalence of the BCR/ABL Fusion Gene and T Cell Stimulation Capacity of Dendritic Cells in Chronic Myelogenous Leukemia. *American Journal of Translational Research*, **15**, 967-981.

[66] Hsieh, Y., Kirschner, K. and Copland, M. (2021) Improving Outcomes in Chronic Myeloid Leukemia through Harnessing the Immunological Landscape. *Leukemia*, **35**, 1229-1242. https://doi.org/10.1038/s41375-021-01238-w

[67] Stein, J., Anand, P., Abdulmajid, J., Hartz, A., Unterfrauner, M., Feng, X., *et al.* (2025) Monitoring of (Leukemia-Specific) Immune Cells in Stages, Treatment Groups and in the Course of Disease and Therapy Contributes to Qualify Antileukemic Potential and Survival in Patients with Aml. *International Journal of Molecular Sciences*, **26**, Article No. 10336. https://doi.org/10.3390/ijms262110336

[68] Fujii, S., Shimizu, K., Fujimoto, K., Kiyokawa, T., Shimomura, T., Taniguchi, O., *et al.* (1999) Analysis of a Chronic Myelogenous Leukemia Patient Vaccinated with Leukemic Dendritic Cells Following Autologous Peripheral Blood Stem Cell Transplantation. *Japanese Journal of Cancer Research*, **90**, 1117-1129. https://doi.org/10.1111/j.1349-7006.1999.tb00686.x

[69] van de Loosdrecht, A.A., van Wetering, S., Santegoets, S.J.A.M., Singh, S.K., Eeltink, C.M., den Hartog, Y., *et al.* (2018) A Novel Allogeneic Off-the-Shelf Dendritic Cell

Vaccine for Post-Remission Treatment of Elderly Patients with Acute Myeloid Leukemia. *Cancer Immunology, Immunotherapy*, **67**, 1505-1518. https://doi.org/10.1007/s00262-018-2198-9

[70] Anguille, S., Van de Velde, A.L., Smits, E.L., Van Tendeloo, V.F., Juliusson, G., Cools, N., *et al.* (2017) Dendritic Cell Vaccination as Postremission Treatment to Prevent or Delay Relapse in Acute Myeloid Leukemia. *Blood*, **130**, 1713-1721. https://doi.org/10.1182/blood-2017-04-780155

[71] Zanotta, S., Galati, D., De Filippi, R. and Pinto, A. (2024) Enhancing Dendritic Cell Cancer Vaccination: The Synergy of Immune Checkpoint Inhibitors in Combined Therapies. *International Journal of Molecular Sciences*, **25**, Article No. 7509. https://doi.org/10.3390/ijms25147509

[72] Gardner, A., de Mingo Pulido, Á. and Ruffell, B. (2020) Dendritic Cells and Their Role in Immunotherapy. *Frontiers in Immunology*, **11**, Article No. 924. https://doi.org/10.3389/fimmu.2020.00924

[73] Miao, L., Zhang, Y. and Huang, L. (2021) mRNA Vaccine for Cancer Immunotherapy. *Molecular Cancer*, **20**, Article No. 41. https://doi.org/10.1186/s12943-021-01335-5

[74] Duan, L., Wang, Q., Zhang, C., Yang, D. and Zhang, X. (2022) Potentialities and Challenges of mRNA Vaccine in Cancer Immunotherapy. *Frontiers in Immunology*, **13**, Article ID: 923647. https://doi.org/10.3389/fimmu.2022.923647

[75] Wculek, S.K., Cueto, F.J., Mujal, A.M., Melero, I., Krummel, M.F. and Sancho, D. (2019) Dendritic Cells in Cancer Immunology and Immunotherapy. *Nature Reviews Immunology*, **20**, 7-24. https://doi.org/10.1038/s41577-019-0210-z

[76] Stavrou, V., Fultang, L., Booth, S., De Simone, D., Bartnik, A., Scarpa, U., *et al.* (2022) Invariant NKT Cells Metabolically Adapt to the Acute Myeloid Leukaemia Environment. *Cancer Immunology, Immunotherapy*, **72**, 543-560. https://doi.org/10.1007/s00262-022-03268-4

[77] Fløisand, Y., Remberger, M., Bigalke, I., Josefsen, D., Vålerhaugen, H., Inderberg, E.M., *et al.* (2023) WT1 and PRAME RNA-Loaded Dendritic Cell Vaccine as Maintenance Therapy in De Novo AML after Intensive Induction Chemotherapy. *Leukemia*, **37**, 1842-1849. https://doi.org/10.1038/s41375-023-01980-3

[78] O'Brien, L.J., Guillerey, C. and Radford, K.J. (2019) Can Dendritic Cell Vaccination Prevent Leukemia Relapse? *Cancers*, **11**, Article No. 875. https://doi.org/10.3390/cancers11060875

[79] Gupta, K., Mandal, R. and Chatterjee, P. (2024) Navigating the Landscape of Cervical Cancer in India: Epidemiology, Prevention, Current Status, and Emerging Solutions. *Journal of Obstetrics and Gynaecology Research*, **50**, 55-64. https://doi.org/10.1111/jog.16030

[80] Okita, T., Enzo, A., Kadooka, Y., Tanaka, M. and Asai, A. (2020) The Controversy on HPV Vaccination in Japan: Criticism of the Ethical Validity of the Arguments for the Suspension of the Proactive Recommendation. *Health Policy*, **124**, 199-204. https://doi.org/10.1016/j.healthpol.2019.12.011

[81] Bandyopadhyay, A., Mukherjee, U., Ghosh, S., Ghosh, S. and Sarkar, S.K. (2018) Pattern of Failure with Locally Advanced Cervical Cancer—A Retrospective Audit and Analysis of Contributory Factors. *Asian Pacific Journal of Cancer Prevention*, **19**, 73-79.

[82] Zheng, Q., He, M., Mao, Z., Huang, Y., Li, X., Long, L., *et al.* (2025) Advancing the Fight against Cervical Cancer: The Promise of Therapeutic HPV Vaccines. *Vaccines*, **13**, Article No. 92. https://doi.org/10.3390/vaccines13010092

[83] Santin, A.D., Bellone, S., Palmieri, M., Zanolini, A., Ravaggi, A., Siegel, E.R., *et al.* (2008) Human Papillomavirus Type 16 and 18 E7-Pulsed Dendritic Cell Vaccination of Stage IB or IIA Cervical Cancer Patients: A Phase I Escalating-Dose Trial. *Journal of Virology*, **82**, 1968-1979. https://doi.org/10.1128/jvi.02343-07

[84] Lin, H., Wu, C., Fu, H. and Ou, Y. (2025) Recent Advances in Cervical Cancer Treatment: Innovations from Early-Stage to Advanced Disease. *Journal of Obstetrics and Gynecology*, **64**, 608-615. https://doi.org/10.1016/j.tjog.2025.04.006

[85] Tewari, K.S., Sill, M.W., Long, H.J., Penson, R.T., Huang, H., Ramondetta, L.M., *et al.* (2014) Improved Survival with Bevacizumab in Advanced Cervical Cancer. *New England Journal of Medicine*, **370**, 734-743. https://doi.org/10.1056/nejmoa1309748

[86] Bermudez, A., Bhatla, N. and Leung, E. (2015) Cancer of the Cervix Uteri. *International Journal of Gynecology & Obstetrics*, **131**, S88-S95. https://doi.org/10.1016/j.ijgo.2015.06.004

[87] Amatore, F., Gorvel, L. and Olive, D. (2018) Inducible Co-Stimulator (ICOS) as a Potential Therapeutic Target for Anti-Cancer Therapy. *Expert Opinion on Therapeutic Targets*, **22**, 343-351. https://doi.org/10.1080/14728222.2018.1444753

[88] Compte, M., Harwood, S.L., Muñoz, I.G., Navarro, R., Zonca, M., Perez-Chacon, G., *et al.* (2018) A Tumor-Targeted Trimeric 4-1BB-Agonistic Antibody Induces Potent Anti-Tumor Immunity without Systemic Toxicity. *Nature Communications*, **9**, Article No. 4809. https://doi.org/10.1038/s41467-018-07195-w

[89] Polesso, F., Weinberg, A.D. and Moran, A.E. (2019) Late-stage Tumor Regression after PD-L1 Blockade Plus a Concurrent OX40 Agonist. *Cancer Immunology Research*, **7**, 269-281. https://doi.org/10.1158/2326-6066.cir-18-0222

[90] Dey, T. and Agrawal, S. (2025) Immunotherapy in Cervical Cancer: An Innovative Approach for Better Treatment Outcomes. *Exploration of Targeted Anti-Tumor Therapy*, **6**, Article ID: 1002296. https://doi.org/10.37349/etat.2025.1002296

[91] Ghosh, T.S., Das, M., Jeffery, I.B. and O'Toole, P.W. (2020) Adjusting for Age Improves Identification of Gut Microbiome Alterations in Multiple Diseases. *eLife*, **9**, e50240. https://doi.org/10.7554/elife.50240

[92] Roshandel, G., Ghasemi-Kebria, F. and Malekzadeh, R. (2024) Colorectal Cancer: Epidemiology, Risk Factors, and Prevention. *Cancers*, **16**, Article No. 1530. https://doi.org/10.3390/cancers16081530

[93] Sato, Y., Tsujinaka, S., Miura, T., Kitamura, Y., Suzuki, H. and Shibata, C. (2023) Inflammatory Bowel Disease and Colorectal Cancer: Epidemiology, Etiology, Surveillance, and Management. *Cancers*, **15**, Article No. 4154. https://doi.org/10.3390/cancers15164154

[94] Lee, C., Kim, M., Kumar, A., Lee, H., Yang, Y. and Kim, Y. (2025) Vascular Endothelial Growth Factor Signaling in Health and Disease: From Molecular Mechanisms to Therapeutic Perspectives. *Signal Transduction and Targeted Therapy*, **10**, Article No. 170. https://doi.org/10.1038/s41392-025-02249-0

[95] Shivshankar, S., Patil, P.S., Deodhar, K. and Budukh, A.M. (2025) Epidemiology of Colorectal Cancer: A Review with Special Emphasis on India. *Indian Journal of Gastroenterology*, **44**, 142-153. https://doi.org/10.1007/s12664-024-01726-8

[96] Bray, F., Ferlay, J., Soerjomataram, I., Siegel, R.L., Torre, L.A. and Jemal, A. (2018) Global Cancer Statistics 2018: GLOBOCAN Estimates of Incidence and Mortality Worldwide for 36 Cancers in 185 Countries. *CA*: *A Cancer Journal for Clinicians*, **68**, 394-424. https://doi.org/10.3322/caac.21492

[97] Lee, S., Surabhi, V.R., Kassam, Z., Chang, K.J. and Kaur, H. (2023) Imaging of Colon and Rectal Cancer. *Current Problems in Cancer*, **47**, Article ID: 100970.

https://doi.org/10.1016/j.currproblcancer.2023.100970

[98] Cervantes, A., Adam, R., Roselló, S., Arnold, D., Normanno, N., Taïeb, J., *et al.* (2023) Metastatic Colorectal Cancer: ESMO Clinical Practice Guideline for Diagnosis, Treatment and Follow-up. *Annals of Oncology*, **34**, 10-32. https://doi.org/10.1016/j.annonc.2022.10.003

[99] Biller, L.H. and Schrag, D. (2021) Diagnosis and Treatment of Metastatic Colorectal Cancer: A Review. *JAMA*, **325**, 669-685. https://doi.org/10.1001/jama.2021.0106

[100] Heras-Murillo, I., Adán-Barrientos, I., Galán, M., Wculek, S.K. and Sancho, D. (2024) Dendritic Cells as Orchestrators of Anticancer Immunity and Immunotherapy. *Nature Reviews Clinical Oncology*, **21**, 257-277. https://doi.org/10.1038/s41571-024-00859-1

[101] Hsieh, H.H., Chen, C.L., Chan, H.W., Chi, K. and Wu, C. (2023) Enhanced Antitumour Response of Gold Nanostar-Mediated Photothermal Therapy in Combination with Immunotherapy in a Mouse Model of Colon Carcinoma. *British Journal of Cancer*, **130**, 406-416. https://doi.org/10.1038/s41416-023-02537-y

[102] Santos, P.M., Adamik, J., Howes, T.R., Du, S., Vujanovic, L., Warren, S., *et al.* (2020) Impact of Checkpoint Blockade on Cancer Vaccine-Activated CD8+ T Cell Responses. *Journal of Experimental Medicine*, **217**, e20191369. https://doi.org/10.1084/jem.20191369