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CERVICAL CANCER: ETIOLOGY AND TREATMENT

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ABSTRACT

Cervical cancer is a type of cancer in the cervix, most commonly caused by a persistent human papillomavirus (HPV) infection. It is a preventable disease through HPV vaccination and regular screenings like Pap smears and HPV tests. Symptoms often include abnormal bleeding and discharge, but early-stage cancer may have no symptoms at all. Cervical cancer is a growth of cells that starts in the cervix. The cervix is the lower part of the uterus that connects to the vagina. Various strains of the human papillomavirus, also called HPV, play a role in causing most cervical cancers. HPV is a common infection that's passed through sexual contact. When exposed to HPV, the body's immune system typically prevents the virus from doing harm. In a small percentage of people, however, the virus survives for years. This contributes to the process that causes some cervical cells to become cancer cells. You can reduce your risk of developing cervical cancer by having screening tests and receiving a vaccine that protects against HPV infection. When cervical cancer happens, it's often first treated with surgery to remove the cancer. Other treatments may include medicines to kill the cancer cells. Options might include chemotherapy and targeted therapy medicines. Radiation therapy with powerful energy beams also may be used. Sometimes treatment combines radiation with low-dose chemotherapy.

KEYWORDS: HPV, biopsy, cell line, adenocarcinoma.

INTRODUCTION

Cervical cancer arises from the cells lining the cervix, the lower narrow part of the uterus that opens into the vagina. It usually develops slowly over years through precancerous changes (dysplasia), which can be detected and treated before invasive cancer develops, mainly by screening tests such as the Pap test and HPV testing. Persistent infection with high-risk human papillomavirus (HPV) types is the essential causal factor, but co-factors such as early onset of sexual activity, multiple sexual partners, smoking, immunosuppression, and poor genital hygiene increase risk. It is a term for diseases involving abnormal cells that grow uncontrollably, invade nearby tissues, and can spread to other parts of the body. Cancer is the second most common cause of death in the U.S. But fewer people are dying of cancer now than 20 years ago. Early detection and innovative treatments are curing cancer and helping people with cancer live longer. There are many types of cancer like-breast, prostate, and testicular cancers, as well as melanoma, thyroid cancer, and cervical cancer and many more.[1-3]

Causes of cervical cancer: Human papillomavirus (HPV) is a common sexually transmitted infection which can affect the skin, genital area and throat. Almost all sexually active people will be infected at some point in their lives, usually without symptoms. In most cases the immune system clears HPV from the body. Persistent infection with high-risk HPV can cause abnormal cells to develop, which go on to become cancer. Persistent HPV infection of the cervix (the lower part of the uterus or womb, which opens into the vagina – also called the

birth canal) if left untreated, causes 95% of cervical cancers. Typically, it takes 15–20 years for abnormal cells to become cancer, but in women with weakened immune systems, such as untreated HIV, this process can be faster and take 5–10 years. Risk factors for cancer progression include the grade of oncogenicity of the HPV type, immune status, the presence of other sexually transmitted infections, and number of births, young age at first pregnancy, hormonal contraceptive use, and smoking.
Cervical cancers are caused by an infection with certain high-risk types of human papillomavirus (HPV).

Symptoms: Cervical cancer might not cause symptoms. As it grows, cervical cancer might cause signs and symptoms.
1. Vaginal bleeding after intercourse, between periods or after menopause.
2. Menstrual bleeding that is heavier and lasts longer than usual.
3. Watery, bloody vaginal discharge that may be heavy and have a foul odor
4. Pelvic pain or pain during intercourse.

Definition of cervical cancer: Cervical cancer is defined as a malignant neoplasm arising from the epithelial tissues of the cervix, the organ connecting the uterus and vagina. It is usually a slow-growing cancer that may remain asymptomatic in early stages and is most often detected by screening before symptoms appear. Histologically, the two major types are squamous cell carcinoma (about 70–90% of cases) originating from the ectocervical squamous epithelium, and adenocarcinoma arising from the glandular epithelium of the endocervix, with rarer variants such as clear-cell adenocarcinoma.[4-6]

Epidemiology – global scenario. Globally, cervical cancer is the fourth most common cancer in women, with about 660,000 new cases and around 350,000 deaths in 2022, accounting for roughly 8% of all female cancer cases and deaths. Recent global estimates indicate that each day in 2022, approximately 1,800 women were newly diagnosed and nearly 1,000 women died from cervical cancer worldwide. About 88–94% of cases and deaths occur in low- and middle-income countries, with the highest incidence and mortality in sub-Saharan Africa, parts of Latin America, and South-East Asia, reflecting limited access to HPV vaccination, screening, and treatment services.

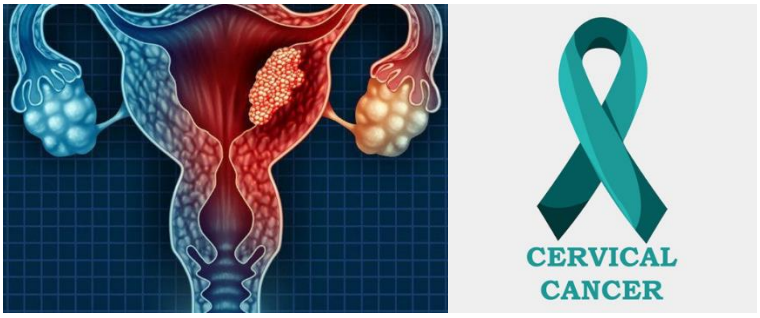

Figure-1: Cervical cancer.

You can get HPV from
- any skin-to-skin contact of the genital area
- vaginal, anal or oral sex
- sharing sex toys

Who is more likely to get cervical cancer: Cervical cancer is most common in women aged between 30 and 35, but it can happen at any age. Anyone with a cervix can get it.
You cannot get cervical cancer if you've had surgery to remove your womb and cervix (total hysterectomy).

You might also be more likely to get cervical cancer if.
- you have a weakened immune system, like if you have HIV or AIDS
- you have given birth to multiple children or had children at an early age (under 17 years old)
- your mother took the hormonal medicine diethylstilbestrol (DES) while pregnant with you – your GP can discuss these risks with you.
- you've had vaginal, vulval, kidney or bladder cancer in the past
- you smoke
- you've taken the contraceptive pill for more than 5 years – this only slightly increases your risk and for many people the benefits of taking it outweigh the risks

Epidemiology – Indian scenario: India contributes a substantial share of the global cervical cancer burden, being among the countries with the highest absolute numbers of cases and deaths. Recent comparative data show that the age-standardized incidence rate (ASIR) of cervical cancer in Indian women is about 17.7 per 100,000 person-years and the age-standardized mortality rate (ASMR) about 11.2 per 100,000, which are among the highest compared with many other countries and above the global median for cervical cancer. Within India, cervical cancer accounts for roughly 6– 29% of all female cancers depending on the region, with wide variation in incidence across population-based cancer registries (e.g., about 23 per 100,000 in Mizoram versus about 5 per 100,000 in Dibrugarh), reflecting differences in socio-economic status, screening coverage, and reproductive/sexual health practices.[7-9]

Parts of cervical cancer

The cervix has two main parts

- The ectocervix (also called exocervix) is the outer part of the cervix that can be seen during a gynecologic exam. The ectocervix is covered with thin, flat cells called squamous cells.
- The endocervix is the inner part of the cervix that forms a canal that connects the vagina to the uterus. The endocervix is covered with column-shaped glandular cells that make mucus.

The squamocolumnar junction (also called the transformation zone) is the border where the endocervix and ectocervix meet. Most cervical cancers begin in this area.

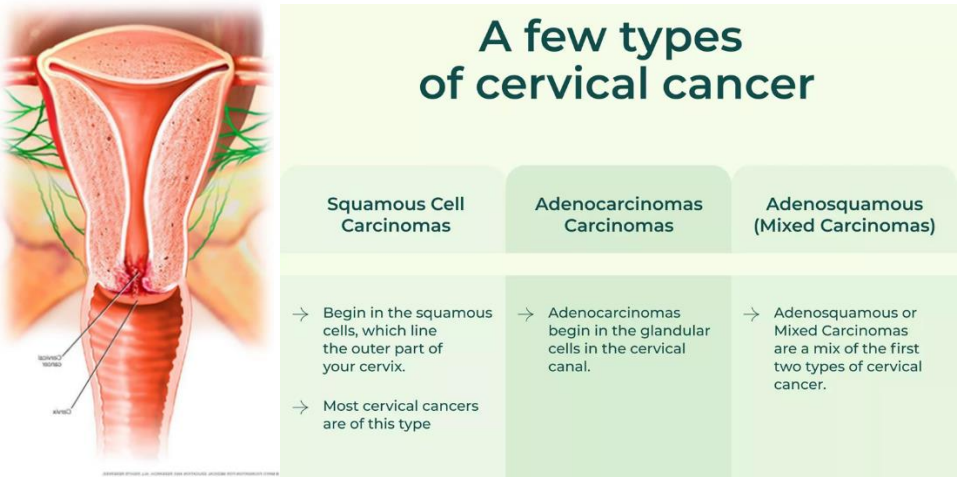

Figure 2: Types of cervical cancer.

Types of cervical cancer

Cervical cancers are named after the type of cell where the cancer started. The two main types are:

- Squamous cell carcinoma: Most cervical cancers (up to 90%) are squamous cell carcinomas. These cancers develop from cells.
- Adenocarcinoma: Cervical adenocarcinomas develop in the glandular cells of the endocervix. Clear cell adenocarcinoma, also called clear cell carcinoma or mesonephroma, is a rare type of cervical adenocarcinoma.

Sometimes, cervical cancer has features of both squamous cell carcinoma and adenocarcinoma. This is called mixed carcinoma or adenosquamous carcinoma. Very rarely, cancer develops in other cells in the cervix.

Public health relevance: Cervical cancer is considered one of the most preventable and treatable cancers because effective tools exist for primary prevention (HPV vaccination), secondary prevention (screening and treatment of precancerous lesions), and timely management of invasive disease. Despite this, it remains a major cause of premature death in women, particularly in low-resource settings, leading to loss of mothers and caregivers, economic hardship for families, and strain on health systems due to late-stage treatment costs. The World Health Organization has launched a global strategy to eliminate cervical cancer as a public health problem, targeting 90% HPV vaccination coverage, 70% screening coverage, and 90% access to treatment and palliative care, highlighting its priority status in global health policy.[10-12]

Figure-3: Identification of cancer spot.

Importance for pharmaceutical sciences: Cervical cancer is highly relevant to pharmaceutical sciences because it spans the full spectrum of drug and biologic development, from prophylactic vaccines to cytotoxic chemotherapy, targeted therapy, and supportive medicines. Development, optimization, and evaluation of

HPV vaccines (bivalent, quadrivalent, and nonavalent), topical and systemic agents for precancerous lesions, chemoradiation regimens (e.g., cisplatin-based protocols), and newer agents such as anti-angiogenic drugs and immunotherapies all involve formulation science, pharmacokinetics, pharmacodynamics, and regulatory considerations. For pharmacy professionals, cervical cancer is also central to pharmacoepidemiology and public health pharmacy: pharmacists play roles in HPV vaccine advocacy, patient counseling on screening and treatment adherence, management of adverse drug reactions, and participation in post-marketing surveillance and cost-effectiveness studies of vaccines and anticancer drugs in different health-care settings.

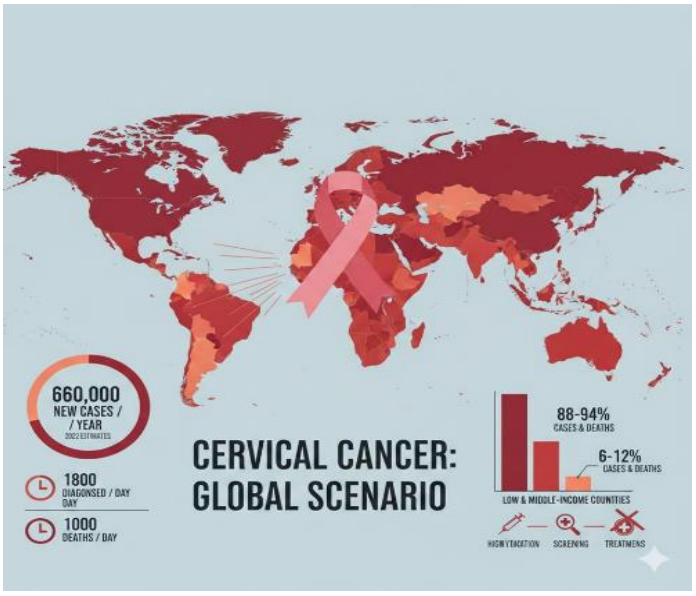

Figure-4: Global scenario of cervical cancer.

Treatment: Treatments of precancers are quick and generally painless causing infrequent complications. Treatment steps include colposcopy or visual inspection of the cervix to locate and assess the lesion followed by.

- thermal ablation, which involves using a heated probe to burn off cells;
- cryotherapy, which involves using a cold probe to freeze off the cells;
- LEETZ (large loop excision of the transformation zone), which involves removing your abnormal tissues with an electrically heated loop; and/or
- a cone biopsy, which involves using a knife to remove a cone-shaped wedge of tissue.

Early detection, diagnosis and treatment of cervical cancer.

Cervical cancer can be cured if diagnosed and treated at an early stage of disease. Recognizing symptoms and seeking medical advice to address any concerns is a critical step. Women should see a healthcare professional if they notice:

- unusual bleeding between periods, after menopause, or after sexual intercourse
- increased or foul-smelling vaginal discharge
- symptoms like persistent pain in the back, legs, or pelvis
- weight loss, fatigue and loss of appetite
- vaginal discomfort
- swelling in the legs.

Clinical evaluations and tests to confirm a diagnosis are important and will generally be followed by referral for treatment services, which can include surgery, radiotherapy and chemotherapy as well as palliative care to provide supportive care and pain management. Management pathways for invasive cancer care are important tools to ensure that a patient is referred promptly and supported as they navigate the steps to diagnosis and treatment decisions. Features of quality care include.

- a multidisciplinary team ensuring diagnosis and staging (histological testing, pathology, imaging) takes place prior to treatment decisions;
- treatment decisions in line with national guidelines; and
- interventions are supported by holistic psychological, spiritual, physical and palliative care.

As low- and middle-income countries scale-up cervical screening, more cases of invasive cervical cancer will be detected, especially in previously unscreened populations. Therefore, referral and cancer management strategies need to be implemented and expanded alongside prevention services.[13-15]

Etiology and Pathophysiology: Cervical cancer is primarily caused by persistent infection with oncogenic (high- risk) human papillomavirus (HPV) types, most notably HPV-16 and HPV-18, which together account for about 70% of cases worldwide. HPV is a sexually transmitted virus, and while most infections clear

spontaneously, persistent infection with high-risk types can result in oncogenic transformation. HPV expresses oncoproteins E5, E6, and E7. The E6 protein degrades the tumour suppressor protein p53, and E7 inactivates the retinoblastoma protein (pRb). These actions disrupt cell cycle control, prevent apoptosis, and promote uncontrolled cell proliferation, forming the basis for malignant transformation.

Mechanism of Oncogenesis: The carcinogenic process begins with HPV infecting the basal epithelial cells of the cervix during microabrasions. Oncogenic strains (HPV-16, HPV-18) integrate into the host genome and overexpress E6 and E7 oncoproteins, leading to.

- Degradation of p53 (inhibits apoptosis and DNA repair)
- Inactivation of Rb (removes control over cellular proliferation)
- Genomic instability and unregulated cell division

Progression from CIN to Invasive Cancer: The development of cervical cancer is generally a multistep process, progressing through cervical intraepithelial neoplasia (CIN).

- CIN 1: Mild dysplasia, often regresses spontaneously.
- CIN 2: Moderate dysplasia, higher risk of progression but still reversible.
- CIN 3: Severe dysplasia or carcinoma in situ, high chance of progressing to invasive cancer if untreated.

On average, it can take 10–20 years for CIN to progress to invasive carcinoma, though progression may be accelerated in immunocompromised individuals. Only a fraction of untreated high-grade CIN ultimately advances to cancer.

Figure-5: Treatment of cervical cancer.

Risk Factors

Several factors increase the risk of developing persistent HPV infection and cervical cancer, including.

- Early onset of sexual activity (increases exposure to HPV)
- Multiple sexual partners (greater risk of HPV exposure)
- Male partner with multiple partners
- Smoking (damages cervical epithelium and immune response)
- Long-term use of hormonal contraceptives
- Immunosuppression (e.g., HIV infection, immunosuppressive drugs)
- Other sexually transmitted infections
- Poor socioeconomic status

All these risk factors either increase exposure to or decrease clearance of high- risk HPV, contributing to the likelihood of malignant transformation in the cervical epithelium.

Prevention: Boosting public awareness, access to information and services are key to prevention and control across the life course. Being vaccinated at age 9–14 years is a highly effective way to prevent HPV infection, cervical cancer and other HPV-related cancers. Screening from the age of 30 (25 years in women living with HIV) can detect cervical disease, which when treated, also prevents cervical cancer. At any age with symptoms or concerns, early detection followed by prompt quality treatment can cure cervical cancer. HPV vaccination and other prevention steps. As of 2023, there are 6 HPV vaccines available globally. All protect against the high-risk HPV types 16 and 18, which cause most cervical cancers and have been shown to be safe and effective in preventing HPV infection and cervical cancer. As a priority, HPV vaccines should be given to all girls aged 9–14 years, before they become sexually active. The vaccine may be given as 1 or 2 doses. People with reduced immune systems should ideally receive 2 or 3 doses. Some countries have also chosen to vaccinate boys to further reduce the prevalence of HPV in the community and to prevent cancers in men caused by HPV.[16-18]

Other important ways to prevent HPV infection include.

- being a non-smoker or stopping smoking
- using condoms
- Voluntary male circumcision.
- Cervical screening and treatment of precancers

Women should be screened for cervical cancer every 5–10 years starting at age 30. Women living with HIV should be screened every 3 years starting at age 25. The global strategy encourages a minimum of two lifetime screens with a high-performance HPV test by age 35 and again by age 45 years. Precancers rarely cause symptoms, which is why regular cervical cancer screening is important, even if you have been vaccinated against HPV. Self-collection of a sample for HPV testing, which may be a preferred choice for women, has been shown to be as reliable as samples collected by healthcare providers. After a positive HPV test (or other screening method) a healthcare provider can look for changes on the cervix (such as precancers) which may develop into cervical cancer if left untreated. Treatment of precancers is a simple procedure and prevents cervical cancer. Treatment may be offered in the same visit (the see and treat approach) or after a second test (the see, triage and treat approach), which is especially recommended for women living with HIV.

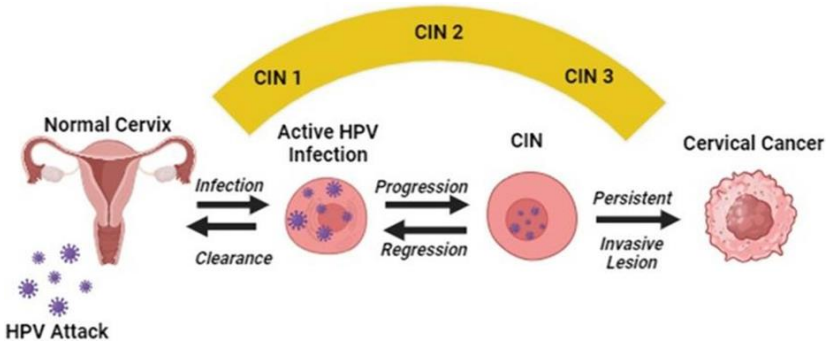

Figure-6: Developmental stages of cervical cancer.

Clinical Presentation and Symptoms: Early-stage cervical cancer is typically asymptomatic, which is why routine screening is crucial. When symptoms do appear, they are often related to abnormal bleeding or discharge. Common symptoms include.

- Abnormal vaginal bleeding (after intercourse, between periods, after menopause, or heavier/longer periods)
- Unusual vaginal discharge (may be watery, bloody, or foul-smelling)
- Pelvic pain or pain during sexual intercourse Advanced cervical cancer may present with:
- Swelling of the legs (due to lymphatic obstruction)
- Difficulty urinating or having a bowel movement
- Blood in the urine or stool
- Persistent pelvic or lower back pain
- Weight loss, fatigue, and loss of appetite

Screening Methods: Screening is vital for detecting cervical cancer at a treatable stage. The main methods include:

- **Pap Smear (Pap Test):** A sample of cervical cells is collected and examined under a microscope for abnormal changes. It is highly effective in detecting precancerous lesions and early-stage cancer.
- **Visual Inspection with Acetic Acid (VIA):** A simple, low-cost method where acetic acid is applied to the cervix, and abnormal areas turn white and can be visually identified. It is widely used in resource-limited settings.
- **HPV DNA Testing:** This test detects the presence of high-risk HPV types in cervical cells. It is increasingly used alongside or instead of Pap smears, especially in women over 30.[19-21]

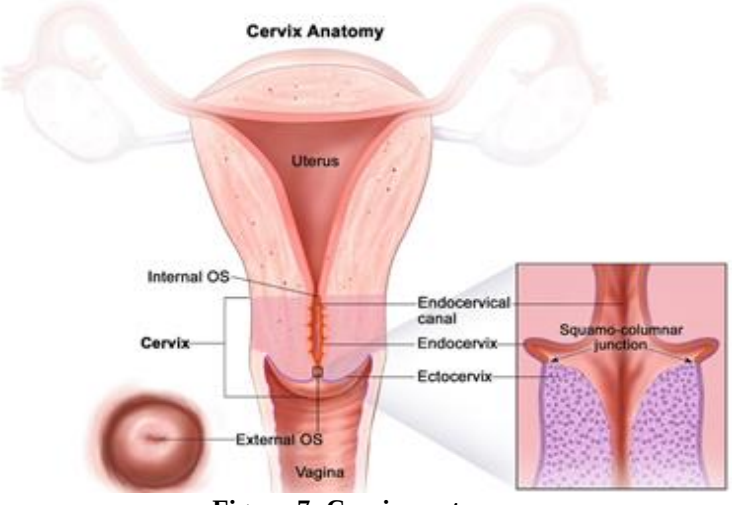

Figure-7: Cervix anatomy.

Staging Systems (FIGO): The International Federation of Gynaecology and Obstetrics (FIGO) staging system is used to classify cervical cancer based on the extent of tumour spread. The stages are.

- Stage I: Cancer is confined to the cervix.
- Stage II: Cancer extends beyond the cervix but not to the pelvic wall or lower third of the vagina.
- Stage III: Cancer extends to the pelvic wall or lower third of the vagina, or causes hydronephrosis (kidney swelling).
- Stage IV: Cancer spreads beyond the pelvis or involves the bladder or rectum.

Accurate staging helps determine the appropriate treatment and prognosis.

Figure-8: Smear test cervical cancer.

Diagnosis: The diagnosis of cervical cancer begins with routine screening, primarily through the Pap smear and HPV DNA testing, which help detect precancerous lesions and high-risk HPV strains responsible for malignant transformation. When screening results are abnormal, a detailed pelvic examination and colposcopy are performed to visualize the cervix under magnification and assess suspicious areas. Targeted biopsies, including punch biopsy, endocervical curettage, or cone biopsy, provide histopathological confirmation, which is the gold standard for diagnosis. Imaging modalities such as MRI, CT, and PET-CT are then employed to evaluate the extent of local invasion, lymph node involvement, and distant metastasis, aiding in accurate staging. Additional tests like cystoscopy and proctoscopy may be used when bladder or rectal involvement is suspected. Together, these diagnostic approaches establish the presence, type, and stage of cervical cancer, enabling optimal treatment planning.

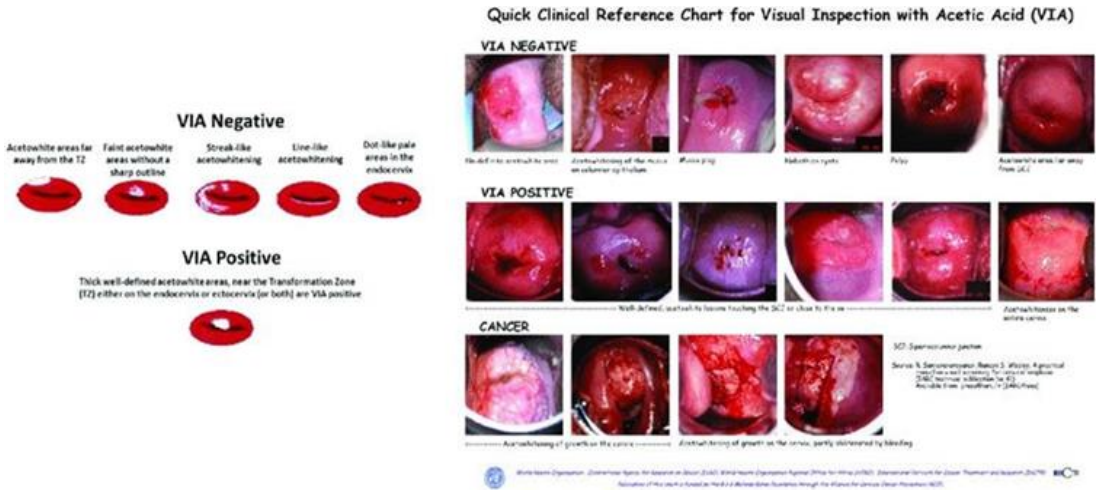

Figure-9: Diagnosis of cervical cancer.

Clinical Examination: Initial evaluation includes a detailed pelvic examination using a speculum and bimanual technique. The clinician checks for visible lesions, abnormal discharge, bleeding, and signs of local invasion, often including rectovaginal assessment to evaluate extension. Lymph node palpation and assessment for extra-pelvic spread are also done as part of comprehensive staging.[21]

Colposcopy: It is performed when screening tests are abnormal (Pap smear, HPV DNA). A colposcope (a magnifier with a bright light) is used to inspect the cervix after application of acetic acid or Lugol's iodine to

visualize abnormal acetowhite or iodine-negative areas. Abnormal regions are targeted for biopsy and further histopathological assessment.

Biopsy: Histological confirmation is required for definitive diagnosis. Directed cervical biopsy samples are collected from suspicious regions identified during colposcopy. In cases of high-grade lesions or suspected glandular involvement, a cone biopsy or LEEP (Loop Electrosurgical Excision Procedure) may be performed. Biopsy specimens are analyzed by a pathologist for cellular atypia, dysplasia, carcinoma in situ, or invasive cancer.

Imaging for Staging

- Imaging helps determine local extension, nodal status, and distant metastases, which is critical for treatment planning.
- MRI (Magnetic Resonance Imaging): Best for assessing tumour size, pelvic wall involvement, parametrial spread, and involvement of bladder or rectum.
- CT (Computed Tomography): Useful for detection of lymph node enlargement, abdominal and chest evaluation, and guiding radiotherapy planning.
- PET (Positron Emission Tomography): FDG-PET combined with CT scans detects metabolically active disease and distant metastases, and may identify lymph node involvement not seen on other modalities.
- Cystoscopy and proctoscopy may be used if bladder or rectal invasion is suspected.

These diagnostic approaches together—clinical examination, colposcopy, biopsy, and advanced imaging—enable accurate diagnosis and staging of cervical cancer, ensuring patients receive the most appropriate therapy for their disease status.[22]

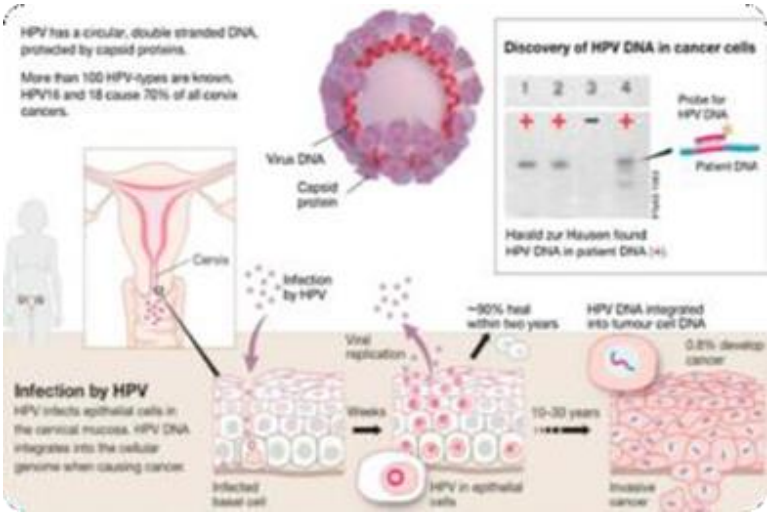

Figure-10: Histopathology of cervical cancer.

Pharmaceutics Perspective

Current Treatment Options: Current treatment options for cervical cancer primarily include chemotherapy, radiotherapy, chemoradiation, and surgery depending on the stage of the disease. Chemotherapy remains a cornerstone, with drugs such as Cisplatin, Paclitaxel, and Carboplatin widely used either alone or in combination to enhance therapeutic response. Cisplatin-based chemoradiation is considered the standard of care for locally advanced cervical cancer, as it sensitizes tumour cells to radiation and improves treatment outcomes. Radiotherapy, delivered as external beam radiation therapy (EBRT) or brachytherapy, plays a major role in regional tumour control. Surgical intervention—including procedures like simple or radical hysterectomy—is typically preferred for early-stage cases, where localized removal of the tumour can lead to complete cure. Although conventional treatments are effective, they often cause significant systemic toxicity, which highlights the need for advanced drug delivery strategies in pharmaceutics to improve patient safety and therapeutic efficiency.

Role of Drug Delivery in Cervical Cancer: Drug delivery plays a crucial role in improving the outcomes of cervical cancer therapy, especially because systemic chemotherapy causes high toxicity and often lacks tumour specificity. Effective drug delivery aims to concentrate anticancer agents directly at the tumour site while minimizing exposure to healthy tissues. However, several challenges hinder optimal drug delivery, such as multidrug resistance mechanisms, the complex tumour microenvironment, poor drug penetration into hypoxic tumour regions, and rapid drug clearance from systemic circulation. By developing targeted or localized delivery systems, pharmaceutics can help overcome these barriers, enhance therapeutic index, reduce side effects, and ultimately improve overall patient response to treatment.

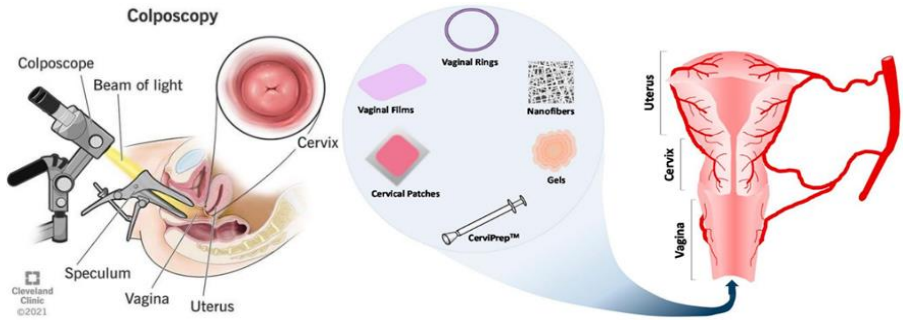

Figure-11: Colposcopy.

Novel Drug Delivery Systems: Several innovative drug delivery systems are being explored to enhance the treatment of cervical cancer. Nanoparticle-based platforms, such as liposomes, polymeric nanoparticles, and dendrimers, improve drug solubility, protect the active drug from degradation, and facilitate enhanced uptake by tumour cells through passive or active targeting. These carriers can accumulate selectively in cancerous tissues and allow controlled drug release. Mucoadhesive vaginal drug delivery systems, including gels, films, and intravaginal rings, provide localized delivery directly to the cervical region, significantly reducing systemic toxicity while achieving higher local drug concentrations. Intra-tumoural delivery approaches allow direct injection of chemotherapeutic agents into the tumour mass for maximum efficacy. Additionally, pH-responsive formulations exploit the acidic microenvironment of tumours to trigger drug release specifically at the cancer site. Targeted drug delivery systems using ligands, antibodies, or peptides directed toward HPV-associated markers or cervical tumour receptors further enhance precision therapy. These novel approaches collectively hold great promise for safer, more effective cervical cancer treatment.[23]

Controlled Release Formulations in Cervical Cancer: Controlled release drug delivery systems offer significant advantages by maintaining steady therapeutic drug levels over extended periods. Sustained release implants, such as biodegradable polymer-based devices, can continuously release anticancer drugs at the tumour site, reducing the need for repeated dosing. Long-acting injectables similarly provide prolonged drug exposure and improve patient compliance, particularly in long-term chemotherapeutic regimens. These systems minimize fluctuations in plasma drug concentrations, reduce treatment- related toxicity, and enhance the therapeutic response by ensuring that the drug remains within the optimal therapeutic window. Controlled release strategies are particularly useful in cervical cancer where consistent local or systemic drug availability is crucial for effective tumour suppression.

Vaccine Formulations (Pharmaceutics Angle): Pharmaceutics plays a central role in the formulation and development of HPV vaccines, which are the most effective preventive strategy for cervical cancer. Vaccines such as Cervarix and Gardasil are composed of recombinant L1 protein virus-like particles (VLPs) that mimic the outer shell of HPV but contain no viral DNA, making them highly safe and immunogenic. These formulations use adjuvants—such as AS04 (aluminum hydroxide + MPL) in Cervarix or aluminum-containing adjuvants in Gardasil—to enhance the immune response. Stability and storage are critical considerations, as HPV vaccines require strict cold chain maintenance to preserve antigen integrity and potency. In India, challenges persist due to limited awareness, cost barriers, and logistical issues in vaccine distribution, especially in rural areas. From a pharmaceutics perspective, optimizing formulation stability, improving thermostable versions, and enhancing delivery strategies can significantly improve vaccine accessibility and cervical cancer prevention.[24]

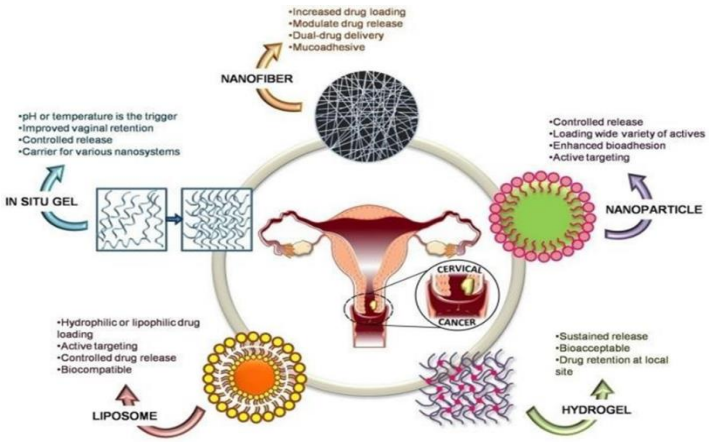

Figure-12: Vaccination in cervical cancer.

Recent Advances: Recent advancements in cervical cancer treatment focus heavily on precision medicine and innovative drug delivery technologies that aim to overcome the limitations of traditional chemotherapy and radiotherapy. Immunotherapy, particularly the use of immune checkpoint inhibitors such as Pembrolizumab, has shown promising results in recurrent or metastatic cervical cancer by enhancing the body's immune response against tumour cells. Gene therapy approaches are also emerging, targeting the viral oncogenes (HPV E6/E7) responsible for malignant transformation, thereby directly interfering with the molecular pathways driving cancer progression. Cutting-edge CRISPR-based gene editing strategies offer precise genome modification, allowing selective disruption of HPV oncogenes and potentially preventing tumour growth at its origin. Additionally, biodegradable implants designed for local drug release offer a controlled and sustained delivery of chemotherapeutic agents directly to the cervical region, reducing systemic toxicity. Another major advancement includes nanocarriers loaded with siRNA targeting HPV oncogenes, which silence the expression of cancer-promoting proteins and provide a highly specific therapeutic approach. Together, these innovations represent a significant shift toward targeted, localized, and personalized cervical cancer therapy.

CASE STUDY

Case Study: Nanoparticle-Enhanced Cisplatin Delivery

One notable example demonstrating the potential of advanced drug delivery systems is the use of nanoparticle formulations to improve cisplatin therapy. Conventional cisplatin chemotherapy is effective but often limited by severe systemic toxicity and poor tumour specificity. To overcome this, researchers have developed polymeric nanoparticles encapsulating cisplatin, allowing the drug to be delivered directly to cancer cells while minimizing exposure to healthy tissues. These nanoparticles improve drug solubility, enhance tumour penetration through the enhanced permeability and retention (EPR) effect, and allow controlled drug release within the tumour microenvironment. Preclinical studies have shown that nanoparticle-based cisplatin formulations can significantly reduce nephrotoxicity and improve overall antitumour activity compared to free cisplatin. This case demonstrates how pharmaceutical innovations can transform chemotherapy outcomes and highlights the growing importance of nanotechnology in cervical cancer management.

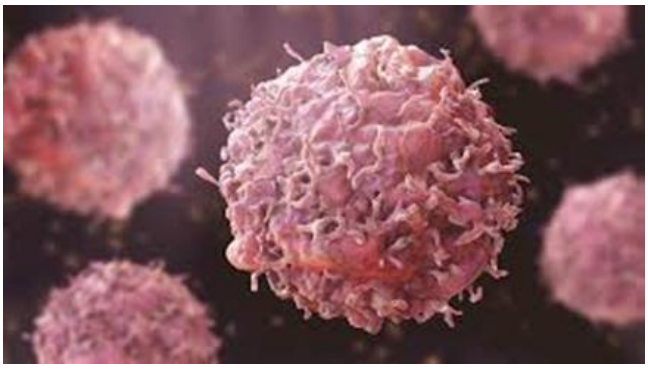

Figure-13: SEM of cervical cancer.

Challenges and Future Prospects: Despite major advancements, several challenges continue to limit the success of cervical cancer therapy. Drug resistance, both intrinsic and acquired, remains a major obstacle that reduces the effectiveness of chemotherapy and limits long- term treatment success. There is also a growing need for personalised medicine, as patients respond differently to therapy depending on molecular characteristics of their tumours. Low vaccine coverage, especially in developing countries, hampers preventive efforts despite the availability of effective HPV vaccines. Issues such as affordability, lack of awareness, social stigma, and limited healthcare infrastructure significantly contribute to poor uptake. Economically disadvantaged populations face barriers in accessing advanced therapies, making affordability a critical concern in public health. Looking ahead, the future of cervical cancer management lies in nanomedicine, targeted therapy, gene editing, and personalized drug delivery systems, which promise greater specificity, reduced toxicity, and improved patient outcomes. Continued research, improved public health initiatives, and cost-effective pharmaceutical innovations will be essential to address these challenges.[25]

CONCLUSION

Cervical cancer remains a major global health burden, especially in low- and middle-income countries, despite being preventable and treatable when detected early. Conventional treatments such as surgery, chemotherapy, and radiotherapy provide significant clinical benefits but are often limited by toxicity and lack of tumour specificity. With advancements in pharmaceutics, innovative drug delivery systems—including nanoparticles, controlled release implants, immunotherapeutics, and gene-based strategies—have opened new avenues for improving the precision and safety of cervical cancer treatment. These modern approaches enhance drug targeting, reduce systemic side effects, and hold the potential to overcome limitations

associated with traditional therapies. Overall, pharmaceutics plays a critical role in shaping the future of cervical cancer management by contributing to more effective, patient-oriented, and technologically advanced treatment strategies. Cervical cancer is a preventable and treatable disease, especially when detected early through vaccination against the human papillomavirus (HPV) and regular screening. While a significant global health issue, particularly in low-resource countries, early detection and intervention dramatically improve survival rates. Continued efforts to improve screening access and "see and treat" strategies are key to reducing the burden of the disease worldwide.

- Primary prevention: HPV vaccination is highly effective for preventing the types of HPV that most commonly cause cervical cancer.
- Secondary prevention: Regular screening is crucial for early detection. Recommended screening methods include Pap smears, HPV tests, or co-testing, depending on age.
- "See and treat" approach: In resource-poor settings, simple screening methods like Visual Inspection with Acetic Acid (VIA) allow for immediate treatment of precancerous lesions, which is vital in areas with poor follow-up rates.
- Community and healthcare system involvement: Successful screening programs require high coverage rates and the ability to provide treatment to those who test positive, highlighting the need for strong health services and community engagement.

Impact and outlook

- Global health burden: Cervical cancer remains a major cause of death for women globally, especially in countries with limited access to vaccination and screening programs.
- Survival rates: Survival is significantly higher with early detection. The 5-year relative survival rate is about 91% if diagnosed in an early stage, but drops to around 60% if the cancer has spread to nearby tissues or organs.
- Future directions: Ongoing research focuses on improving screening tests (like point-of-care HPV tests), developing more accessible vaccines for different regions, and exploring new therapies such as targeted therapies and immunotherapies.

REFERENCES

1. Bosch FX, de Sanjosé S (2007). "The epidemiology of human papillomavirus infection and cervical cancer". Disease Markers, 23(4): 213–227.
2. Sung H, Ferlay J, Siegel RL, Laversanne M, Soerjomataram I, Jemal A, et al. (May 2021). "Global Cancer Statistics 2020: GLOBOCAN Estimates of Incidence and Mortality Worldwide for 36 Cancers in 185 Countries". CA: A Cancer Journal for Clinicians. 71 (3): 209–249.
3. Singh A., & Gupta R. (2021). Advances in nanotechnology-based cervical cancer therapy. Journal of Pharmaceutical Sciences, 110(4): 1450–1462.
4. Coleman RL., et al. (2019). Pembrolizumab in advanced cervical cancer. New England Journal of Medicine, 382(20): 1923–1934.
5. Dunne EF, Park IU (2013). "HPV and HPV-associated diseases". Infectious Disease Clinics of North America, 27(4): 765–778.
6. Tewari KS (2025). "Cervical Cancer". New England Journal of Medicine, 392(1): 56–71.
7. Canavan TP, Doshi NR (March 2000). "Cervical cancer". American Family Physician, 61(5): 1369–1376.
8. Canfell K, Kim JJ, Brisson M, Keane A, Simms KT, Caruana M, et al. (2020). "Mortality impact of achieving WHO cervical cancer elimination targets: a comparative modelling analysis in 78 low-income and lower-middle-income countries". Lancet, 395(10224): 591–603.
9. Gadducci A, Barsotti C, Cosio S, Domenici L, Riccardo Genazzani A (2011). "Smoking habit, immune suppression, oral contraceptive use, and hormone replacement therapy use and cervical carcinogenesis: a review of the literature". Gynecological Endocrinology, 27(8): 597–604.
10. Snijders PJ, Steenbergen RD, Heideman DA, Meijer CJ (2006). "HPV-mediated cervical carcinogenesis: concepts and clinical implications". The Journal of Pathology, 208(2): 152–164.
11. Marrazzo JM, Koutsky LA, Kiviat NB, Kuypers JM, Stine K (2001). "Papanicolaou test screening and prevalence of genital human papillomavirus among women who have sex with women". American Journal of Public Health, 91 (6): 947–952.
12. Kufe D (2009). Holland-Frei cancer medicine (8th ed.). New York: McGraw-Hill Medical, p. 1299. ISBN 978-1-60795-014-1. Archived from the original on 1 December 2015.
13. Bosch FX, de Sanjosé S (2007). "The epidemiology of human papillomavirus infection and cervical cancer". Disease Markers, 23(4): 213–227.
14. van Nagell JR, Greenwell N, Powell DF, Donaldson ES, Hanson MB, Gay EC (April 1983). "Microinvasive carcinoma of the cervix". American Journal of Obstetrics and Gynecology, 145(8): 981–991.
15. Erstad S (12 January 2007). "Cone biopsy (conization) for abnormal cervical cell changes". WebMD. Archived from the original on 19 November 2007. Retrieved 2 December 2007.
16. Lin Y, Zhou J, Dai L, Cheng Y, Wang J (September 2017). "Vaginectomy and vaginoplasty for isolated vaginal recurrence 8 years after cervical cancer radical hysterectomy: A case report and literature review". The Journal of Obstetrics and Gynaecology Research, 43(9): 1493–1497.
17. Muñoz N, Bosch FX, de Sanjosé S, Herrero R, Castellsagué X, Shah KV, et al. (2003). "Epidemiologic classification of human papillomavirus types associated with cervical cancer". The New England Journal of Medicine, 348(6): 518–527.

18. Jones WB, Mercer GO, Lewis JL, Rubin SC, Hoskins WJ (1993). "Early invasive carcinoma of the cervix". Gynecologic Oncology, 51(1): 26–32.
19. Peng Q, Wang L, Zuo L, Gao S, Jiang X, Han Y, et al. (2024). "HPV E6/E7: insights into their regulatory role and mechanism in signaling pathways in HPV-associated tumor". Cancer Gene Therapy, 31(1): 9–17.
20. Burnett AF (2006). "Radical trachelectomy with laparoscopic lymphadenectomy: review of oncologic and obstetrical outcomes". Current Opinion in Obstetrics & Gynecology, 18(1): 8–13.
21. Cibula D, Ungár L, Svárovský J, Zivný J, Freitag P (2005). "[Abdominal radical trachelectomy--technique and experience]". Ceska Gynekologie (in Czech), 70(2): 117–122.
22. Plante M, Renaud MC, Hoskins IA, Roy M (2005). "Vaginal radical trachelectomy: a valuable fertility-preserving option in the management of early-stage cervical cancer. A series of 50 pregnancies and review of the literature". Gynecologic Oncology, 98(1): 3–10.
23. Roy M, Plante M, Renaud MC, Têtu B (1996). "Vaginal radical hysterectomy versus abdominal radical hysterectomy in the treatment of early-stage cervical cancer". Gynecologic Oncology, 62(3): 336–339.
24. Dargent D, Martin X, Sacchetoni A, Mathevet P (2000). "Laparoscopic vaginal radical trachelectomy: a treatment to preserve the fertility of cervical carcinoma patients". Cancer, 88(8): 1877–1882.
25. Preetam Datta, Dr. Dhrubo Jyoti Sen, Dr. Pruthviraj K. Chaudhary, Shloka V. Chaudhari and Honey Riteshkumar Parmar; Focus on prevention & HPV and cervical cancer: progress in prevention, vaccination and early detection: European Journal of Biomedical and Pharmaceutical Sciences, 2025; 12(11): 311-316.