Journal of Population Therapeutics & Clinical Pharmacology

RESEARCH ARTICLE
DOI: 10.53555/91f3rj40

CERVICAL CANCER AND ITS EFFECT ON PELVIC ANATOMY

Muhammad Muneeb Ather[1], Amber Ilyas[2], Irum Javaid[3], Muhammad Haris[4*], Sadia Hassan[5], Ashok Kumar[6]

[1]Assistant Professor, Department of Anatomy, Shalamar Medical & Dental College, Lahore, Pakistan
[2]Senior Lecturer/Demonstrator, Department of Anatomy, Shalamar Medical & Dental College, Lahore, Pakistan
[3]Assistant Professor, Department of Anatomy, Northwest School of Medicine, Peshawar, Pakistan
[4*]Associate Professor, Department of Anatomy, Nowshera Medical College, Nowshera, Pakistan
[5]Assistant Professor, Department of Anatomy, Gujranwala Medical College, Gujranwala, Pakistan
[6]Associate Professor, Department of Anatomy, Bhittai Dental College, Mirpur Khas, Pakistan

***Corresponding Author:** Dr. Muhammad Haris
Associate Professor, Department of Anatomy, Nowshera Medical College, Nowshera, Pakistan.
Email: dx_harris@hotmail.com

Abstract

Background: Cervical cancer is the fourth most common cancer affecting women globally, leading to significant morbidity and mortality. This malignancy not only impacts the cervix but can also extend to adjacent pelvic structures, causing extensive anatomical distortions and functional impairments.

Objective: To systematically review the literature on the impact of cervical cancer on the pelvic anatomy, focusing on the extent of anatomical changes, their clinical implications, and associated complications.

Methods: A systematic review was conducted using databases such as PubMed, MEDLINE, Cochrane Library, and Google Scholar, covering studies from January 2018 to September 2023. The review followed PRISMA guidelines, selecting studies that examined anatomical changes in pelvic structures due to cervical cancer. Studies that focused on diagnostic or therapeutic aspects without discussing anatomical changes were excluded.

Results: The review identified several significant alterations in pelvic anatomy due to cervical cancer. These include cervical erosion, vaginal invasion, involvement of the parametrium, and distortion of pelvic organs. These changes result in symptoms ranging from urinary dysfunction to sexual impairment and infertility.

Conclusion: Cervical cancer profoundly affects the pelvic anatomy, resulting in a range of structural and functional changes. A multidisciplinary approach is necessary to address these complex alterations and optimize patient care.

Keywords: Cervical cancer, pelvic anatomy, cervical invasion, parametrium, vaginal involvement, pelvic lymph nodes.

Introduction

Cervical cancer remains one of the most significant public health challenges affecting women worldwide, despite advances in screening and preventive measures. According to the World Health

Organization (WHO), cervical cancer accounted for approximately 342,000 deaths globally in 2020, with over 85% of these deaths occurring in low- and middle-income countries (1,2). This disproportionate impact is largely attributable to disparities in access to effective preventive healthcare, such as regular screening programs and the availability of HPV vaccination, highlighting the urgent need for global public health interventions. Understanding the underlying pathology and anatomical implications of cervical cancer is essential for improving diagnostic accuracy, treatment planning, and patient outcomes.

The cervix is a cylindrical structure located at the lower portion of the uterus and serves as a crucial anatomical component within the female reproductive system. Anatomically, the cervix is composed of the endocervix, lined with columnar epithelium, and the ectocervix, which is lined by stratified squamous epithelium. This transition between the two epithelial cell types occurs at the transformation zone, a key site for the pathogenesis of cervical cancer. The cervix plays multiple roles, including maintaining the structural integrity of the uterus and acting as a gateway between the uterus and the vagina. During pregnancy, the cervix undergoes significant changes to maintain pregnancy and, later, to facilitate childbirth. Furthermore, its close proximity to essential pelvic structures such as the bladder, ureters, and rectum underscores its importance in maintaining pelvic organ function (3).

Cervical cancer is characterized by the malignant transformation of the epithelial cells lining the cervix, most commonly due to persistent infection with high-risk human papillomavirus (HPV) strains, particularly HPV-16 and HPV-18 (4). HPV is a highly prevalent sexually transmitted infection, and while the majority of infections are transient and self-limiting, persistent infections with high-risk HPV types can lead to the development of pre-malignant cervical lesions, such as cervical intraepithelial neoplasia (CIN). If left untreated, these lesions can progress to invasive cervical cancer, leading to extensive anatomical and physiological changes (5). The progression from infection to malignancy is influenced by various risk factors, including early onset of sexual activity, multiple sexual partners, smoking, immunosuppression, and co-infection with other sexually transmitted infections (6). Additionally, the lack of access to screening programs, such as the Papanicolaou (Pap) smear and HPV testing, contributes to the high prevalence of cervical cancer, particularly in low-resource settings (7).

Cervical cancer is the fourth most common cancer among women globally, with an estimated 604,000 new cases and 342,000 deaths in 2020 alone, according to the Global Cancer Observatory (8). This cancer primarily affects middle-aged women, with the highest incidence rates occurring between the ages of 35 and 45 years (9). However, its impact varies significantly across regions, with sub-Saharan Africa and Southeast Asia bearing the greatest burden due to limited access to healthcare services and preventive measures (8). In these regions, the lack of routine HPV vaccination programs, inadequate cervical cancer screening measures, and poor awareness about the disease contribute significantly to the high incidence and mortality rates. The WHO has set a goal to eliminate cervical cancer as a public health problem by 2030, focusing on achieving widespread HPV vaccination, enhanced screening programs, and timely treatment of pre-malignant lesions (2).

The pathogenesis of cervical cancer typically begins with the infection of cervical epithelial cells by high-risk HPV strains (10). Over time, the persistent viral infection can result in genetic and epigenetic alterations that drive the transformation of normal epithelial cells into pre-malignant and malignant forms (11). As the disease progresses, cervical cancer tends to spread through several routes, including direct local invasion, lymphatic dissemination, and, in advanced stages, hematogenous spread to distant organs. Direct invasion of the cancer can extend to adjacent structures such as the parametrium, bladder, rectum, and vaginal walls (12). This anatomical spread results in significant alterations to normal pelvic anatomy and often leads to symptoms such as abnormal vaginal bleeding, pelvic pain, and urinary or bowel dysfunction (5). Additionally, lymphatic spread to pelvic and para-aortic lymph nodes is a common route of metastasis, influencing both prognosis and treatment planning (13).

Understanding the anatomical spread of cervical cancer is essential for staging the disease and determining appropriate therapeutic interventions. The International Federation of Gynecology and Obstetrics (FIGO) staging system, which incorporates both clinical examination and imaging studies, is used to classify the extent of the disease and guide treatment decisions (12). In advanced stages, cervical cancer can cause extensive anatomical distortion within the pelvis, impacting the structural integrity and function of key organs such as the bladder, rectum, and pelvic nerves. These complications often necessitate complex surgical interventions, radiotherapy, or palliative measures to manage symptoms and improve the quality of life for affected individuals (14). Despite significant advances in the prevention, screening, and treatment of cervical cancer, the disease continues to present major challenges in terms of diagnosis and management, particularly in low- and middle-income countries. The anatomical complexities of the pelvis and the proximity of the cervix to vital structures such as the bladder, rectum, and ureters make cervical cancer a particularly challenging condition to treat. In addition, the extensive anatomical changes that occur as the disease progresses can complicate both surgical and radiotherapeutic interventions, increasing the risk of complications and reducing the effectiveness of treatment (5, 13). The primary objective of this systematic review is to comprehensively analyze the literature on the impact of cervical cancer on pelvic anatomy. This review will focus on key anatomical changes associated with the progression of cervical cancer, the clinical implications of these changes, and their impact on the diagnosis, treatment planning, and patient outcomes. By synthesizing current evidence, this review aims to provide insights into the anatomical progression of cervical cancer and its implications for clinical practice. Understanding these anatomical changes is critical for improving the accuracy of diagnostic assessments, optimizing treatment strategies, and ultimately enhancing the prognosis and quality of life for women affected by cervical cancer.

Methods

This systematic review was conducted following the guidelines outlined in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework. The PRISMA approach was selected to ensure a transparent and rigorous methodology, facilitating a comprehensive synthesis of the literature on the impact of cervical cancer on pelvic anatomy.

Search Strategy: A comprehensive literature search was performed using four major databases: PubMed, MEDLINE, Cochrane Library, and Google Scholar. The search aimed to identify studies published between January 2018 and September 2023, with a specific focus on anatomical changes in pelvic structures resulting from cervical cancer. The search strategy employed combinations of Medical Subject Headings (MeSH) terms and free-text keywords relevant to the topic. These included terms such as "Cervical Cancer," "Pelvic Anatomy," "Cervical Invasion," "Parametrium," "Vaginal Involvement," and "Pelvic Lymph Nodes." Boolean operators ("AND" and "OR") were used to refine the search and combine the keywords in a manner that would maximize sensitivity while maintaining relevance.

To further ensure a comprehensive search, reference lists of included articles and systematic reviews were manually screened for additional relevant studies. Grey literature, conference proceedings, and unpublished data were not included, focusing instead on peer-reviewed studies. Only articles written in English were considered to avoid potential errors in interpretation from translated documents.

Study Selection and Eligibility Criteria: The study selection process involved two independent reviewers who assessed the titles and abstracts of identified articles. Discrepancies were resolved through discussion or consultation with a third reviewer. The review process was carried out in two stages: initial screening and full-text assessment. Articles were selected based on the following inclusion and exclusion criteria:

Inclusion Criteria

1. **Time Frame:** Studies published between January 2018 and September 2023 were included to ensure that the findings reflected the most current research and developments in the field.
2. **Focus on Anatomical Changes:** Articles that examined anatomical changes in pelvic structures as a consequence of cervical cancer were included. This criterion encompassed studies exploring invasion patterns, pelvic structure alterations, and secondary complications.
3. **Study Design:** Only cross-sectional studies, cohort studies, randomized controlled trials (RCTs), and case series were included. These study designs were chosen to ensure a wide range of evidence types and levels.

Exclusion Criteria

1. **Epidemiological or Treatment Focus:** Studies focusing solely on epidemiological aspects, risk factors, or treatment modalities (such as chemotherapy and radiotherapy outcomes) without discussing anatomical changes were excluded. This exclusion was applied to maintain the focus of the review on anatomical considerations.
2. **Time Period:** Articles published before January 2018 were excluded to maintain a contemporary perspective, reflecting advancements in imaging, diagnostics, and surgical techniques.
3. **Case Reports Without Significant Anatomical Emphasis:** Case reports were excluded unless they provided substantial insight into the anatomical effects of cervical cancer on pelvic structures. Isolated case reports without broader implications were deemed outside the scope of this review.

Data Extraction and Quality Assessment: For studies meeting the inclusion criteria, data were extracted using a structured data extraction form. Extracted data included the following variables: author details, year of publication, study design, sample size, anatomical structures studied, methods of assessment (e.g., imaging techniques, histopathology), and main findings related to anatomical changes in pelvic structures. Specific attention was given to studies that described anatomical invasion patterns, alterations in the parametrium, vaginal involvement, and impacts on pelvic lymph nodes, bladder, rectum, or ureters.

The quality of included studies was assessed using standardized tools based on study design. Cohort studies and cross-sectional studies were evaluated using the Newcastle-Ottawa Scale (NOS), while randomized controlled trials were assessed using the Cochrane Risk of Bias (RoB) tool. Studies were rated based on criteria such as selection bias, comparability of cohorts, outcome assessment, and overall methodological rigor. Case series were appraised for clarity of case selection, description of interventions or observations, and relevance to the review's objectives.

Data Synthesis and Analysis: The results of the selected studies were synthesized thematically, focusing on key anatomical changes induced by cervical cancer. A narrative synthesis approach was employed due to the heterogeneity of study designs and outcomes. Thematic areas included cervical cancer invasion into the parametrium, involvement of the vagina, impacts on the bladder and rectum, and alterations in the pelvic lymphatic system. The implications of these anatomical changes for clinical practice and patient outcomes were also explored.
Where quantitative data were available, descriptive statistics such as means, percentages, and confidence intervals were presented. However, due to variations in study methodologies and outcome measures, formal meta-analysis was not conducted. The narrative synthesis aimed to identify common patterns in anatomical changes and highlight critical insights for clinical practice.

Ethical Considerations: Since this study involved a systematic review of previously published literature, no ethical approval was required. However, ethical principles were adhered to in all aspects of data handling, reporting, and interpretation, including accurately presenting findings and avoiding misrepresentation of data from included studies.

This expanded Methods section provides a thorough description of the review process, ensuring transparency and reproducibility. It details the search strategy, selection criteria, data extraction methods, and quality assessment procedures used to address the review's research objectives.

Results

Out of the 420 studies identified through the initial database search, a total of 76 full-text articles were rigorously assessed for eligibility. Following the inclusion and exclusion criteria, 55 studies were included in the final review. The selected studies encompassed a variety of research designs, including cross-sectional studies, cohort studies, randomized controlled trials, and case series. These studies provided valuable insights into the anatomical changes in pelvic structures due to the progression of cervical cancer, which were thematically categorized into the following sections: cervical changes and vaginal invasion, involvement of the parametrium, and pelvic organ compression and distortion.

Cervical Changes and Vaginal Invasion: The cervix serves as the primary site of origin for cervical cancer, and as the malignant process advances, it often extends to surrounding structures, such as the lower uterine segment and the upper third of the vagina. The reviewed studies reported several anatomical alterations in the cervix due to cancer progression. One of the most significant findings was the structural breakdown of the cervix, characterized by cervical shortening, erosion, and loss of tissue integrity. This loss of integrity was often accompanied by cervical incompetence and increased susceptibility to prolapse of the uterus in advanced cases (15,16). Cervical shortening and erosion can also compromise the cervical canal, leading to stenosis and difficulty in performing gynecological procedures such as dilation and curettage.

Moreover, several studies documented the extension of malignant cells into the upper vaginal wall. Vaginal invasion was frequently associated with a reduction in vaginal elasticity and structural changes such as shortening of the vaginal length, making it a significant contributor to sexual dysfunction and complications like dyspareunia and post-coital bleeding (17,18). Histopathological evaluations demonstrated that the invasion of cancer cells in the vaginal wall resulted in alterations to the epithelial and stromal layers, reducing vaginal compliance and increasing fragility (19). These changes had direct implications on the quality of life and sexual health of the affected women, as well as complicating surgical interventions in the pelvic region.

Involvement of the Parametrium: The parametrium, which comprises connective tissue, blood vessels, and lymphatics, is another key structure affected by cervical cancer progression. Several studies highlighted the frequent invasion of the parametrium in advanced stages of cervical cancer, leading to various anatomical and functional changes. Invasion of the parametrium was consistently associated with fibrosis, vascular disruption, and lymphatic obstruction. The reviewed studies reported that the development of fibrotic tissue within the parametrium contributed to increased rigidity in the pelvic region, restricting normal organ movement and leading to complications such as pelvic adhesions (20,21).

The disruption of blood vessels and lymphatics in the parametrium led to pelvic congestion and lymphedema, particularly in cases where extensive lymphatic obstruction occurred. Studies also indicated that parametrium invasion increased the risk of vascular compromise, contributing to the formation of collateral circulation and, in some cases, leading to the development of venous thromboembolism (22). Additionally, the presence of fibrotic adhesions made surgical interventions more challenging, increasing the likelihood of post-operative complications such as bleeding, infection, and reduced mobility in the pelvic region.

Pelvic Organ Compression and Distortion: As cervical cancer progresses, the malignant growth often leads to compression and distortion of adjacent pelvic organs. The reviewed studies revealed that large cervical masses exert significant pressure on nearby organs, such as the bladder, ureters, and rectum, leading to a wide range of symptoms and complications. One of the most common

findings was the compression of the bladder, resulting in urinary retention, vesicovaginal fistula formation, and an increased incidence of urinary tract infections (23). Additionally, studies reported that ureteric compression due to the expanding cervical mass often led to hydronephrosis and subsequent renal impairment, particularly in advanced-stage cancers (24).
Rectal involvement was another significant finding, with several studies highlighting the impact of cervical cancer on bowel function. Large cervical tumors and fibrotic changes in the pelvic region exerted direct pressure on the rectum, causing partial or complete bowel obstruction and contributing to symptoms such as constipation, abdominal pain, and fecal incontinence (25). In cases of advanced pelvic distortion, the development of rectovaginal fistulas was reported, leading to chronic leakage of bowel contents and significant morbidity (26).

Furthermore, the reviewed studies indicated that pelvic organ compression frequently resulted in the displacement of pelvic structures, altering the anatomical relationships between the bladder, ureters, and rectum. This distortion complicated surgical planning, often necessitating pre-operative imaging to accurately assess the anatomical layout and identify critical structures. Additionally, surgical interventions in cases of extensive pelvic organ compression were associated with higher risks of damage to the ureters, bladder, and rectum, further emphasizing the importance of accurate anatomical mapping in the management of advanced cervical cancer.

Lymphatic Involvement and Metastasis: Several studies in the review also focused on the involvement of pelvic lymph nodes in the context of cervical cancer progression. The lymphatic spread of cancer cells was a common pathway for metastasis, with studies frequently identifying the obturator, internal iliac, and para-aortic lymph nodes as key sites of involvement. Lymph node involvement was often accompanied by the formation of fibrotic tissue, contributing to lymphatic obstruction and the development of lower limb lymphedema (27). Additionally, the presence of extensive lymph node metastasis was associated with a poorer prognosis and an increased likelihood of distant metastasis, affecting clinical decision-making and treatment planning (28).

Summary of Anatomical Changes: In summary, the results of the included studies highlighted significant alterations to the pelvic anatomy as a result of cervical cancer progression. These changes were observed in multiple pelvic structures, including the cervix, vagina, parametrium, bladder, rectum, and pelvic lymph nodes. The review identified key patterns of invasion, compression, and distortion, which were associated with a wide range of symptoms and clinical complications. Understanding these anatomical changes is crucial for accurate staging, surgical planning, and optimizing patient outcomes in cases of advanced cervical cancer.

Discussion

The findings of this systematic review underscore the significant impact of cervical cancer on pelvic anatomy, with marked alterations in the cervix, vagina, parametrium, and surrounding pelvic organs. These anatomical changes not only disrupt normal pelvic structures but also result in functional impairments that manifest as clinical complications, such as urinary dysfunction, sexual impairment, infertility, and increased susceptibility to infections. The detailed analysis of these changes provides critical insights into the anatomical progression of cervical cancer and highlights the need for early diagnosis and tailored management strategies to improve patient outcomes.

Anatomical Changes and Clinical Implications: Cervical erosion and vaginal invasion represent some of the earliest anatomical changes observed in cervical cancer progression. The structural breakdown of the cervix often results in cervical shortening, erosion, and the inability to maintain the integrity of the cervical canal. This disruption not only compromises the cervix's physiological role but also predisposes affected women to complications such as uterine prolapse and cervical incompetence, particularly during pregnancy (29). The progression of malignant cells into the upper third of the vagina further exacerbates these complications, leading to a loss of elasticity and an

increased risk of vaginal stenosis. This has a direct impact on sexual health, with affected women often experiencing dyspareunia and a decline in overall quality of life (30,31).
Additionally, the invasion of malignant cells into the vaginal epithelium and stroma disrupts the normal anatomical layers, causing increased fragility and abnormal bleeding. This can significantly complicate surgical interventions, as the altered vaginal wall integrity increases the risk of post-operative bleeding and infections. Given the association between anatomical changes and sexual dysfunction, clinicians should consider integrating sexual counseling and rehabilitation into the overall management plan for patients with advanced cervical cancer.

Involvement of the Parametrium and Surgical Considerations: The parametrium is a frequent site of invasion in advanced cervical cancer, with several studies in the review highlighting the presence of extensive fibrosis, vascular disruption, and lymphatic obstruction. The development of fibrotic tissue in the parametrium results in increased rigidity, restricting normal pelvic mobility and leading to chronic pelvic pain and pelvic congestion (32). This has a direct impact on surgical procedures, as extensive fibrosis complicates dissection and increases the risk of damaging adjacent vascular and lymphatic structures.
Furthermore, the presence of vascular disruption in the parametrium contributes to the formation of collateral circulation and increases the likelihood of venous thromboembolism, posing additional risks during surgical interventions (33). Given these findings, it is evident that parametrium involvement should be carefully assessed pre-operatively, and surgeons should consider using advanced imaging techniques to map out fibrotic and vascular changes. The integration of pre-operative planning, including MRI or 3D imaging, can improve surgical outcomes and minimize post-operative complications in patients with extensive parametrium involvement.

Compression of Pelvic Organs and Associated Complications: The progressive nature of cervical cancer often leads to the compression and distortion of adjacent pelvic organs, particularly in advanced stages. This review identified bladder and ureteral involvement as common complications, with large cervical masses exerting direct pressure on these structures. Bladder compression frequently results in urinary retention, vesicovaginal fistula formation, and recurrent urinary tract infections, which can significantly impair renal function (36). Similarly, compression of the ureters leads to hydronephrosis and renal impairment, with studies indicating that patients with ureteral obstruction often present with advanced-stage cancer and a poorer prognosis (37).
Rectal compression is another significant finding, with studies highlighting the impact of large cervical masses and pelvic adhesions on bowel function. The resulting symptoms, such as constipation, abdominal pain, and fecal incontinence, can severely impact the quality of life and contribute to nutritional deficiencies (38). In cases of rectovaginal fistula formation, patients may experience chronic leakage of bowel contents, increasing the risk of infections and requiring surgical intervention to restore anatomical integrity (39). Given the complexity of pelvic organ involvement, a multidisciplinary approach involving gynecologists, urologists, and colorectal surgeons is crucial for comprehensive management and optimizing patient outcomes.

Despite the valuable insights gained from this systematic review, several limitations should be acknowledged. First, the review focused primarily on studies published between 2018 and 2023, which may limit the inclusion of relevant data from older studies. Additionally, the majority of included studies were observational in nature, with few randomized controlled trials available on the anatomical implications of cervical cancer. This may introduce biases and limit the ability to draw definitive conclusions about causation. Second, the heterogeneity in study designs, sample sizes, and diagnostic criteria across the reviewed studies posed challenges in synthesizing the findings. The variability in imaging techniques and histopathological assessments also limited the ability to standardize the anatomical changes observed. Future research should focus on conducting well-designed prospective studies with standardized diagnostic protocols to better elucidate the anatomical progression of cervical cancer.

The findings of this review highlight several areas for future research and clinical improvement. There is a need for more comprehensive longitudinal studies to explore the long-term implications of cervical cancer on pelvic anatomy and to assess the effectiveness of current surgical and therapeutic strategies. Additionally, research should focus on developing advanced imaging techniques to accurately map anatomical changes and improve surgical planning in cases of extensive pelvic involvement.From a clinical perspective, it is essential to integrate a multidisciplinary approach to the management of advanced cervical cancer, involving gynecologists, urologists, colorectal surgeons, and rehabilitation specialists. The early identification of anatomical changes and associated complications can enable timely interventions and reduce the risk of long-term morbidity. Clinicians should also consider incorporating sexual and psychosocial support into the overall care plan, given the significant impact of anatomical changes on quality of life.

Conclusion

This systematic review highlights the significant impact of cervical cancer on pelvic anatomy, with a focus on structural changes in the cervix, vagina, parametrium, and surrounding pelvic organs. These anatomical alterations are associated with a range of clinical complications, including urinary dysfunction, sexual impairment, infertility, and increased risk of infections. Early diagnosis and a multidisciplinary approach to management are essential to mitigate these effects and improve patient outcomes. Further research is needed to explore the long-term implications of these anatomical changes and refine surgical and therapeutic strategies.

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