
CHAPTER 1

INTRODUCTION

1.1 An Overview of Cervical Cancer

Cervical Cancer (CC) is considered as the third most common type of cancer in females. In developed nations impacting factors such as, the advancement in screening techniques and vaccination systems have intensified the burden disparity between females particularly in a poor resource environment. Owing to CC, the escalating death has been witnessed among females in the world. However, the development of advanced technology majorly focuses on cost effectiveness, sensitive and rapid CC screening (Bedell et al., 2020).

Correspondingly, contagious causes are responsible for 25% of cancer cases, and 15% of cancers are due to viral causes. In this context, a number of various viruses could contribute to the steps involved in carcinogenic processes. The Human papillomavirus (HPV) is a significant contributor to cancer, where 30% of all cancers are caused by infectious agents. In the CC and many other tumors, RNA's non-coding single strands, known as miRNAs, play a critical role. Consequently, HPVs are persistent and responsible for high-risk oral and various malignancies, which affect the neck, head, anus, vagina, penis, vulva, and particularly the cervix; however, viral infections are especially responsible for all CCs (Sammarco et al., 2020).

Meanwhile, cervix is the bottom portion of the uterus in the female reproductive system which has a length of 2 to 3 cm and it has a rough cylindrical shape. The central, narrow cervix canal runs with complete length, associating the uterine cavity and vagina lumen. An opening of the cervix to the uterus is known as internal os whereas, opening leading to the vagina is known as external os. The lower part of cervix is called vaginal portion of cervix and it bulges into the vagina top. The cervix is made up of various types of microscopic cells.

Furthermore, individual cells have limited lifespan and separated to produce new cells based on the necessity of the body. Sometimes, the process is disturbed and the cell divides when new cells are not essential, or it may develop abnormal cells. The growth of abnormal cells can lead to malignancy. The diverse changes in cervical cells were known as dysplasia.

The different stages of CC are predicted using a five stage system which is mentioned below in detail.

- **Stage 0:** The presence of pre-cancerous cells.
- **Stage 1:** The evolution of cancer cells in the cervix deeper tissues from the surface that affects the uterus and lymph nodes.
- **Stage 2:** Advancement of cancer cells beyond the uterus and the cervix, but fails to reach pelvis walls or the vagina's lower part.
- **Stage 3:** The presence of cancer cells in the lower area of the vagina.
- **Stage 4:** Possible infection in rectum or bladder and can infect outer pelvis. Later, it affects distant organs (Hagar Kamal et al., 2021).

In general, CC originates in the cervix part, a small opening into the uterus associated with the vagina by the endocervical canal. It is separated into endocervix and ectocervix. The endocervix is covered with simple columnar epithelial cells, while ectocervix covers stratified squamous epithelial cells. The columnar epithelial and stratified squamous constitutes the squamocolumnar junction, which leads into the endocervical canal.

The regions where the mentioned areas meet are known as Transformation Zone (TZ). It comprises of a portion that replaces the columnar-lined epithelium of the endocervix known as metaplastic epithelium. The TZ is a site for an improvement of CC due to its main site where premalignant transformation occurs through insistent HPV infection. There are two main histological subtypes of CC. They are Adenocarcinoma (ADC) and Squamous cell Carcinoma (SCC) (Burmeister et al., 2022).

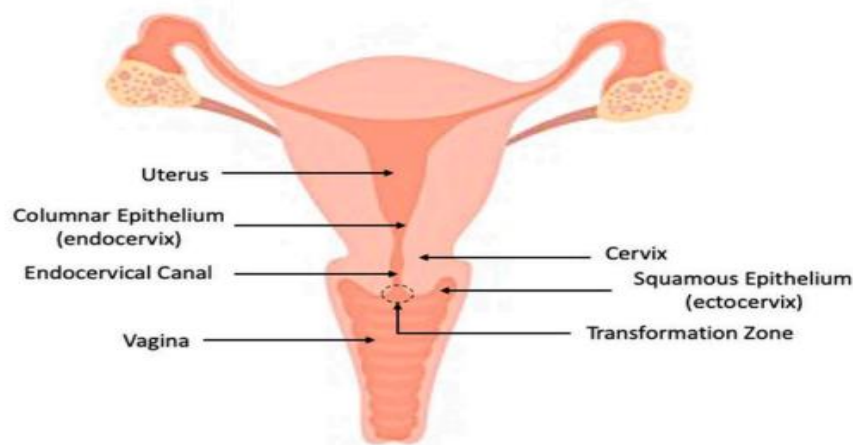


Figure 1.1 Cervical Cancer's Anatomical Location (CA Burmeister et.al. 2022)

The figure 1.1 shows the anatomical representation of the female reproductive organ. The TZ is the area where the CC improves in the females' body.

Correspondingly, the most common type of CC is SCC, which comes under 75-90% of CCs, followed by ADC, which accounts for 10-25% of all CC cases. It has been described that the persistent infection with high-risk HPV (hrHPV) types 58, 52, 35, 33, 31, 45, 18, and 16 are the casual factors in the improvement of CCs. Such histological types are related based on the patient's prognosis. Treatment suggested for early stage is surgery and chemoradiotherapy for an advanced disease, along with survival results being uncertain (Campos-Parra et al., 2022).

Similarly, an insistent infection with HPV is demonstrated as a significant etiologic factor for the CC. The types of HPV, such as HPV16 and HPV18, are responsible for 71% of CCs. Additionally; other risk factors are usage of oral contraceptives, an infection of Human Immunodeficiency Virus (HIV), and risky sexual behaviors. These factors have an effect by impacting the acquisition of HPV cause or impairing the response of the immune system after the HPV infection. Nonetheless, screening and prophylactic vaccination are often identified as primary and secondary methods, respectively, for CC prevention (Lin et al., 2021).

Moreover, HPV is considered essential, but not a sufficient etiological factor for CC. HPV in general is known as a sexually transferable infection. However, many HPV infections eradicate the immune system in the human body. Some genotypes are related with high oncogenicity, which is named hrHPV. Commonly, HPVs are classified based on their tropism as cutaneous epithelia and mucosal; these low-risk HPVs could cause benign skin warts and genitalia. Furthermore, HPVs are presented in more than 95% of CCs. Henceforth, the treatment techniques and results for patients with CC are highly dependent on the predicted stage of disease.

In a similar vein, CC precursors are categorized as dysplasia grades of growing severity. The Cervical Intraepithelial Neoplasia (CIN) grades are CIN1, CIN2 and CIN3. CIN1 is recognized as Low-grade Squamous Intraepithelial lesion (LSIL), which signifies productive HPV infection. Additionally, CIN2 and CIN3 are acknowledged as High-grade Squamous Intraepithelial Lesions (HSIL), which are deliberated to be immediate lesions of

precursors. Treatment techniques and results for patients along with CC are vastly dependent on disease level at prediction (Ferrall et al., 2021).

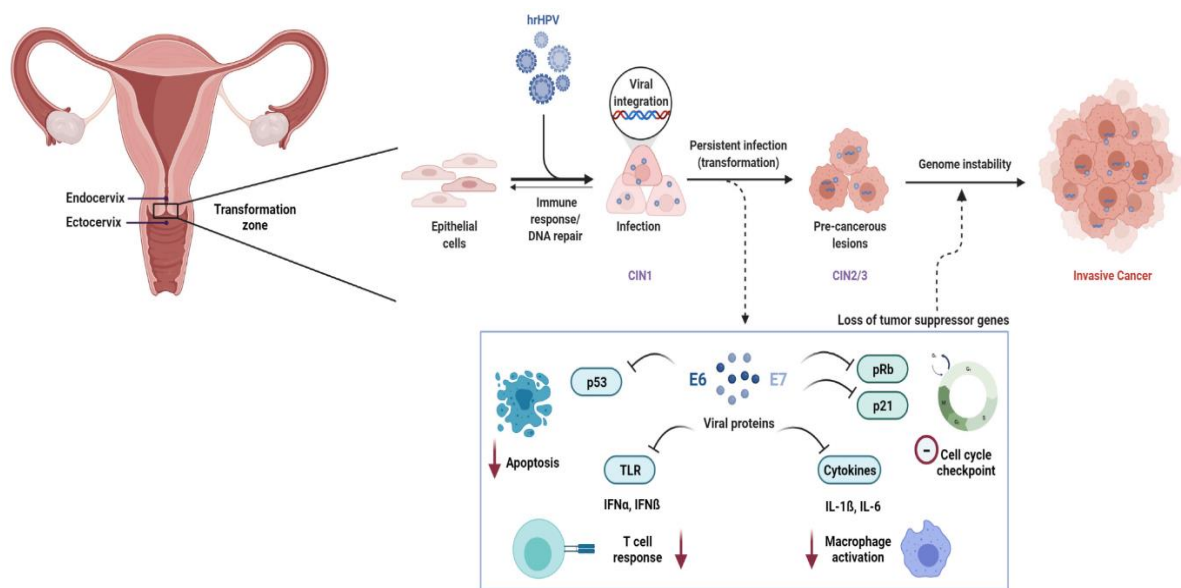


Figure 1.2 Pathogenesis of CC (Ramachandran et al., 2021)

Figure 1.2 shows the pathogenesis of CC. Epithelial cells located in the TZ acquire lesions due to the continuing infection along with hrHPV. Often, these lesions resolve upon the viral combination; cells were transformed and processed from CIN1, CIN2, and CIN3. Simultaneously, vital proteins such as E6, E7 are released, which prevents apoptosis mediated by TP53 and disrupts the cell cycle checkpoint controlled by p21. T-cells respond via Toll-Like Receptors (TLR), and cytokines activate macrophages, which leads to inadequate viral replication and immune response, resulting in genome instability, uncontrolled cell proliferation, and the progression to Cancer in Situ (CIS) also known as invasive cervical cancer (Ramachandran et al., 2021).

Concomitantly, other than HPV, several factors contributed to the further development of CC, including high parity and continuous usage of oral hormonal contraceptives, a co-infection along with HIV, promiscuity, and smoking Tobacco (comprised of cigars, pipes, hookah, shisha, and cigarettes). Furthermore, co-infection, along with immune suppression, chlamydia trachomatis, herpes simplex virus type-2, and nutrient problems, also contribute to CC progression and development.

Similarly, environmental risk factors also include compounds related to cigarette smoke, tar-based vaginal sanitary products (lysol), coal tar derivatives, and the smoke

inhaled from the stoves of biomass burning. Therefore, these environmental factors could trigger the signaling pathways that are responsible for HPV carcinogenesis-related cancers (Hull et al., 2020).

In the following study by P. E. Castle et al. (2021), the benefits of HIV care that goes beyond the risk reduction of CC and their impact in each step along cancer control continuum includes:

- More efficient secondary measures like diagnosis, prediction, cervical pre-cancer treatment and early cervical cancer.
- In the incidence of CC and mortality attained by primary, secondary and tertiary prevention services, which is highly effective in better HIV care.
- The developing immune response towards the prophylactic HPV vaccination is significant for vaccine efficiency among immune-suppressing populations.

Basically, CC is preventable and curable. However, the cure rate depends on the prediction stage and the treatment efficiency. The target of tertiary prevention is to enhance the patient's life quality and decrease the disability by effective rehabilitation and treatment. Hence, the multidisciplinary teams are invigorated to work together to examine and prepare for conventional health factors such as financial resources, human resources, and infrastructure. Therefore, the recommended factors for active tertiary prevention are

- Provision of the most suitable treatment based on the prediction.
- Provision of referral mechanism to encourage timely treatment and diagnosis.
- Provision of palliative care for progressive-stage CC patients (Castle et al., 2021).

Approximately 90% of CC patients suffered from most common sexual dysfunction including dyspareunia, lack of desire, and vaginal dryness at several points while undergoing treatment. Moreover, most of the cancer patients experienced tension, stress, anxiety, and depression disorders. Changes in sexual desire and physiological dysfunction in sexual desire are marked as sexual dysfunctions. In addition, an arousal disorder or sexual interest, pelvic pain or genital, and orgasm disorder are the three frequent sexual dysfunctions in females.

Since the CC patients plead for life satisfaction and sexual well-being while undergoing radial hysterectomy, they encounter two chronic shortcomings such as vaginal

shrinking and vaginal shortening, which include factors such as feminine shortening, chronic pelvic pain, pubic numbness, lymphedema, anorgasmia, and sexual dissatisfaction. Due to the resection of vascular and nerve supplies in the vagina during radical hysterectomy, sexual function could be witnessed (Abd El Salam et al., 2021).

Contrastingly, external factors influencing the high risk HPV infection that results in cervical carcinogenesis are mentioned below. It includes high parity, long-run use of tobacco, lifestyle factors like multiple sexual partners, immune suppression, diet, oral contraceptive pills, early-age intercourse, and co-infection with other sexual transmission agents. However, the development of diverse screening methods and rates of epidemiological patterns minimizes the impact of CC, especially in several developed countries. Owing to the existing solutions for CC detection in terms of epidemiological patterns comprised of HPV genotypes is effective in controlling and preventing CC infection.

In addition, a healthy diet of vegetables and fruits plays one of the most important roles in reducing the risk of CC, which includes the consumption of fruits and vegetables rich in vitamin C, carotenoids, and Vitamin E, containing retinol and folate which has minimal induce to CC infection. As a result, mortality and incidence of CC are still considered major public health problems worldwide except for several developed regions due to the availability of resources for the detection and prevention of CC. Identifying the variations in CC tracking trends and epidemiological patterns would give insight into progressive assessment and challenges in CC prevention to facilitate the eradication of CC (Pimple et al., 2022).

According to World Health Organization (WHO), cervical cancer is assessed as the third most common cancer in global women population, with about 6,60,000 new cases and almost 3,50,000 deaths in 2022. Based on the Indian Council of Medical Research's National Cancer Registry Programme (ICMR-NCRP) 2023 (Malabadi et al., 2024), it is observed that the number of cervical cancer cases in India was above 3.4 lakh which is currently more prevalent (Economic Times, 2024)

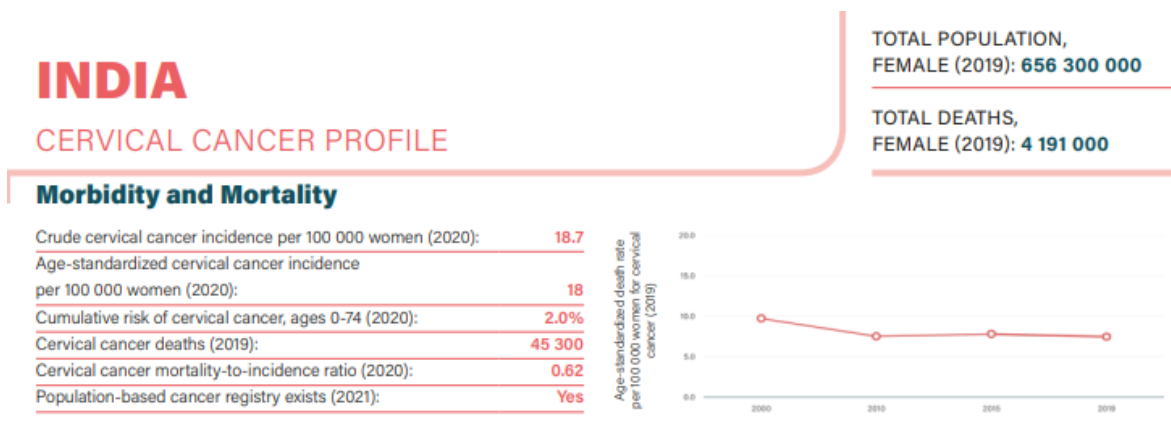


Figure 1.3 WHO Cervical Cancer Country profile of India (WHO, 2021).

Figure 1.3 shows the Cervical Cancer Country profile of India published by the World Health Organization. The WHO website provides country profile data till 2020. In the figure, the total number of demises due to cervical cancer is shown as 45300. It is an average of 3775 deaths in a month in India due to CC. The crude cervical cancer incidence per 100,000 women is shown as 18.7. The term "crude" in CC statistics refers to the number of new cases reported in a given population during a specific period without adjusting the age (WHO, 2021).

1.2 Importance of Cervical Cancer Detection

CC Detection is accomplished by asymptomatic tests and screening of females to detect the pre-cancerous modifications, which are further harmful if not treated. However, screening or detection is highly preferred to track the changes in the working of a regular organ system. If females with abnormalities are detected, further predictions and possible treatment are prescribed to prevent the progression of cancer in the early stages. This includes numerous tests for successful screening of CC, where a Pap smear is highly preferred. It is considered as one of the tests preferred for huge populations to decrease the mortality and incidence of the CC (Agustiansyah et al., 2021).

The existing trends of AI, such as Deep Learning and Machine Learning, are highly utilized for CC detection, physical activity recognition, the cognitive health assessment of dementia individuals, breast cancer detection, thermal sensation detection, and brain tumor detection. At present, with the rapid advancements of technology in computer technological innovation and clinical innovation, different diagnostic and screening strategies depend on Computer-aided Design (CAD). Additionally, data mining methods are more useful in the

medical field to elevate the prognosis & diagnostic indicator applications for appropriate early treatment of serious condition diseases. The major disadvantage of the data mining techniques is to maintain the data standards in a hospital environment and increase the recovery rates of cancer patients (Mehmood et al., 2021).

Recently, cancer prevention techniques are responsible for preventing 37% of CC cases with the condition of early detection and are considered curable. Meanwhile, processing the low-level features requires more effort for optimal classification, which may lead to intelligent learning failures due to misclassification. This can be overcome by feature extraction techniques in Machine Learning based mechanisms for detection strategies to acquire an enhanced CAD framework. On the contrary, several testing and predicting procedures requires different data that results in complications. Thus, an optimal screening method is considered as a vital issue for diagnosing the component behavior of the person. Therefore, the primary risk factors for the contiguous CC are adolescent pregnancy, cigarettes, oral prevention methods, and poor menstruation sanitation (Lilhore et al., 2022).

As mentioned earlier, early-stage presentation has a high chance of curability due to precise cancer treatment policies. A symptom that undergoes prompt support might lead to early-stage predictions and being aware of risk factors and symptoms. Individual understanding of disease risks and its symptoms are included with lay beliefs that could also influence help-seeking activities and risk reduction.

The predictors, nature of cancer symptoms and awareness of risk factors are significant to underpin the improvement of locally related interventions. Programs focused on raising awareness among public and lay medical workers on CC showcases promotion of support-seeking activity and down staging disease. The differences between rural and urban settings within a country underscore a requirement for geographically targeted intervention practices (Moodley et al., 2020).

In the United States, CC screening method is responsible for minimal mortality and incidence rates. In contrast, diverging socioeconomic and racial disparities encountered in the screening method results in disease existence. In addition, the screening rates fell short of the focused levels set forth by healthy people in 2020. The guidelines of screening type, risk-benefit considerations, and optimal interval have evolved due to data emergence. Congruently, the screening guidelines are slightly shifting to recommend HPV testing alone

rather than a combination of HPV and Pap smear testing. Primary care clinicians play an important role for guide-lining HPV vaccination for young adult patients, adolescents and in executing the comprehensive evidence for CC screening activities (Stumbar et al., 2019).

Correspondingly, treatment at initial stage cancer often is surgical therapies such as cervical conization, radical hysterectomy, or total simple hysterectomy to some extent of CC transmission. In recent years, platinum-based chemotherapy treatment series has been applied for advanced and recurrent CC. Although screening and innovative preventive approaches enhance the survival rate of CC, drug resistance and metastasis are still prevalent.

Moreover, several reproductive factors, including genetics, sexually transmitted infections, hormonal infections, and host factors, are highly responsible for the CC incidence. A combination of economic, biological and health factors are contributed to the CC incidence. A huge proportion of CC could be effectively prevented through lifestyle development, timely treatment of pre-cancerous lesions, prevention programs, and smoking cessation (Balakrishnan et al., 2021).

In parallel, necessary impact indicators of CCs are death and incidence. Establishing the cancer register is significant in monitoring the death and incidence rate of CC patients. Thus, the register could help to assess the long-run impacts of cancer screening, vaccination, and treatment. The main reporting and recording tools used for immunization have been adapted to encompass the HPV vaccine. The tools for reporting and recording should comprise the tally sheet, defaulter tracking system, stock record, immunization register, immunization card, and combined monthly report.

Furthermore, CC prevention components and control system consists of primary prevention, secondary prevention, and tertiary prevention. Some CC preventive measures, such as HPV vaccination and safe sex practices, are difficult to practice due to affordability and screening in most of the countries. CC control measures and prevention could be effectively implemented by 2030, and almost 800,000 cases of CC would be diagnosed annually. Women with HIV infection have a higher risk for CC than women without HIV infection (Ersado, 2021).

Concomitantly, the impact of the CC screening method on mortality and incidence depends on effective screening, patient participation, and diagnostic workups such as colposcopy, treatment and further follow-ups. The high CC mortality and incidence rates in

older women were witnessed. Thus, older women with results of positive cancer screening tests are perplexed compared to young women. The impact of CC detection relied on sensitive screening. To attain high protection against cancer, women should take part in screening frequently. As the detection is considered significant, it reduces the disease severity and the number of deaths from the disease.

In accordance with the seriousness of a typical CC screening test outcome, females either undergo repeat testing or prefer colposcopy. The colposcopy performance is exceedingly observer-dependent, and subsequently, appropriate education and colposcopists training are significant in confirming high quality and decreasing the omitted cancer risk. In aged women, colposcopy performance is often reduced, especially because of epithelial weakness of the cervix that is integrated with hormonal changes. At the same time, menopause is the reason for the squamocolumnar junction retraction into the cervical canal. An insufficient colposcopy risk upsurges along with age; almost 67% of females aged 61.5 years have an inadequate colposcopy (Gustafson et al., 2021).

Similarly, in past years, CC prevention has undergone various modifications with the establishment of HPV vaccination, in which several countries witnessed an intense decline in HPV-mediated CC. However, the prevention mentioned above strategies, such as vaccine availability, are restricted to highly developed countries due to economic considerations.

Additionally, an alternative to the cytology is major DNA testing that detects 99.7% of CCs caused by HPV. The risk of HPV-DNA testing among women (who are HPV-negative) is trivial in CC detection and requires retesting for possible detection. The HPV detection advantage is tempered through the improvement of better triage techniques. Unique vulnerabilities and HPV of the cervical TZ are some of the potentials for healthier screening, diagnostic markers, and technical developments (for example. sequencing/omics). It is inexpensive to execute, and CC screening reverts the disease diagnosis instead of detecting the presence of HPV (Shiraz et al., 2020).

1.3 Significance of Cervical Cancer detection using AI

According to the American Cancer Society, the screening test is responsible for risk prevention by evaluating unvaccinated women. The natural evolution of HPV- infected CC is depicted in Figure. 1.4.

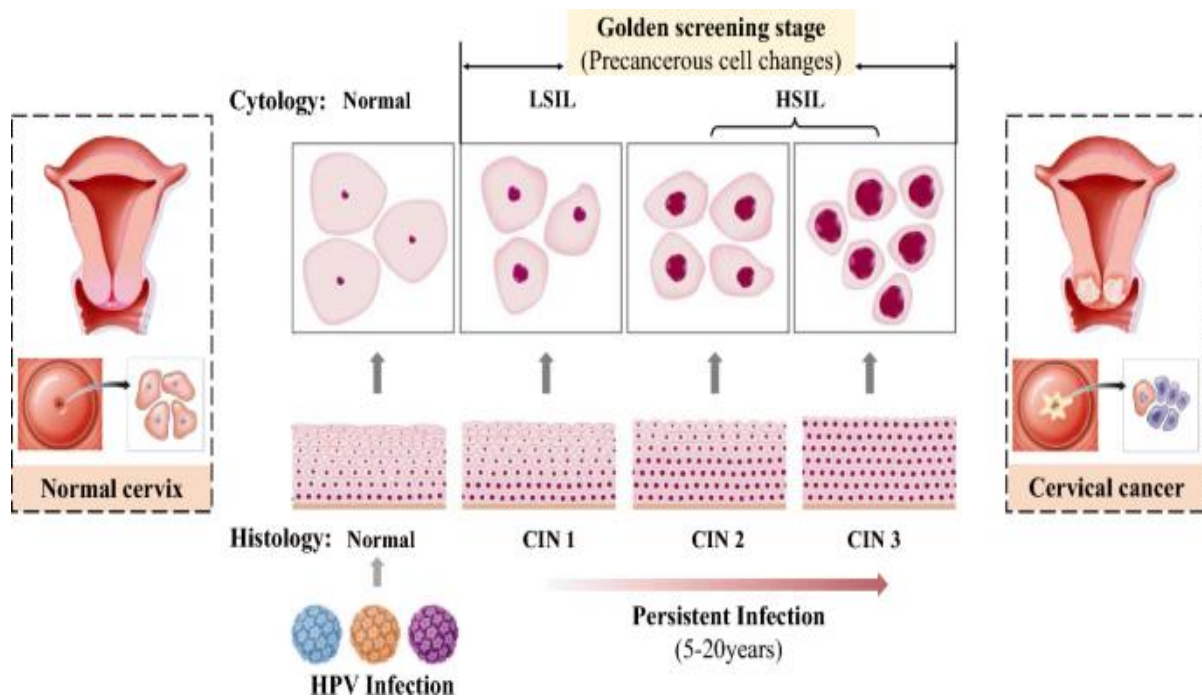


Figure 1.4 Natural Evolution of CC Infected By HPV (Jiang et al., 2023)

Figure 1.4 illustrates CC infected by HPV infection and the normal cervix. Within 30 years, nearly 30% of CIN grade 3 lesions are developed into invasive cancers. The detection and diagnosis of these lesions were done through slow progression, which offers many opportunities. The most effective way to avoid CC in women is by screening and treatment of pre-cancerous lesions.

The mortality rate was decreased because of continuous improvement of screening techniques with an increased rate of CC detection. However, Low and Middle-Income Countries (LMICs) face the most CC deaths. Many effective screening programs are not implemented and maintained because of the weak health infrastructure. Usage of ineffective techniques could lead to imprecise detection of lesions. Hence, an appropriate model needs to be used to enhance the process of cervical cancer detection.

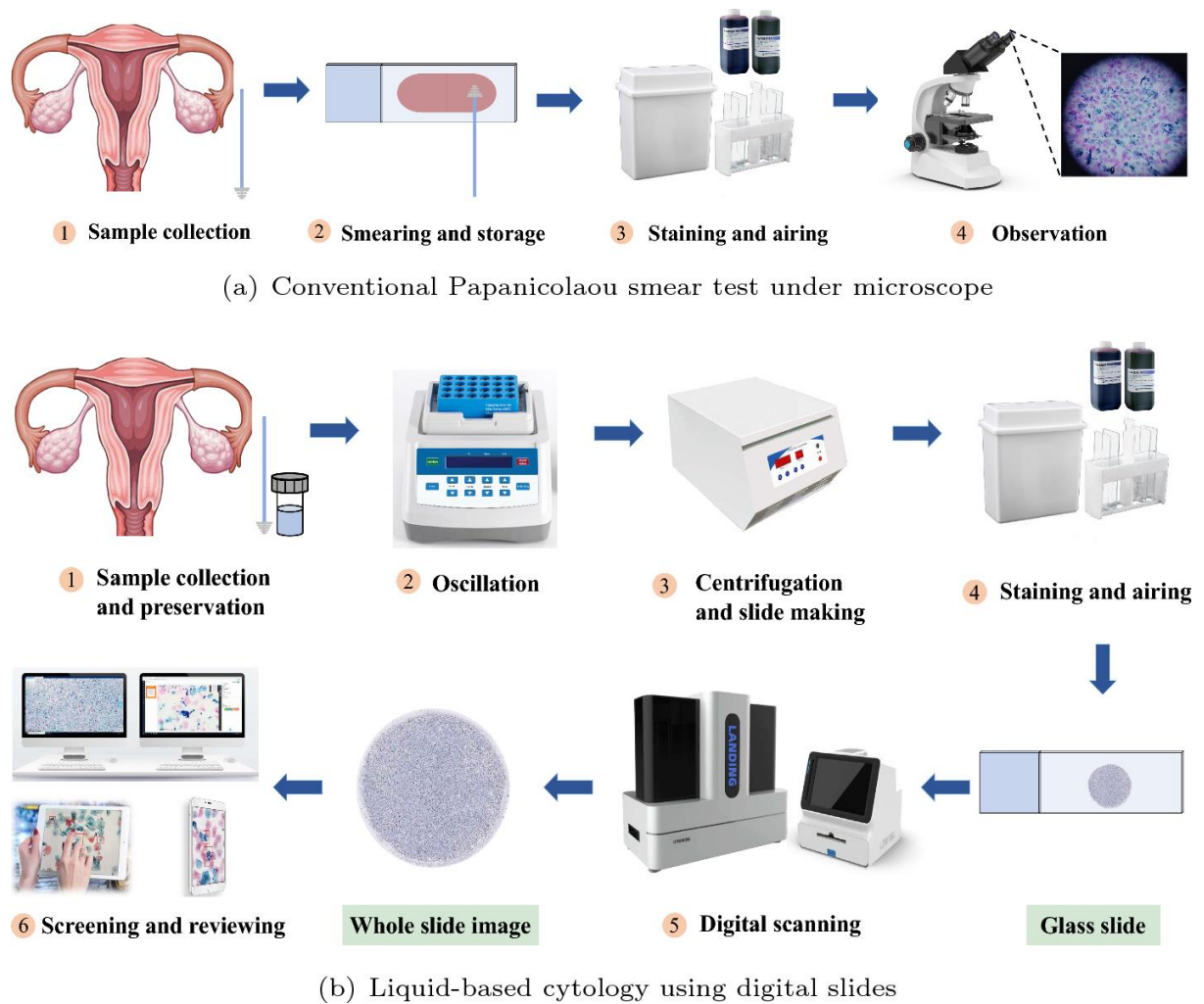


Figure 1.5 Traditional methods used for CC detection (Jiang et al., 2023)

Figure 1.5 showcases the process involved in traditional methods like the Papanicolaou smear test and liquid-based cytology using digital slides. The main goal is to develop a more accurate and cost-effective CC screening method.

AI techniques are widely used to overcome the issues in many sectors, including the medical field; they are used for retinal disease classification, treatment, image detection of tumors, and skin tumor classification. Using the complex algorithm, AI can show promising outcome and automatically identify images for data processing, feature extraction and classification. AI is able to detect and treat CC in the early stage, which leads to improving diagnostic accuracy and fewer manual resources (Hou et al., 2022). Moreover, traditional colposcopy is an overburden in the healthcare system because women in LMICs sustained to agonize the encounters of insufficient performance (Broutet et al., 2022).

Many researchers attempt to find an efficient solution for improving cervical screening and the performance of colposcopy. To obtain High-Definition (HD) cervical images for diagnostic purposes, the conventional binocular colposcopy is accelerating towards the direction of digital colposcopy. The hospitals are more digitally enabled, thereby empowering the colposcopists with advanced equipment. Owing to a high degree of inter- and intra-colposcopic variability, digital colposcopy has augmented the accuracy of cervical examinations, and it remains sub-optimal in medical practice.

To overcome these problems in colposcopy, AI is capable of providing a better solution in recent years. The characteristics of cervical lesions from the images of annotated colposcopy are incorporated into digital or automated colposcopy by AI methods, namely Deep Learning (DL) algorithms. The performance of colposcopy is improved with dynamic digital imaging by this approach in the subjectivity of traditional colposcopy. With the aim of enhancing clinical workflow in a busy colposcopy clinic, the advantage provided by AI gives diagnostic outcomes in real-world scenarios.

Furthermore, the gap between primary care hospitals and tertiary hospitals is due to the accessibility of cloud-based AI platforms because of the imbalance of medical resources available in rural and urban areas. The diagnostic performance of colposcopy in the identification of CINs and guidance of biopsy procedures will be improved by the advancement and the application of AI-guided colposcopy. This plays a vital role in improving clinical imaging judgment and optimizing colposcopy services (Xue et al., 2020).

A well-trained person along the best-functioning healthcare infrastructure is essential for Visual Inspection with Acetic acid (VIA) based screening programs. A skilled healthcare worker is required in order to achieve diagnostic accuracy. To identify women with a high risk of CC, the VIA is connected with a problem of over-treatment in a single-visit approach along with failing possibilities (Cuzick et al., 2008).

In addition to CC screening, AI has increasingly been used in healthcare industries in recent years. The application of AI in HPV colposcopy, cytology, and testing has attained a good rate of detection of pre-cancerous lesions with a good precision rate in both low and high-income countries. During the screening process in a primary care setting, the AI could improvise the decision support system function and precision of VIA in order to obtain better performance (Nakisige et al., 2023).

In the traditional biopsy routine for CC diagnosis, the process to obtain a tissue sample includes the uterine cervix observed with a colposcope by the gynecologists manually. The colposcopes are expensive and large, which is the first problem of this method. The next issue is the correct part of the cervix tissue to be obtained by the practice and experienced gynecologists (Ito et al., 2022).

The recent advancements in AI-related image identification technology direct many perspectives in AI-based clinical tests. An early accomplishment in AI related to the analysis of cervical images for screening is a promising application (Egemen et al., 2024; Shanthi et al., 2022), which has yet to be proven to be convenient. Some important lesions were revealed through several years of research during the redesign and interdisciplinary process. AI evaluated the individuals with triage HPV-positive assisted visual. To determine which area of the cervix to biopsy, the most high-resource settings with highly magnified visual evaluations of the cervix through physicians with colposcopy are measured, primarily to demonstrate cancer. Rather than excision to assess the need for treatment, a simpler unmagnified VIA is often used for triage and suitability for a simple thermal ablation procedure (Egemen et al., 2024).

In LMICs, 90% of deaths occur because of the CC across geographical regions characterized by varying economic conditions. Efficient early pre-cancer identification with the help of colposcopy tests and Pap smear cytology-based tests by high-income countries minimizes the deaths from preventable CC. Due to the lack of resources and experts required, these tests have proven struggles to demonstrate and scale in LMICs. To identify high-risk populations, the cytology test is frequently emphasized, along with a molecular test, to determine the HPV, which usually has low specificity.

Many low-income countries lack cytology-based tests because of their resources, demand for complex infrastructure, and high-quality healthcare services. The most expensive and resource-constrained settings of the LMICs are molecular tests. This method is a barrier for women in rural areas because the process requires women to make several visits to the health center. The health center provides such a service, but women have to travel several hours or a day to reach it.

In large parts of LMICs, there is a lack of expensive devices and expert gynecologists to access the visual inspection with colposcopy. However, another alternative for this test

that does not need any laboratory equipment, resource-constrained settings, and the results come quickly in VIA. Instead, an effective single-visit screen method can be implemented as it permits women to be diagnosed instantly by ablating the target cervix region of pre-cancerous tissue by cryotherapy and thermoblation (Poudel et al., 2024).

Overall, all CC cases contain 15 carcinogenic HPV kinds of genotypes produced by the determined infection. In the development of CC, there are four stages:

- In the cervical transitional zone of metaplastic epithelial infection
- A persistent HPV infection
- Development of constantly infected epithelium to cervix pre-cancerous lesions
- Penetration of the epithelial basement membrane.

The age-appropriate females are protected from HPV infection by the HPV vaccine, and the coverage that can be provided by the HPV vaccine remains less in some developed countries. About 30% of all Cervical Intraepithelial Neoplasia (CIN) level 3 lesions may progress to invasive cancer in nearly 30 years. This is because of the slow progress of cervical lesion identification and diagnosis, which presents a number of very expensive opportunities. The death rates have decreased, and cancer identification rates have increased due to the improvement of screening techniques. However, LMICs faced a high rate of death. Due to a lack of medical conditions, the experience and quantity of physicians are relatively low in diagnosis, effective screening, accuracy, generalizability of screening, and prevention, which are important for early CC screening. It is important to develop cost-effective and precise methods for CC screening and treatment. AI is widely used in the detection of several diseases, namely tumor image diagnosis, skin cancer classification, and retinal disease and classification. It helps in improving the accuracy level and limits the manual power (Liu et al., 2023).

AI and DL technologies have gradually developed in recent years. Diagnostic techniques like counting methods of DL and intelligent recognition of medical images have made the usage of AI possible with pathology, X-ray, mammography, and CT.

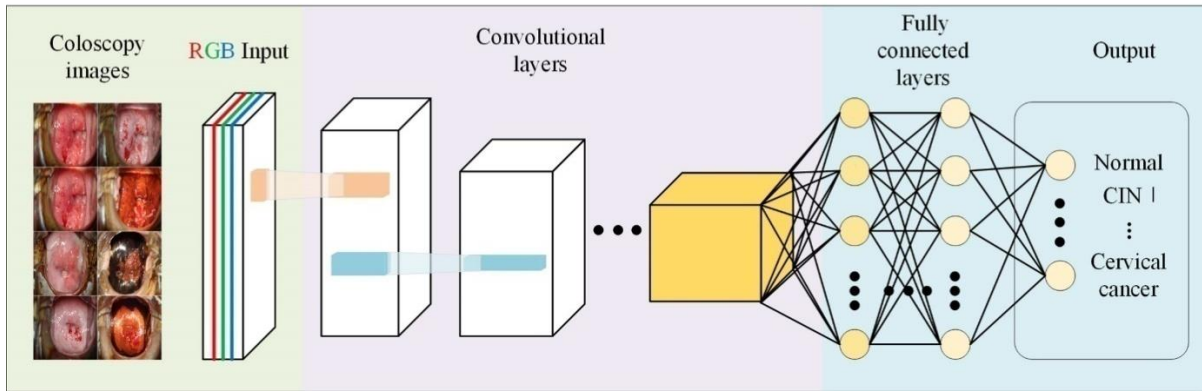


Figure 1.6 AI based approaches for CC detection (D. Sehra et al 2023)

Figure 1.6 depicts the incorporation of AI-based approaches namely CNN for effective detection of CC. In first step, remote slide interpretation, automated microscopes, and telepathology are used to improve the speed and data quality of whole slide scanners. Particularly for a second option, the present telepathology is an integral part of almost every pathology, and even adoption was slow. Through the millions of cervical specimens, the use of AI in laboratory medicine was the next technological development.

In primary hospitals without cytopathologists, the system was executed in Hubei province, China, and is the first AI diagnostic technique used for large-scale CC screening. The data are evaluated at a very high speed in the cloud, and it allows the identification process without physical transportation of samples. The cytology results for patients provide reduced time costs and enhanced the fast turnaround time and accessibility of expert pathologists. Robotic data analysis and slide scanning are the first steps towards the present use of AI (Turic et al., 2021).

To improve the CC screening efficacy in China by AI screening that offers a real-world substitute to overcome the pathologists' shortage. Thin Prep Imaging Systems along with Liquid Based Cytology (LBC) are mainly used in previous automated screening systems and based on the Convolutional Neural Network (CNN) are used in Becton Dickinson Focal Point GS Imaging System.

Due to their high cost, the two systems are also utilized in small-scale screening practices and hospital environments in China. With the affordable price for screening and the rapid development of AI using DL algorithms, Landing Medical Laboratory developed the AI cytology system and implemented the LBC testing, which outperformed AI-assisted with manual LBC testing by 5.8% of high sensitivity screening.

To choose women with low-grade cytology for a colposcopy test in the UK, the cost-effective manual AI-aided testing and AI-based LBC were evaluated as the crucial screening when utilizing HPV-DNA testing as the triage. Many studies stressed that manual LBC testing is much less cost-effective than AI-based LBC. When compared to other methods such as primary HPV and Auto LBC, primary HPV screening saves more years of life and cost (Shen et al., 2023).

In India, Aindra Systems has developed CervAstra, which uses an AI-based pathology system. Although the classification model is not disclosed, it contains two components. Aindra IntelliStain, an automated stainer that uses futuristic software and mechatronics to stain biological samples pasted on glass slides. Aindra VisionX, provides clean and clear Whole Slide Images (WSI) of the slides, enabling the pathologists with a quicker turnaround time.(Roy et al., 2019).

Correspondingly, image-based methods for cervix diagnosis is conducted by directly employing a colposcope and visual inspection, and through professional training, it fully depends on the skills acquired and subjective knowledge. Nowadays, the diagnosis approaches are based on the biopsy and colposcopy methods. It might escape the naked eye's notice because colposcopy enables the detection of tissue irregularities and facilitates the magnification of images. The diagnostic accuracy is triggered by both the intra-observer and the inter-observer variability and ranges from 30% to 70%.

Simultaneously, the method that is frequently limited in low-income countries is digital colposcopy with DL combination. It can improve the automatic image classification; however, it requires colposcope availability and professional expertise. For these areas, the cervical images captured with smartphones and led to a colposcope will be helpful for the diagnostic test. The above limitations were overcome by AI-based devices developed by the scientific community for imaging or historical diagnosis. Without the need for highly trained staff, AI diagnostic imaging of the cervix that includes the TZ with 87% of lesions arises with few laboratory requirements for offering real-time requirements (Vargas-Cardona et al., 2023). The impact of AI methods on CC detection is tabulated in Table 1.

Table 1 Function and Description of AI Based Methods for CC Detection

Function	Description
Reduced time consumption	AI applications in CC screening and diagnosis substantially minimizes the time required for analysis, leading to quicker outcome
Improved accuracy	AI technologies improve the accuracy of early diagnosis by generating accurate, precise and reliable outcome in CC screening.
Tailored risk based approaches	Usage of AI based algorithms can be personalized to individual settings; this is due to the exceptional risk tolerance and treatment capacity, thus improving the overall screening process.
Reduced need for professionals and technical personnel	AI based systems reduces the dependency on specialized professionals for the interpretation of results making screening more accessible.
Hybrid/ Ensemble approach	Different AI systems combine different ML or DL techniques (hybrid or ensemble approaches) for accurately predicting CC in a better way than conventional approaches.
Enhanced detection of pre-cancers	AI based algorithms can effectively detect cervical pre-cancers than utilizing traditional approaches. This is due to the unique risk tolerance and treatment capacity which can aid the overall screening process.
Unbiased Outcome	AI eliminates bias that may arise from subjective factors in traditional screening methods, providing more objective and consistent results

The proficiency and skill of healthcare workers are the main influences for VIA test accuracy. In remote areas, a major barrier is the need for comprehensive training. The digital image of the cervix is used to improve the quality of VIA tests. These digital cervical images were captured by smartphones, which offer cost-effective, fast, non-invasive capture and are easily accessible. Thus, to fill the gap in human resources, the digital cervical images can be sent to experts who are at a long distance to reexamine the VIA test result after the screening. Due to the requirement of broadband connections in remote places, the execution of real-time expert consultations is limited.

In the world of medicine, AI has made a breakthrough by automatically processing test images, extracting features, classifying and learning using complicated algorithms. Thus, AI-based methods are primarily used for cervical cancer detection since they possess the ability to detect cervical cancer effectively (Harsono et al., 2022). The microscopy with Lugol's solution of colposcopy and acetic acid is used to predict cervical lesions using low-magnification microscopy. In diagnosing cervical lesions, it carries a specificity of 35% - 98% and sensitivity of 66% - 96%. The accuracy may vary depending on the physician's proficiency and skill. To improve the cost-effectiveness and quality of care, AI is used in the medical sector (Kim et al., 2022).

Even though AI plays a vital role in the easy classification of CC cells, healthcare providers are essential for the final decision-making and treatment. AI systems are not capable of replacing the judgment capability and accountability of medical professionals. Ethical considerations, legal responsibilities, and the need for ongoing patient monitoring are also the reasons behind the involvement of medical professionals in planning the treatment and the final diagnosis.

1.4 Motivation

Cervical malignancy is considered to be the 3rd most distinctive reason for demise due to disease in women across the globe. Therefore, an early screening of the CC is needed to make it a preventable disease. This could be predominantly accomplished by employing manual approaches. However, there are various risks involved in opting for manual tactics, such as misclassification of CC cells and false negative and false positive development of abnormal cells between screenings. These are some of the major limitations of carrying out manual approaches. Thus, these limits can be overcome by using AI-based methods. Regardless of several advancements in the field of medicine using AI technology, there exist

some things that could be improved, such as the accuracy of the models in modern approaches.

Motivated by these factors, the proposed model predominantly focuses on using effective pre-processing, segmentation, feature extraction and classification methods for CC cell classification. Thus, model I utilizes diffusion stop function – Contrast Limited Adaptive Histogram Equalization (CLAHE) for pre-processing, Topographic Weibull Bounding Segmentation (TWBS) for segmentation, Chaos and Exponential Scale based Butterfly Optimization Algorithm (CES-BOA) for feature extraction and Selection and Radiance and Variance Enabled Deep Learning Neural Network (RVDLNN) Model for feature classification.

Likewise, Model II utilizes Anisotropic Diffusion Filter with Histogram Equalization (ADF-HE) for pre-processing, Improved Weighted Fuzzy C Means (i-WFCM) for segmentation, and Restricted Boltzmann Machine (RBM) for classification and eventually, Model III uses Adaptive Diffusion Filter-Dragonfly Optimization (ADF-DO) for pre-processing, i-WFCM- Grasshopper Optimization Algorithm (i-WFCM-GOA) for segmentation and Deep-Convolutional Neural Network with Rectified Linear Unit(DCNN-ReLU) for classification. Eventually, the performance of these proposed models can be assessed by using different metrics like the value of accuracy, recall rate, precision and F1 score.

1.5 Problem Statement

Since CC is considered one of the deadliest cancers, it requires early diagnosis and treatment to avoid life-threatening complications. Therefore, it is essential to detect CC as quickly as possible, as it possesses the potential to cause deadly consequences. This could be accomplished using several manual detection techniques such as VIA, Papanicolaou (Pap) test, HPV testing, and LBC.

Despite using these manual techniques, some of the unavoidable pitfalls are observed, including time consumption, more dependency on pathologists, and a need for more skilled experts, especially in rural areas. Therefore, to overcome these limitations, advanced technology such as AI-based methods are preferred to provide accurate results in screening programs for the detection of CC cells. Hence, it eradicates the subjectivity and inconsistencies caused by traditional methods.

AI models can automatically extract features from recognized images and train the data for classification by implementing advanced and complex algorithms. Thus, existing works suggested different AI-based solutions that witness various shortcomings such as computational complexity (P. Guo et al., 2019), low accuracy (Z. Alyafeai et al., 2020; C. Guo *et al.*, 2021), misclassified images (P. Guo et al. 2019), overfitting of the model, and lack of pre-processing. These limitations are due to a lack of effective algorithms which can upscale the performance of the model. Hence, these limitations are dealt with in the proposed models, which use different phases to address these issues by utilizing effective algorithms.

Further, Given image datasets D containing multiple classes (D_a, D_b, \dots, D_n) with a set of features F , the research problem is to develop enhanced pre-processing and segmentation techniques that can effectively classify the images from D into O outcomes, where O contains various classes. The deep learning techniques are enhanced to classify cervical cancer images and non-cervical cancer images and assessed based on the performance metrics such as accuracy, precision, recall, and F-measure.

1.6 Significance

As CC can result in dangerous consequences, early detection can save patients, especially women, from precise positions. Therefore, it is extremely important to detect the CC cells present in the human body by using advanced technology like AI. Thus, the significance of the proposed work emphasizes using AI-based models as they can help with the better classification of CC cells due to their ability to work with a huge amount of data and precisely classify cervix cancer cells.

1.7 Research Objectives

1.7.1. Primary objective:

To enhance the identification and classification of cervical cancer in pap smear images using Deep Convolutional Neural Network Deep Learning techniques that are capable of categorizing cell samples from pap smear tests into normal or abnormal consisting of various classes by integrating image pre-processing, image segmentation, and feature-based classification methods, and evaluate the performance in terms of accuracy, precision, recall, and F-measure.

1.7.2. Secondary objectives:

- To preprocess and segment the image datasets using Contrast Limited Adaptive Histogram Equalization based Diffusion Stop Function and Topographic Weibull Bounding Segmentation for further multi-class classification using Radiance and Variance enabled Deep Learning Neural Networks for CC cell detection.
- To combine Anisotropic Diffusion Filter –Histogram Equalization based pre-processing technique and improved - Weighted Fuzzy C-Means based segmentation for further CC cell detection and classification using Restricted Boltzmann Machine in pap smear images.
- To combine Anisotropic Diffusion Filter –Dragonfly Optimization based pre-processing technique and improved - Weighted Fuzzy - C Means –Grasshopper Optimization Algorithm based segmentation in image dataset for further CC cell detection and classification using Deep-Convolutional Neural Network with Rectified Liner Unit.
- To compare the performance of all three models with other state-of-the-art methods to find the best among them for cervical cancer cell detection with a higher performance.

1.8 Thesis Organization

Thesis is organized as follows,

Chapter 1

This chapter deals with overview and the importance of CC, the problem statement, motivation and objectives of the thesis.

Chapter 2

In this chapter existing works done by the researchers for CC classification along with the research gaps are identified.

Chapter 3

Overall crux of the proposed works are highlighted and mentioned in this chapter.

Chapter 4

This chapter showcases the proposed work carried out by using diffusion stop function CLAHE for pre-processing, TWBS for segmentation, RVDLNN for classification of CC cells.

Chapter 5

This chapter highlights the algorithms and equations employed for cervical cells using ADF-HE for pre-processing, i-WFCM for segmentation and RBM for classification.

Chapter 6

This chapter deliberates on using ADF-DO for pre-processing, i-WFCM-GOA for segmentation and Deep CNN with ReLU for classification

Chapter 7

Results obtained by using these three models are assessed and interpreted in this chapter. Moreover, performance metrics and comparative analysis is performed in this chapter by evaluating the efficacy of the proposed model with other most modern approaches.

Chapter 8

This chapter summarizes the entire research work and provides future recommendations for the model.

1.9 Summary

Chapter 1 predominantly focuses on the overview of the CC detection, where the importance of CC detection, influence of AI in CC detection. Further, research objectives, problem statement, motivation of the proposed work, significance of the proposed work are also deliberated in this chapter.