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A Review on Natural Herbal Anticancer Drugs

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Abstract

Cancer remains one of the leading causes of morbidity and mortality worldwide. Despite remarkable advances in surgery, chemotherapy, radiotherapy, immunotherapy, and targeted therapy, cancer treatment continues to face several challenges including drug resistance, toxicity, recurrence, and high treatment costs. Natural products obtained from medicinal plants have played a vital role in cancer management and have contributed significantly to the discovery of modern anticancer drugs. Several plant-derived compounds such as vincristine, vinblastine, paclitaxel, and camptothecin derivatives have become important components of current cancer therapy. In recent years, increasing attention has been directed toward herbal medicines because of their diverse bioactive constituents, including alkaloids, flavonoids, terpenoids, phenolic compounds, and glycosides, which exhibit anticancer activities through multiple mechanisms.

The present review summarizes the role of medicinal plants in cancer prevention and treatment, focusing on major herbal anticancer agents, their active phytochemicals, mechanisms of action, therapeutic applications, and limitations. Important medicinal plants including Catharanthus roseus, Curcuma longa, Withania somnifera, Allium sativum, Taxus brevifolia, Azadirachta indica, Aloe vera, Panax ginseng, Glycyrrhiza glabra, and Zingiber officinale are discussed in detail. The review also highlights current challenges associated with herbal medicines, including standardization, quality control, bioavailability, and safety concerns. Furthermore, future perspectives such as nanotechnology-based herbal formulations and integration of traditional medicine with modern oncology are presented.

The findings suggest that medicinal plants remain valuable sources of novel anticancer compounds and may contribute significantly to future cancer therapeutics. However, extensive clinical studies and standardized formulations are required to establish their safety, efficacy, and therapeutic applicability.

Keywords: Cancer, Medicinal Plants, Herbal Medicine, Phytochemicals, Anticancer Agents, Natural Products, Oncology.

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1. Introduction

Cancer is a complex group of diseases characterized by uncontrolled growth and division of abnormal cells. These cells can invade surrounding tissues and spread to distant organs through a process known as metastasis. According to the World Health Organization (WHO), cancer is one of the leading causes of death globally and is responsible for millions of deaths every year. The increasing burden of cancer represents a major public health challenge affecting both developed and developing countries.

The development of cancer is influenced by several genetic, environmental, and lifestyle factors. Tobacco use, excessive alcohol consumption, obesity, unhealthy diet, physical inactivity, exposure to radiation, environmental pollutants, chronic infections, and genetic predisposition are among the major risk factors associated with cancer development. Common forms of cancer include breast cancer, lung cancer, colorectal cancer, prostate cancer, liver cancer, cervical cancer, and leukemia.

Conventional cancer treatment mainly includes surgery, chemotherapy, radiotherapy, hormone therapy, immunotherapy, and targeted therapy. Although these approaches have improved patient survival rates, they are often associated with significant limitations. Chemotherapeutic agents frequently produce adverse effects such as nausea, vomiting, hair loss, myelosuppression, organ toxicity, and immunosuppression. Furthermore, cancer cells may develop resistance to anticancer drugs, reducing treatment effectiveness.

Natural products have served as an important source of therapeutic agents throughout human history. Medicinal plants have been used for thousands of years in traditional healthcare systems such as Ayurveda, Traditional Chinese Medicine (TCM), Unani, and folk medicine. These plants contain a wide range of bioactive compounds capable of producing beneficial pharmacological effects. Many currently used anticancer drugs originated from medicinal plants, highlighting the importance of natural products in oncology.

Unlike earlier assumptions, herbal medicines are not completely free from toxicity. While some herbal products may produce fewer adverse effects than synthetic drugs, their safety depends on dose, duration of use, preparation method, and individual patient factors. Therefore, scientific evaluation and clinical validation are necessary before therapeutic application.

The objective of this review is to critically evaluate important medicinal plants with anticancer potential, discuss their bioactive constituents and mechanisms of action, examine current scientific evidence, and highlight future directions for herbal anticancer drug development.

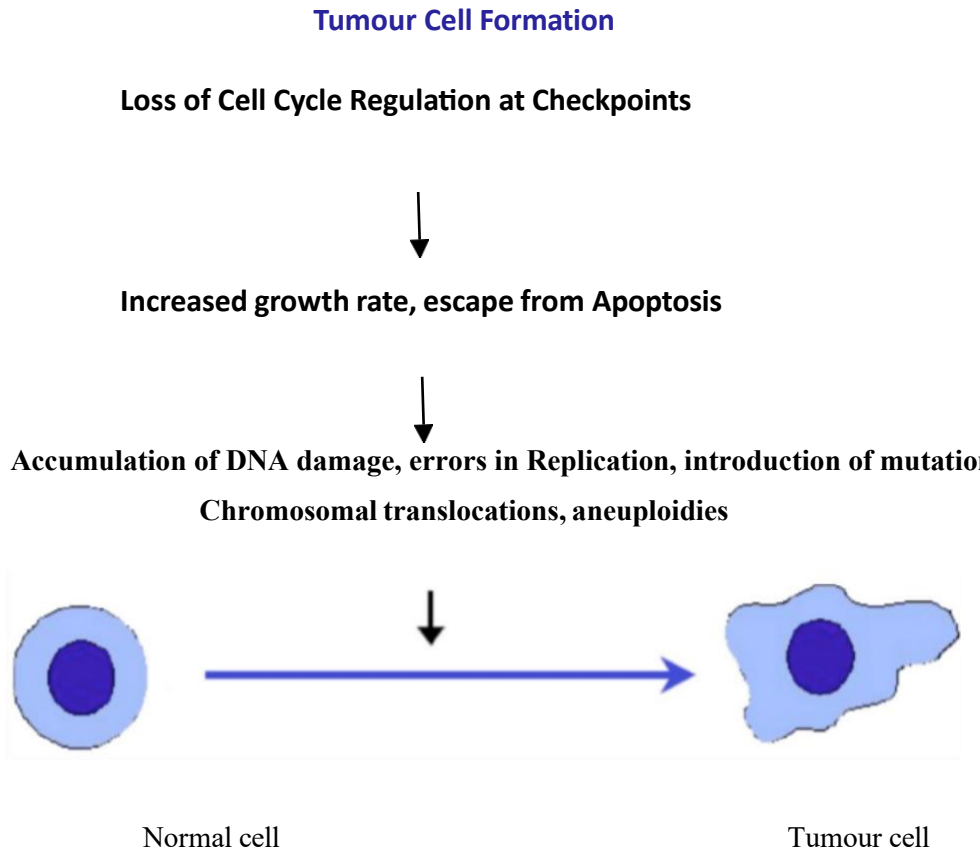

Figure No.1 Tumour cell formation

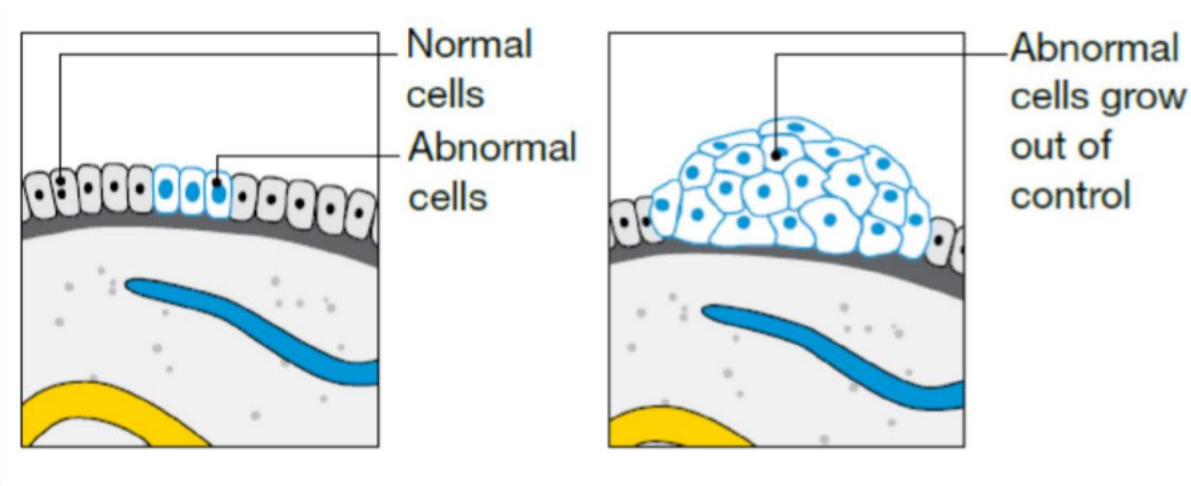

Figure No. 2 Normal and abnormal cell

2. Methodology of Literature Review

This review was prepared through a comprehensive literature search conducted using internationally recognized scientific databases including PubMed, Scopus, Web of Science, Google Scholar, ScienceDirect, SpringerLink, and Wiley Online Library.

The literature search covered publications from 2000 to 2026. Keywords used during the search included:

Herbal anticancer agents, Medicinal plants and cancer, Natural products in oncology, Phytochemicals and anticancer activity, Plant-derived anticancer drugs, Herbal medicine in cancer therapy, Curcumin and cancer, Vincristine and vinblastine, Paclitaxel, Withaferin A

Research articles, review articles, systematic reviews, clinical studies, and authoritative reports from international health organizations were included. Studies focusing on anticancer activity, mechanisms of action, phytochemical characterization, clinical applications, and safety evaluation of medicinal plants were considered.

Duplicate publications, non-peer-reviewed sources, incomplete reports, and studies lacking scientific evidence were excluded from the review.

3. Role of Natural Products in Cancer Therapy

Natural products have made a remarkable contribution to modern cancer treatment. Historically, many important anticancer drugs were discovered from plants. These discoveries have demonstrated that nature remains one of the most valuable sources of novel therapeutic agents.

Plant-derived compounds possess several advantages, including structural diversity, multiple mechanisms of action, and the ability to interact with various molecular targets involved in cancer progression. Phytochemicals can inhibit cell proliferation, induce apoptosis, suppress angiogenesis, prevent metastasis, regulate immune responses, and reduce oxidative stress.

3.1 Historical Importance of Plant-Derived Anticancer Drugs

The discovery of vinca alkaloids from *Catharanthus roseus* represented a major breakthrough in cancer chemotherapy. Vincristine and vinblastine are widely used in the treatment of leukemia, lymphoma, and several solid tumors.

Similarly, paclitaxel isolated from *Taxus brevifolia* became one of the most successful anticancer drugs used for breast, ovarian, and lung cancers. Camptothecin derived from *Camptotheca acuminata* led to the development of irinotecan and topotecan, which remain important chemotherapeutic agents.

These examples clearly demonstrate that medicinal plants provide valuable lead compounds for drug discovery.

3.2 Major Classes of Anticancer Phytochemicals

Alkaloids : Alkaloids are nitrogen-containing compounds widely distributed in medicinal plants. They exhibit potent biological activities including anticancer effects. Vincristine, vinblastine, camptothecin, and berberine are important examples.

Flavonoids : Flavonoids are naturally occurring polyphenolic compounds found in fruits, vegetables, and medicinal plants. They possess antioxidant, anti-inflammatory, and anticancer properties. Quercetin, kaempferol, apigenin, and luteolin have demonstrated significant anticancer potential.

Terpenoids : Terpenoids represent one of the largest classes of natural compounds. Paclitaxel is a well-known diterpenoid with strong anticancer activity. Terpenoids can induce apoptosis and inhibit tumor growth.

Phenolic Compounds : Phenolic compounds such as curcumin, resveratrol, and epigallocatechin gallate (EGCG) exhibit powerful antioxidant and anticancer activities. These compounds can modulate several cellular signaling pathways involved in carcinogenesis.

Saponins : Saponins are glycosides known for their ability to induce apoptosis and inhibit cancer cell proliferation. Ginsenosides from Panax ginseng are among the most extensively studied anticancer saponins.

3.3 Mechanisms of Anticancer Action

Medicinal plants exert anticancer effects through multiple mechanisms:

Induction of Apoptosis : Apoptosis is a programmed cell death process essential for maintaining cellular homeostasis. Many phytochemicals activate apoptotic pathways in cancer cells, resulting in their elimination.

Cell Cycle Arrest : Several plant-derived compounds interfere with cell cycle progression, preventing cancer cell proliferation.

Anti-Angiogenic Activity : Tumors require new blood vessels for growth and metastasis. Herbal compounds can inhibit angiogenesis, thereby restricting tumor development.

Antioxidant Effects : Excessive production of reactive oxygen species contributes to DNA damage and carcinogenesis. Antioxidant phytochemicals protect cells from oxidative stress.

Anti-Metastatic Effects : Certain herbal compounds suppress cancer cell migration and invasion, reducing the spread of cancer to distant organs.

Immunomodulatory Effects : Medicinal plants may enhance immune surveillance and improve the body's ability to recognize and eliminate cancer cells. The ability of phytochemicals to target multiple pathways simultaneously makes them promising candidates for cancer prevention and therapy.

4. Important Medicinal Plants with Anticancer Potential

4.1 Catharanthus roseus (Madagascar Periwinkle)

Botanical Information

- Family: Apocynaceae
- Common Name: Madagascar Periwinkle
- Part Used: Whole plant, especially leaves
- Major Constituents: Vincristine, Vinblastine, Vindesine, Vinorelbine

Catharanthus roseus is one of the most important medicinal plants in cancer therapy. The discovery of vinca alkaloids from this plant revolutionized cancer treatment and demonstrated the enormous potential of plant-derived compounds in modern medicine.

Mechanism of Action : Vincristine and vinblastine interfere with microtubule formation during cell division. They bind to tubulin proteins and prevent mitotic spindle formation, leading to cell cycle arrest at metaphase and eventual apoptosis of cancer cells.

Therapeutic Applications : These compounds are widely used in the treatment of:

- Acute lymphoblastic leukemia
- Hodgkin's lymphoma
- Non-Hodgkin's lymphoma
- Breast cancer
- Lung cancer
- Neuroblastoma

Scientific Evidence : Several clinical studies have confirmed the effectiveness of vinca alkaloids in treating hematological malignancies. Despite their success, adverse effects such as neurotoxicity and bone marrow suppression require careful monitoring.

Table 1. Botanical Information and Major Bioactive Constituents of Important Herbal Anticancer Plants

S. No.	Botanical Name	Family	Common Name	Part Used	Major Bioactive Constituents
1	*Catharanthus roseus*	Apocynaceae	Madagascar Periwinkle	Whole plant (especially leaves)	Vincristine, Vinblastine, Vindesine, Vinorelbine
2	*Curcuma longa*	Zingiberaceae	Turmeric	Rhizome	Curcumin, Demethoxycurcumin, Bisdemethoxycurcumin
3	*Withania somnifera*	Solanaceae	Ashwagandha	Roots and Leaves	Withaferin A, Withanolides, Withanone
4	*Allium sativum*	Amaryllidaceae	Garlic	Bulb	Allicin, Alliin, Diallyl Sulfide, Diallyl Disulfide
5	*Taxus brevifolia*	Taxaceae	Pacific Yew	Bark and Leaves	Paclitaxel (Taxol)
6	*Azadirachta indica*	Meliaceae	Neem	Leaves, Bark and Seeds	Azadirachtin, Nimbolide, Quercetin
7	*Aloe vera*	Asphodelaceae	Aloe Vera	Leaves	Aloe-emodin, Acemannan
8	*Panax ginseng*	Araliaceae	Ginseng	Root	Ginsenosides
9	*Glycyrrhiza glabra*	Fabaceae	Licorice	Root	Glycyrrhizin, Liquiritigenin, Licochalcone A
10	*Zingiber officinale*	Zingiberaceae	Ginger	Rhizome	Gingerols, Shogaols, Zingerone

Table 2. Mechanisms of Action and Therapeutic Potential of Major Herbal Anticancer Plants

Botanical Name	Major Mechanism of Action	Cancer Types / Therapeutic Potential
Catharanthus roseus	Inhibits microtubule formation, arrests mitosis, induces apoptosis	Leukemia, Hodgkin's lymphoma, breast cancer, lung cancer
Curcuma longa	NF-κB inhibition, apoptosis induction, anti-angiogenesis, anti-metastatic activity, antioxidant action	Colorectal, breast, prostate, pancreatic, liver and skin cancers
Withania somnifera	Apoptosis induction, cell cycle arrest, angiogenesis inhibition, anti-inflammatory action	Breast, lung, colon, prostate and ovarian cancers
Allium sativum	Immune enhancement, DNA protection, apoptosis induction, inhibition of tumor proliferation	Gastric, colon, lung, breast and prostate cancers

Taxus brevifolia	Stabilizes microtubules, inhibits cell division, induces apoptosis	Breast, ovarian, lung, cervical and head & neck cancers
Azadirachta indica	Apoptosis induction, immune modulation, anti-metastatic and antioxidant activity	Breast, oral, liver and skin cancers
Aloe vera	Apoptosis induction, inhibition of cell proliferation and angiogenesis	Colon, lung, liver cancers and leukemia
Panax ginseng	Apoptosis induction, immune stimulation, antioxidant activity	Breast, lung, gastric and liver cancers
Glycyrrhiza glabra	Cell cycle arrest, apoptosis induction, antioxidant activity	Lung, gastric, liver and prostate cancers
Zingiber officinale	Anti-inflammatory activity, apoptosis induction, inhibition of angiogenesis and oxidative stress	Colorectal, breast, pancreatic and ovarian cancers
Catharanthus roseus	Inhibits microtubule formation, arrests mitosis, induces apoptosis	Leukemia, Hodgkin's lymphoma, breast cancer, lung cancer
Curcuma longa	NF-κB inhibition, apoptosis induction, anti-angiogenesis, anti-metastatic activity, antioxidant action	Colorectal, breast, prostate, pancreatic, liver and skin cancers

Supportive Care : Ginger is also effective in reducing chemotherapy-induced nausea and vomiting, making it useful as supportive care for cancer patients.

Table 3. Important Medicinal Plants and Their Anticancer Constituents

Plant	Major Active Compound	Mechanism
Catharanthus roseus	Vincristine, Vinblastine	Microtubule inhibition
Curcuma longa	Curcumin	Apoptosis, anti-inflammatory
Withania somnifera	Withaferin A	Cell cycle arrest
Allium sativum	Allicin	Immunomodulation
Taxus brevifolia	Paclitaxel	Microtubule stabilization
Azadirachta indica	Nimbolide	Apoptosis induction
Aloe vera	Aloe-emodin	Cell proliferation inhibition
Panax ginseng	Ginsenosides	Immune enhancement
Glycyrrhiza glabra	Glycyrrhizin	Antioxidant activity
Zingiber officinale	Gingerols	Anti-inflammatory activity

5. Mechanisms of Herbal Anticancer Action

Medicinal plants contain numerous bioactive compounds that target multiple molecular pathways involved in cancer development and progression. Unlike many synthetic drugs that act on a single target, phytochemicals often influence several biological processes simultaneously.

5.1 Induction of Apoptosis

Apoptosis, also known as programmed cell death, is an important defense mechanism against cancer. Many cancer cells evade apoptosis, allowing uncontrolled growth. Several herbal compounds restore this process and eliminate abnormal cells.

Examples include: Curcumin from Curcuma longa, Withaferin A from Withania somnifera, Aloe-emodin from Aloe vera, Nimbolide from Azadirachta indica

These compounds activate caspases, regulate Bcl-2 family proteins, and promote mitochondrial-mediated cell death.

5.2 Cell Cycle Arrest

Cancer cells divide continuously due to disruption of normal cell cycle regulation. Certain phytochemicals interrupt this process and stop cancer cell proliferation.

Examples: Vincristine, Vinblastine, Paclitaxel

These compounds interfere with microtubule dynamics and prevent proper chromosome separation during mitosis.

5.3 Inhibition of Angiogenesis

Tumors require new blood vessels for oxygen and nutrient supply. This process, known as angiogenesis, is essential for tumor growth and metastasis.

Several phytochemicals suppress angiogenesis by reducing vascular endothelial growth factor (VEGF) expression and other pro-angiogenic mediators.

Examples:Curcumin, Ginsenosides, Withaferin A

5.4 Antioxidant Activity

Oxidative stress contributes significantly to DNA damage and carcinogenesis. Many medicinal plants contain antioxidant compounds that neutralize reactive oxygen species (ROS).

Examples:Curcumin, Gingerols, Flavonoids, Polyphenols

These compounds help protect healthy cells from oxidative damage.

5.5 Immunomodulatory Effects

The immune system plays a crucial role in identifying and destroying cancer cells. Certain medicinal plants strengthen immune responses and enhance anticancer immunity.

Examples: Garlic, Ginseng, Ashwagandha

These herbs may stimulate natural killer cells, macrophages, and T lymphocytes.

5.6 Inhibition of Metastasis

Metastasis is responsible for the majority of cancer-related deaths. Herbal compounds can inhibit cancer cell migration, invasion, and adhesion.

Examples: Curcumin, Garlic constituents, Withaferin A

By suppressing metastatic pathways, these compounds may reduce cancer spread.

6. Advantages of Herbal Anticancer Agents

Medicinal plants offer several advantages in cancer management:

1. Natural source of bioactive compounds.
2. Multiple mechanisms of action.
3. Potential reduction in treatment-related side effects.
4. Availability in many regions of the world.
5. Long history of traditional use.
6. Potential synergistic effects with conventional therapy.
7. Source of lead compounds for drug discovery.

Several successful anticancer drugs currently used in clinical practice originated from medicinal plants, demonstrating their importance in modern oncology.

7. Limitations and Challenges

Despite their therapeutic potential, herbal medicines face several limitations.

7.1 Lack of Standardization

The concentration of active constituents may vary depending on: Geographic location, Climate, Soil conditions, Harvesting methods, Storage conditions

This variation can affect therapeutic outcomes.

7.2 Limited Clinical Evidence

Many studies are limited to: In vitro experiments, Animal models

Large-scale human clinical trials remain insufficient for many herbal anticancer agents.

7.3 Bioavailability Issues

Several phytochemicals exhibit poor oral absorption.

Examples: Curcumin, Resveratrol

Low bioavailability may reduce therapeutic effectiveness.

7.4 Safety Concerns

Contrary to common belief, herbal medicines are not completely free from toxicity.

Potential risks include: Hepatotoxicity, Nephrotoxicity, Allergic reactions, Herb-drug interactions.

Therefore, safety evaluation remains essential.

7.5 Regulatory Challenges

Quality control and regulatory requirements differ among countries, leading to inconsistencies in herbal product quality and safety.

8. Future Perspectives

The future of herbal anticancer therapy appears promising due to advances in biotechnology, nanotechnology, and molecular pharmacology.

8.1 Nanotechnology-Based Drug Delivery

Nanoparticles can improve: Solubility, Stability, Bioavailability, Targeted delivery

Curcumin-loaded nanoparticles and paclitaxel nanocarriers have shown encouraging results.

8.2 Combination Therapy

Combining herbal compounds with conventional chemotherapy may:

Improve efficacy, Reduce toxicity, Overcome drug resistance

Several ongoing studies are evaluating these approaches.

8.3 Personalized Medicine

Advances in genomics may allow personalized herbal treatment strategies based on individual genetic profiles.

8.4 Artificial Intelligence in Drug Discovery

Artificial intelligence and machine learning can accelerate:

Identification of active phytochemicals, Molecular target prediction, Drug development processes.

8.5 Clinical Validation

Future research should focus on:

Well-designed clinical trials, Standardized formulations, Long-term safety assessment, Pharmacokinetic studies

These investigations are essential for integrating herbal medicines into evidence-based oncology.

9. Conclusion

Medicinal plants represent a valuable source of bioactive compounds with significant anticancer potential. Several plant-derived compounds, including vincristine, vinblastine, paclitaxel, curcumin, withaferin A, allicin, and ginsenosides, have demonstrated promising anticancer activities through multiple mechanisms such as apoptosis induction, cell cycle arrest, inhibition of angiogenesis, antioxidant activity, immune modulation, and suppression of metastasis.

The successful development of plant-derived anticancer drugs highlights the importance of natural products in modern medicine. However, challenges including poor bioavailability, lack of standardization, limited clinical evidence, and safety concerns continue to restrict their widespread clinical application.

Future advances in nanotechnology, molecular biology, artificial intelligence, and clinical research are expected to improve the development and therapeutic utilization of herbal anticancer agents. Continued scientific investigation may lead to the discovery of safer, more effective, and affordable treatments for cancer patients worldwide.

Abbreviations

ROS – Reactive Oxygen Species

VEGF – Vascular Endothelial Growth Factor

WHO – World Health Organization

TCM – Traditional Chinese Medicine

HBV – Hepatitis B Virus

HCV – Hepatitis C Virus

HPV – Human Papilloma Virus

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