"ROLE OF DIFFUSION WEIGHTED MAGNETIC RESONANCE IMAGING AND APPARENT DIFFUSION COEFFICIENT VALUE IN CARCINOMA CERVIX AND TO EVALUATE ITS RESPONSE TO CHEMORADIATION"

BY

Dr. D VAMSI VENKAT

DISSERTATION SUBMITTED TO
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IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF MEDICINE
IN
RADIODIAGNOSIS

UNDER THE GUIDANCE OF
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PROFESSOR & HEAD
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UNDER THE CO-GUIDANCE OF
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DEPARTMENT OF RADIODIAGNOSIS,
SRI DEVARAJ URS MEDICAL COLLEGE
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The Institutional Ethics Committee of Sri Devaraj Urs Medical College, Tamaka, Kolar has examined and unanimously approved the synopsis entitled **" Role Of Diffusion Weighted Magnetic Resonance Imaging And Apparent Diffusion Co-Efficient Values In Carcinoma Cervix And To Evaluate Its Response To Chemoradiation."** being investigated by **Dr.Doddala Vamsi Venkat, Dr. Anil Kumar Sakalecha, & Dr. Manjunath G.N[1]** in the Departments of Radio-Diagnosis & Radiotherapy[1] at Sri Devaraj Urs Medical College, Tamaka, Kolar. **Permission is granted by the Ethics Committee to start the study.**

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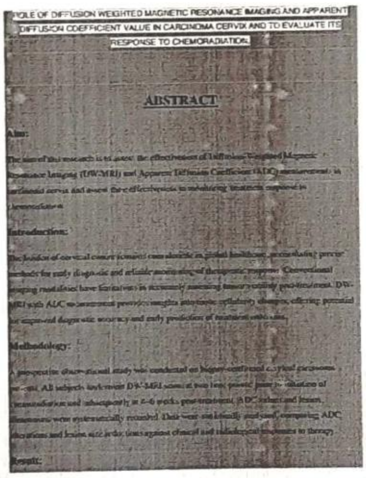
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ROLE OF DIFFUSION WEIGHTED MAGNETIC RESONANCE IMAGING AND APPARENT DIFFUSION COEFFICIENT VALUE IN CARCINOMA CERVIX AND TO EVALUATE ITS RESPONSE TO CHEMORADIATION. ABSTRACT Aim: The aim of this research is to assess the effectiveness of Diffusion-Weighted Magnetic Resonance Imaging (DW-MRI) and Apparent Diffusion Coefficient (ADC) measurements in carcinoma cervix and assess their effectiveness in monitoring treatment response to chemoradiation. Introduction: The burden of cervical cancer remains considerable in global healthcare, necessitating precise methods for early diagnosis and reliable monitoring of therapeutic response. Conventional imaging modalities have limitations in accurately assessing tumor viability post-treatment. DW- MRI with ADC measurement provides insights into tissue cellularity changes, offering potential for improved diagnostic accuracy and early prediction of treatment outcomes. Methodology: A prospective observational study was conducted on biopsy-confirmed cervical carcinoma patients. All subjects underwent DW-MRI scans at two time points: prior to initiation of chemoradiation and subsequently at 4–6 weeks post-treatment. ADC values and lesion dimensions were systematically recorded. Data were statistically analyzed, comparing ADC alterations and lesion size reductions against clinical and radiological responses to therapy. Result: Significant elevation of ADC values post-treatment correlated positively with favorable therapeutic responses ($p<0.001$). All patients demonstrated complete response. Lesion dimensions mildly decreased following chemoradiation. Conclusion: DW-MRI combined with ADC measurement proves to be an effective imaging approach for evaluating cervical cancer treatment response. Early post-treatment ADC value alterations correlate strongly with tumor response to treatment, highlighting its potential role in guiding adaptive therapeutic strategies. Future integration of DW-MRI with complementary imaging and biomarkers may further

ABBREVIATIONS

1	**DW-MRI**: Diffusion-Weighted Magnetic Resonance Imaging
2	**ADC**: Apparent Diffusion Coefficient
3	**MRI**: Magnetic Resonance Imaging
4	**CT**: Computed Tomography
5	**PET-CT**: Positron Emission Tomography-Computed Tomography
6	FDG: Fluoro-Deoxy Glucose
7	**HPV**: Human Papilloma Virus
8	**PAP**: Papanicolaou
9	**CIN**: Cervical Intraepithelial Neoplasia
10	**WHO**: World Health Organisation
11	**FIGO**: Fédération Internationale de Gynécologie et d'Obstétrique
12	**HPE**: Histopathological
13	**ECC**: Early Cervical Cancer
14	**PLNM**: Pelvic Lymph Node Metastasis
15	**ESMO**: European Society of Medical Oncology
16	**LACC**: Locally Advanced Cervical Cancer
17	**ISBT**: Interstitial Brachytherapy
18	**CMR**: Complete Metabolic Resolution
19	**RT**: Radiation Therapy
20	**USG**: Ultrasonography
21	**TUS**: Transabdominal Ultrasound
22	**SUVmax**: Maximum Standardized Uptake Value
23	**MTV**: Metabolic Tumor Volume
24	**TLG**: Total Lesion Glycolysis
25	**DWI**: Diffusion-Weighted Imaging
26	**b-values**: B-values refer to the strength and duration of the diffusion-sensitizing gradient pulses in DW-MRI
27	**ROI**: Region of Interest
28	**FOV**: Field-Of-View
29	**EBRT**: External Beam Radiotherapy
30	**DCE-MRI**: Dynamic Contrast-Enhanced MRI
31	**CCRT**: Concurrent Chemoradiation Therapy
32	**IVIM**: Intravoxel Incoherent Motion
33	**DKI**: Diffusion Kurtosis Imaging
34	**AI**: Artificial Intelligence

ABSTRACT

Aim:

The aim of this research is to assess the effectiveness of Diffusion-Weighted Magnetic Resonance Imaging (DW-MRI) and Apparent Diffusion Coefficient (ADC) measurements in carcinoma cervix and assess their effectiveness in monitoring treatment response to chemoradiation.

Introduction:

The burden of cervical cancer remains considerable in global healthcare, necessitating precise methods for early diagnosis and reliable monitoring of therapeutic response. Conventional imaging modalities have limitations in accurately assessing tumor viability post-treatment. DW-MRI with ADC measurement provides insights into tissue cellularity changes, offering potential for improved diagnostic accuracy and early prediction of treatment outcomes.

Methodology:

A prospective observational study was conducted on biopsy-confirmed cervical carcinoma patients. All subjects underwent DW-MRI scans at two time points: prior to initiation of chemoradiation and subsequently at 4–6 weeks post-treatment. ADC values and lesion dimensions were systematically recorded. Data were statistically analyzed, comparing ADC alterations and lesion size reductions against clinical and radiological responses to therapy.

Result:

Significant elevation of ADC values post-treatment correlated positively with favorable therapeutic responses ($p<0.001$). All patients demonstrated complete response. Lesion dimensions mildly decreased following chemoradiation.

Conclusion:

DW-MRI combined with ADC measurement proves to be an effective imaging approach for evaluating cervical cancer treatment response. Early post-treatment ADC value alterations correlate strongly with tumor response to treatment, highlighting its potential role in guiding adaptive therapeutic strategies. Future integration of DW-MRI with complementary imaging and biomarkers may further enhance its predictive accuracy and clinical utility.

Key words:

Diffusion-weighted MRI, Apparent Diffusion Coefficient, Carcinoma cervix, Chemoradiation, Treatment response, Cervical cancer.

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INTRODUCTION

Global and Regional Burden of Carcinoma cervix:

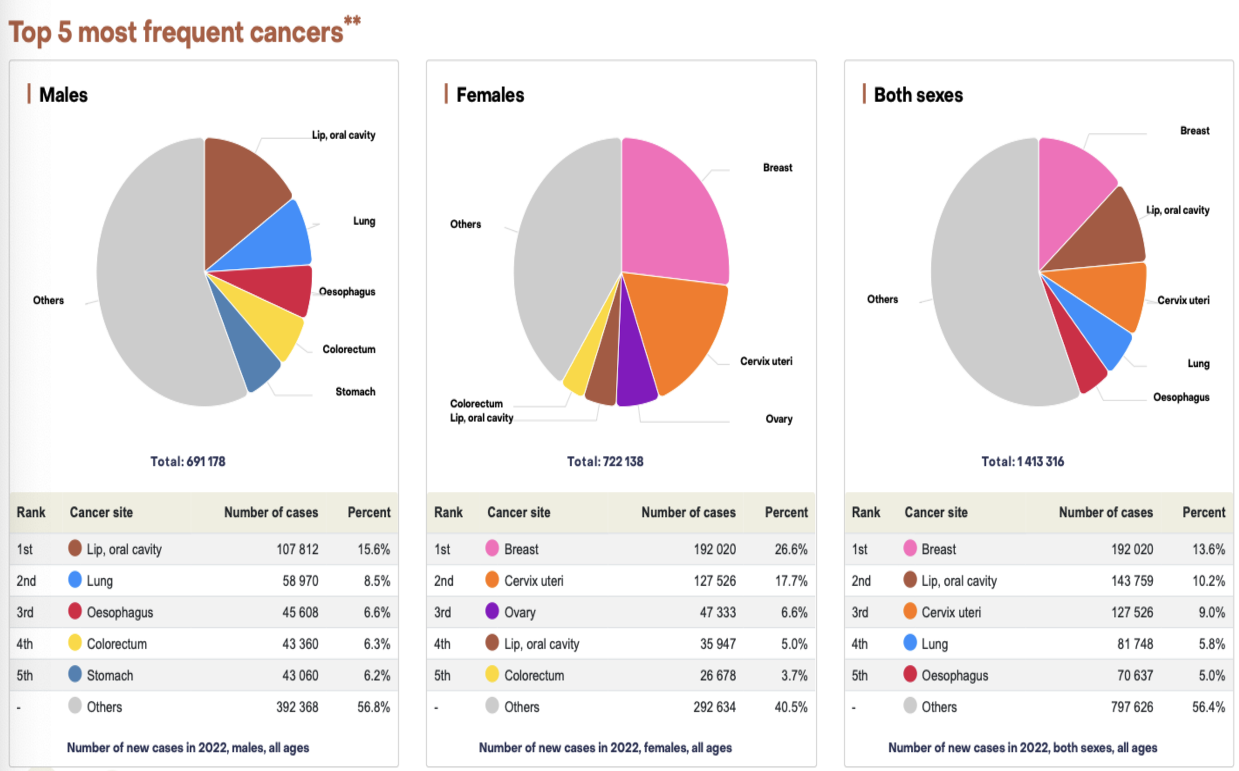
Cervical cancer is the fourth most frequently diagnosed cancer and the fourth leading cause of cancer-related deaths among women worldwide.[1] In 2020 alone, an estimated 604,000 new cases of carcinoma cervix were diagnosed globally, and about 342,000 women died of the disease.[2] In 2020, India contributed to around 20% of all new cervical cancer cases and almost 25% of related deaths globally, highlighting its significant role in the worldwide cervical cancer burden.[3] Certain regions bear a particularly large share of the caseload; for example, about 39% of all new cervical cancer cases occur in just two countries, China (18%) and India (21%), which together also account for approximately 40% of global cervical cancer deaths.[2] Cervical cancer ranks as the second most prevalent cancer among women in India, following breast cancer, with more than 120,000 new cases and approximately 80,000 deaths reported each year. These statistics underscore the public health importance of carcinoma cervix and the urgent need for effective strategies in prevention, early detection and treatment.

Significance of Early Detection and Treatment Response Assessment:

Early detection of carcinoma cervix significantly improves patient outcomes. Carcinoma cervix is largely preventable through screening and early intervention; organized screening programs [Pap smear cytology and high-risk Human Papilloma Virus (HPV) testing] have led to substantial declines in incidence and mortality in high-income countries.[2] When detected at a premalignant stage or early invasive stage, carcinoma cervix can be cured with timely treatment. In contrast, delayed diagnosis often leads to advanced disease, which is associated with lower survival rates and higher mortality. This makes early diagnosis and treatment initiation critically important in carcinoma cervix management.

Equally important is the assessment of treatment response once therapy has begun. Concurrent chemoradiation is the established standard treatment for locally advanced cervical cancer, which typically extends over 5–8 weeks. Assessing tumor response to treatment during this time is crucial for guiding clinical management decisions. The ability to evaluate a tumor's response early in the course of treatment has immense clinical value.[4]

If a tumor shows suboptimal response or resistance to standard chemoradiation, alternative strategies (such as treatment intensification, early surgical intervention, or enrollment in clinical trials) could be considered promptly. Conversely, early identification of good responders can reassure both clinicians and patients that the treatment is effective. However, reliable early markers of treatment response are limited. Currently, response is often assessed only at completion of therapy or weeks thereafter (using clinical examination or imaging to measure tumor shrinkage). By that time, valuable opportunity may have been lost to modify the treatment for non-responders. Therefore, developing techniques to monitor tumor response during therapy—while changes are still potentially reversible—has become a priority in carcinoma cervix research, care and management.



Rank	Cancer site	Number of cases	Percent
1st	Lip, oral cavity	107 812	15.6%
2nd	Lung	58 970	8.5%
3rd	Oesophagus	45 608	6.6%
4th	Colorectum	43 360	6.3%
5th	Stomach	43 060	6.2%
-	Others	392 368	56.8%

Number of new cases in 2022, males, all ages

Rank	Cancer site	Number of cases	Percent
1st	Breast	192 020	26.6%
2nd	Cervix uteri	127 526	17.7%
3rd	Ovary	47 333	6.6%
4th	Lip, oral cavity	35 947	5.0%
5th	Colorectum	26 678	3.7%
-	Others	292 634	40.5%

Number of new cases in 2022, females, all ages

Rank	Cancer site	Number of cases	Percent
1st	Breast	192 020	13.6%
2nd	Lip, oral cavity	143 759	10.2%
3rd	Cervix uteri	127 526	9.0%
4th	Lung	81 748	5.8%
5th	Oesophagus	70 637	5.0%
-	Others	797 626	56.4%

Number of new cases in 2022, both sexes, all ages

Figure 1: shows the top 5 most frequent cancers across males and females as per 2022 data in India.

Gaps in Conventional Imaging and Advantages of DW-MRI:

Conventional imaging modalities have well-recognized limitations in both initial staging of carcinoma cervix and post-treatment evaluation. Pelvic examination and anatomical imaging [such as T2-weighted MRI or Computed Tomography (CT) scans] are excellent for assessing tumor size, local spread, and morphological changes. However, these methods rely purely on macroscopic changes (tumor shrinkage or growth) to infer response. Early in the treatment course, tumor cells may be dying without a significant change in size due to inflammation or fibrosis; conversely, persistent viable tumor might be masked by treatment-related edema. Standard MRI sequences often cannot reliably distinguish residual tumor from post-therapy changes like scarring or inflammation. Fluorodeoxyglucose PET-CT is another modality used in carcinoma cervix, particularly for detecting metabolic activity of tumors. PET-CT has high sensitivity for residual disease, but its specificity can be limited (inflammation can also show uptake), and it involves ionizing radiation and high cost. There is a clear need for imaging techniques that can bridge this gap by detecting physiological or cellular changes in tumors earlier than gross anatomical changes.

DW-MRI offers several potential advantages in this context. As a radiation-free, contrast-free functional imaging technique, it can be repeated during therapy without adding significant risk or patient burden. DW-MRI is sensitive to the microenvironment: as cancer cells undergo apoptosis or necrosis from effective treatment, the cell density drops and water diffusion increases before the tumor visibly shrinks. Studies have shown that the ADC of carcinoma cervix tends to increase during successful chemoradiation, reflecting therapy-induced cell kill and increased extracellular space.[5] These molecular and cellular alterations occur before any noticeable decrease in tumor size can be detected on anatomical MRI.[5] Therefore, DW-MRI can provide early indications of therapeutic outcome, in contrast to waiting until the end of treatment for size-based assessment. This initial response provides an important opportunity to adjust the treatment plan if necessary, which could lead to better patient outcomes.[5]

An additional key benefit of DW-MRI is its capability to distinguish between different tissue types by analyzing their diffusion characteristics. Post-radiation fibrosis or edema in the cervix typically shows higher ADC values (closer to normal tissue), whereas residual or recurrent tumor remains relatively restricted with low ADC. Incorporating diffusion-weighted imaging (DWI) into standard MRI protocols has been shown to markedly enhance the specificity for detecting residual cervical cancer following treatment.[6] In other words, DW-MRI helps distinguish residual tumor from post-therapy changes that may appear similar on T2-weighted images.[5] This can prevent both false positives (mistaking scar tissue for tumor) and false negatives (missing small residual tumors). Furthermore, emerging evidence suggests that DW-MRI may perform on par with, or even better than, PET-CT in certain aspects of post-treatment evaluation. In one study, ADC-based assessment showed higher specificity and a similar overall accuracy compared to PET-CT for identifying treatment responders vs. non-responders in carcinoma cervix.[5] Such findings highlight the promise of DW-MRI as a cost-effective, widely accessible imaging biomarker for carcinoma cervix, particularly valuable in settings with limited resources where PET-CT may not be available.

Early Response Monitoring in Cervical Cancer Management:

Timely evaluation of therapeutic response chemoradiation is paramount for personalized carcinoma cervix therapy. Patients with locally advanced cervical carcinoma typically undergo 5 weeks of external beam radiotherapy with concurrent chemotherapy, followed by brachytherapy. This lengthy course means that if a tumor is not responding, the patient might endure the full treatment (and its side effects) with little benefit. Detecting a lack of response as soon as possible can prompt clinicians to adjust the therapeutic plan – for example, by escalating radiation dose, adding salvage chemotherapy, or considering surgical options. Evidence indicates that early treatment responses correlate with long-term outcomes: patients whose tumors respond rapidly to therapy have higher chances of control and survival than those with slow or minimal response.[7,8] Thus, a method to verify response even partway through therapy could serve as a prognostic indicator.

DW-MRI has emerged as one such method, given its ability to reflect cellular changes. Research has demonstrated that changes in ADC values measured during the first few weeks of chemoradiation can predict final treatment response in carcinoma cervix.[5] For instance, a significant increase in tumor ADC by mid-therapy often correlates with a complete response at the end of treatment.[5]

This study performed for early response monitoring using DW-MRI as it could improve carcinoma cervix management by identifying non-responders, sparing them from ineffective therapy and allowing timely transition to alternative treatments, while confirming responders so that therapy can continue as planned with confidence.[5, 9]

AIMS & OBJECTIVES

AIMS & OBJECTIVES OF THE STUDY

1. To perform and assess Diffusion Weighted Magnetic Resonance Imaging and Apparent Diffusion Coefficient values in carcinoma cervix before and after chemoradiation.
2. To evaluate the efficacy of Diffusion Weighted Magnetic Resonance Imaging and Apparent Diffusion Coefficient values in predicting response to chemoradiation.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Global & regional incidence and mortality rates:

Carcinoma cervix is the second most common cancer in developing countries.[10] Even while developed nations have made significant progress in early detection and carcinoma cervix prevention, the overall number of carcinoma cervix cases in developing nations are still high.[10] Carcinoma cervix incidence and mortality have dramatically dropped as a result of improvements in medical diagnosis and treatment techniques. Carcinoma cervix is preventable / curable especially if diagnosed at an early stage. Early detection and management of cervical cancer are crucial, especially as India's population has reached its peak, placing a significant strain on the healthcare system. Naturally, a large population needs a lot of human and medical resources.[10] Before the introduction of the Papanicolaou (PAP) smear test in the 1950s, carcinoma of the cervix was a significant health concern.[3]

Anatomy of Cervix:

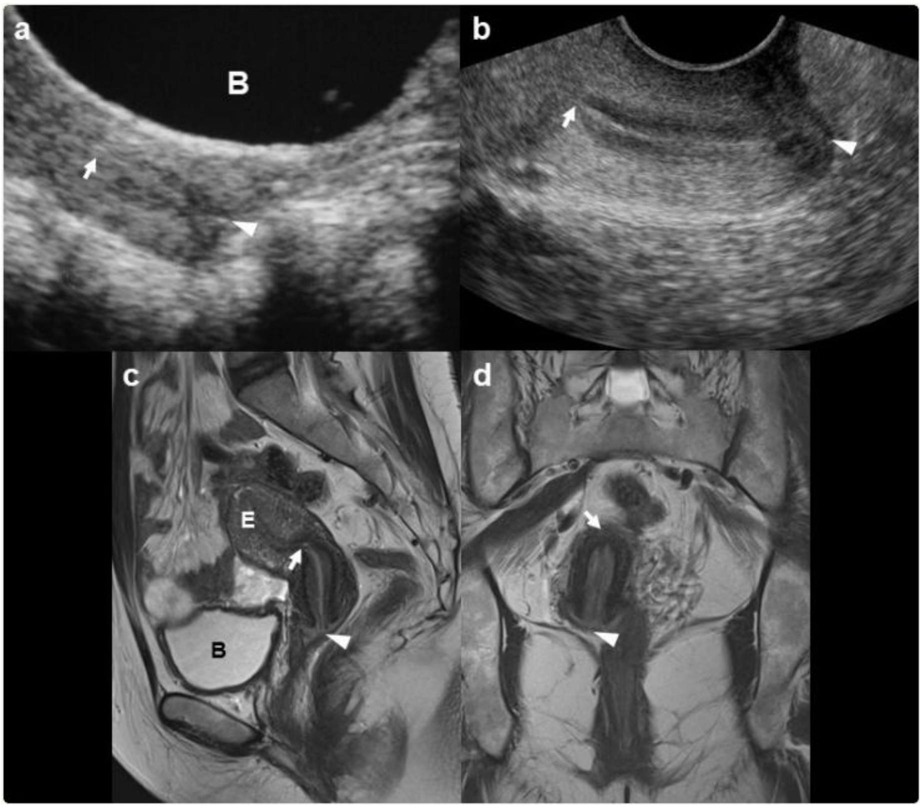


Figure 2. shows the imaging appearance of cervix on Ultrasound and MRI.

Normal ultrasound appearance of the uterine cervix (a), (b) Sagittal transabdominal ultrasound (a) and transvaginal ultrasound (b) obtained in a 35-year-old female show that the cervix appears cylindrical. The echogenic central line represents the interface between the two mucosal layers. The regions of the internal cervical os (small arrow) and external cervical os (arrowhead) are shown. B: bladder (c), (d) Sagittal (c) and coronal (d) T2-weighted magnetic resonance images obtained in a 32-year-old female show normal zonal anatomy of the uterus. The regions of the internal cervical os (small arrow) and external cervical os (arrowhead) are shown. E: endometrium; B: bladder

Pathophysiology of cervical cancer:

Both behavioral and infectious factors act as risk factors for development of cervical cancer. Behavioral factors such as sexual practices and lifestyle choices — including early age at first intercourse, having multiple partners, high parity, smoking, co-infections, extended use of oral contraceptives, and cervical dysplasia — contribute to the risk. Human papillomavirus (HPV) infection is the primary cause of cervical cancer in sexually active individuals.[13]

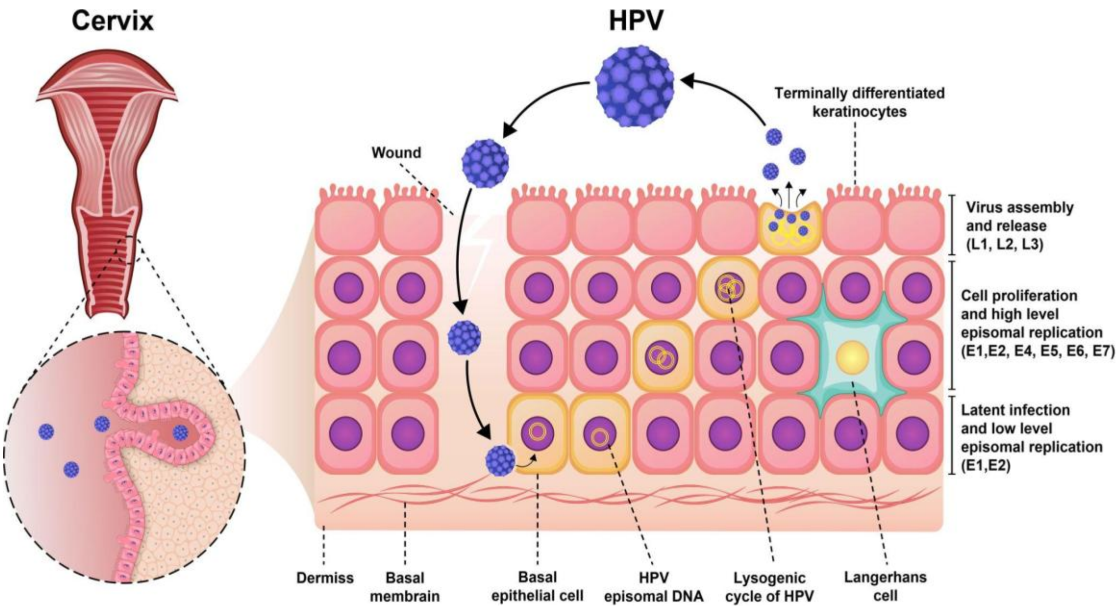


Figure 3. Pathogenesis of HPV infection. Initially, the virus was latent inside the epithelial cell and had a low proliferation rate. As the virus enters the lysogenic cycle, the rate of proliferation increases. Finally, the viruses are assembled and secreted from keratinocytes to repeat the infection cycle.

The transformation zone refers to the area where the squamous epithelium of the ectocervix meets the columnar epithelium of the endocervical canal. This zone is the site of metaplasia, where columnar cells are replaced by squamous cells, and it is the most frequent location for the development of cervical intraepithelial neoplasia (CIN), which may advance to cervical cancer.[14]

Cervical cancers are classified into different types based on their histological appearances on smear taken from the cervix. The commonest type being squamous cell carcinomas, constituting approximately 70-80% of cervical cancers. Glandular histological subtypes, such as adenocarcinomas, comprise about 25% of cases and are generally linked to a worse prognosis.[14,15] The histological subtype and degree of differentiation can influence disease progression, treatment response, and overall patient survival.[15]

Among the 200 known types of HPV, 12 have been classified as cancer-causing by the International Agency for Research on Cancer. Notably, HPV-16 is responsible for approximately 50% of cervical cancer cases, while HPV-18 contributes to around 10%.

If we look at the percentage of newly diagnosed cervical cancers More than 70% of newly diagnosed cervical cancer cases are attributed to HPV subtypes 16 and 18, while HPV types 31, 33, 45, 52, and 58 are responsible for about 19% of cases.[14]

Understanding the epidemiology of HPV and its significant impact on healthcare has prompted the World Health Organization (WHO) to initiate a global HPV elimination program. As part of its strategy, the WHO has set a 90–70–90 target to be achieved by 2030 to advance toward cervical cancer eradication. This goal includes fully vaccinating 90% of girls against HPV by the age of 15, ensuring 70% of women undergo high-quality screening by ages 35 and 45, and providing treatment to 90% of women diagnosed with cervical disease, including both precancerous lesions and invasive cancer.[14]

Prevention of HPV infection:

Vaccinating adolescent girls against HPV has proven to be the most effective long-term strategy for lowering the risk of cervical cancer. Initiated in 2007, the HPV vaccination program targeted girls aged 9 to 12 years, while the high-risk HPV (hrHPV) test was introduced as the primary screening method for women between 35 and 64 years of age.[16] According to current guidelines, full protection is achieved by administering two doses of the vaccine between the ages of 9 and 14 years. Beyond preventing cervical lesions and cancer, these vaccines also lower the risk of developing diseases in the vulva, vagina, and anus.[14]

FIGO Classification:

The internationally recognized staging system for cervical cancer primarily depends on clinical examination to determine tumor stage. However, the updated FIGO 2018 classification permits the use of imaging techniques as an additional tool for staging, with several studies demonstrating that imaging, particularly MRI, offers greater accuracy than clinical examination alone in assessing the stage of cervical carcinoma.[15] Treatment strategies for cervical cancer are tailored based on the FIGO stage of the disease.[17]

Stage	2009 FIGO Definition	2018 FIGO Definition
I	Confined to the cervix	Confined to the cervix
IA	≤5 mm depth and ≤7 mm width	≤5 mm depth*
IA1	≤3 mm depth	≤3 mm depth
IA2	>3 mm and not >5 mm depth	>3 mm and ≤5 mm depth
IB	>5 mm depth	>5 mm depth
IB1	≤4 cm maximum diameter	≤2 cm maximum diameter*
IB2	>4 cm maximum diameter	>2 cm and ≤4 cm maximum diameter*
IB3	...	>4 cm maximum diameter*
II	Beyond the uterus but not involving the lower one-third of the vagina or pelvic sidewall	Beyond the uterus but not involving the lower one-third of the vagina or pelvic sidewall
IIA	Upper two-thirds of the vagina	Upper two-thirds of the vagina
IIA1	Upper two-thirds of the vagina and ≤4 cm	Upper two-thirds of the vagina and ≤4 cm
IIA2	Upper two-thirds of the vagina and >4 cm	Upper two-thirds of the vagina and >4 cm
IIB	Parametrial invasion	Parametrial invasion
III	Lower vagina, pelvic sidewall, and ureters	Lower vagina, pelvic sidewall, ureters, and lymph nodes*
IIIA	Lower one-third of the vagina	Lower one-third of the vagina
IIIB	Pelvic sidewall	Pelvic sidewall
IIIC	...	Pelvic and para-aortic lymph node involvement*
IIIC1	...	Pelvic lymph node involvement*
IIIC2	...	Para-aortic lymph node involvement*
IV	Adjacent and distant organs	Adjacent and distant organs
IVA	Rectal or bladder involvement	Rectal or bladder involvement
IVB	Distant organs outside the pelvis	Distant organs outside the pelvis

Source.—Reference 18.
*Changes made in the 2018 FIGO staging classification.

Table 1 shows comparison of 2009 and 2018 FIGO classification systems

<u>Role of Imaging in staging:</u>

1. **"Stage I is confined to the cervix and is divided into two substages."**
   "Stage IA: Microinvasive Disease with the Deepest Invasion Less than or Equal to 5 mm."

   "Stage IA1 is now defined as disease measuring less than or equal to 3 mm in depth.

   Stage IA2 is defined as disease measuring greater than 3 mm but less than or equal to 5 mm in depth."

"Stage IA disease can be staged only at histopathologic analysis as tumors are not visible at MRI. However, pelvic MRI is performed when invasive or microinvasive disease is confirmed to ensure that lesions have not been underestimated and to assess for skip lesions and nodal metastases, even though the risk of nodal disease at this stage is very low."[17]

"Stage IB: Disease Confined to the Cervix with the Deepest Invasion Greater than 5 mm."

"Stage IB1 is defined now as less than or equal to 2 cm in maximum diameter. These patients are eligible for trachelectomy (fertility-sparing cervical excision with uterovaginal anastomosis) if there are no other contraindications."

"Stage IB2 is greater than 2 cm and less than or equal to 4 cm in maximum diameter. These patients are not usually eligible for trachelectomy."

"Stage IB3 as greater than 4 cm in maximum diameter."[17]

"A study by Matsuo et al showed that patients with tumors measuring less than 2 cm have a twofold increase in survival compared with those with tumors measuring between 2 cm and 4 cm, providing evidence for the change to 2018 FIGO staging."[17]

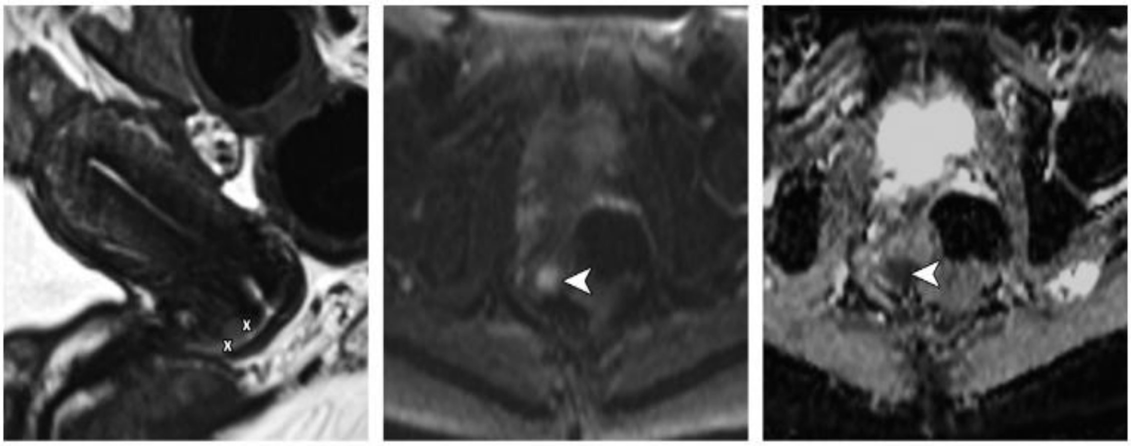
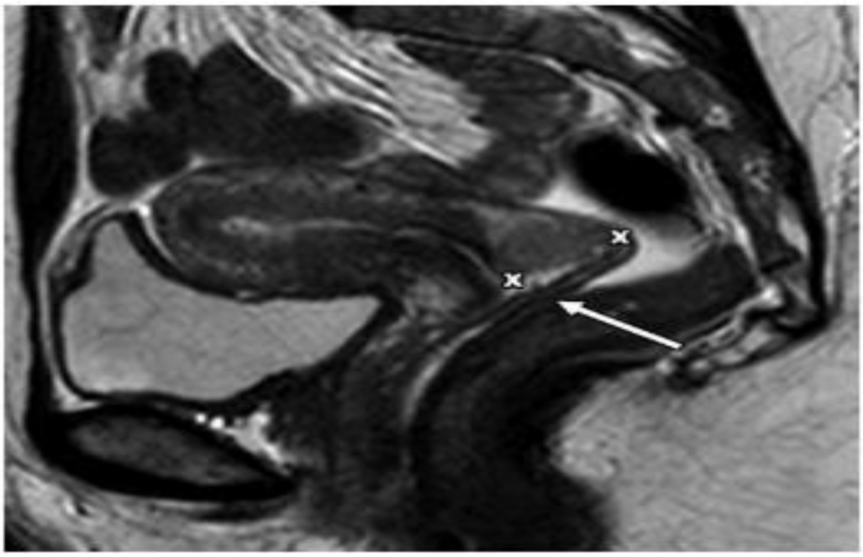
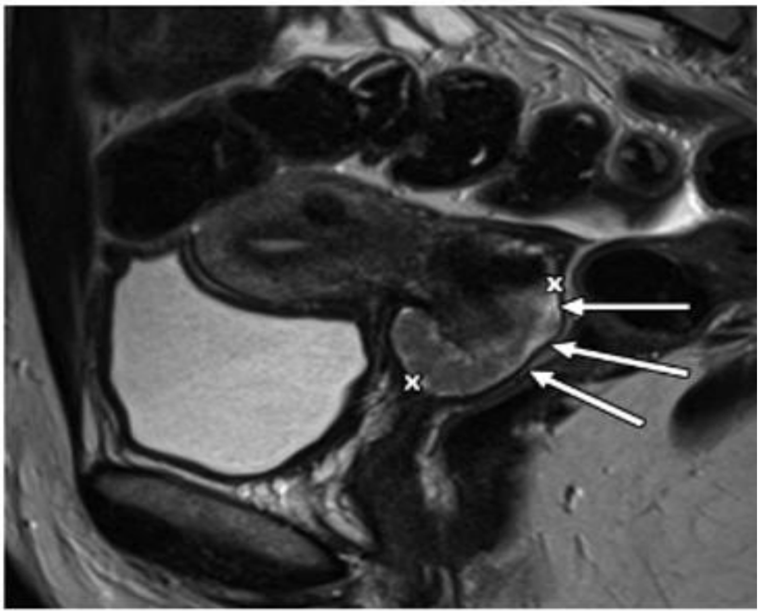


Figure 4. 2018 FIGO stage IB1 disease in a 23-year-old woman with an abnormal cervical smear at screening. (a) Sagittal T2-weighted MR image shows a 1.4-cm tumor with intermediate T2-weighted signal intensity (calipers) centered on the anterior cervix. (b, c) Axial diffusion-weighted image (b) and apparent diffusion coefficient (ADC) map (c) show the tumor (arrowhead) more conspicuously with restricted diffusion. With no disease outside the cervix, these imaging findings are consistent with 2018 FIGO stage IB1 (unchanged from the 2009 FIGO classification). Given the tumor size and location, this patient would be suitable for fertility-sparing surgery (trachelectomy).



"Figure 5. 2018 FIGO stage IB2 disease in a 37-year-old woman who presented with intermenstrual bleeding. Sagittal T2-weighted MR image shows a 3-cm tumor with inter- mediate T2-weighted signal intensity (calipers) arising from the posterior cervix and filling the posterior vaginal fornix but with no vaginal wall invasion. There is preservation of the low T2-weighted signal intensity (arrow) of the posterior vaginal wall. These imaging findings are consistent with 2018 FIGO stage IB2 (previously 2009 FIGO stage IB1)."



"Figure 6. 2018 FIGO stage IB3 disease in a 46-year-old woman who presented with a 3- month history of vaginal bleeding. Sagittal T2-weighted MR image shows a 4.3-cm cervical tumor with intermediate signal intensity (calipers) protruding into the upper vagina with a rim of increased T2-weighted signal intensity fluid (arrows) between the tumor and the vaginal wall. These imaging findings are consistent with 2018 FIGO stage IB3 (previously 2009 FIGO stage IB2)."

2. **"Stage II is defined as disease that extends beyond the uterus but does not involve the lower one-third of the vagina or the pelvic sidewall."** "The pelvic sidewall consists of the obturator internus and piriformis muscles and contains the iliac vessels, pelvic ureters, and lateral lymph nodes. There has been no change to stage II between the 2009 and 2018 FIGO staging classifications."

"Stage IIA disease involves the upper two-thirds of the vagina. It has two subgroups:"

- "Stage IIA1: Tumors less than or equal to 4 cm in maximum diameter"
- "Stage IIA2: Tumors greater than 4 cm"

"Importance of subgroups in IIA - The distinction between tumors smaller or larger than 4 cm is again made for prognostic purposes. Masses larger than 4 cm have a higher chance of recurrence and nodal metastases than do tumors measuring less than 4 cm. These subgroups also serve to guide management."[17]

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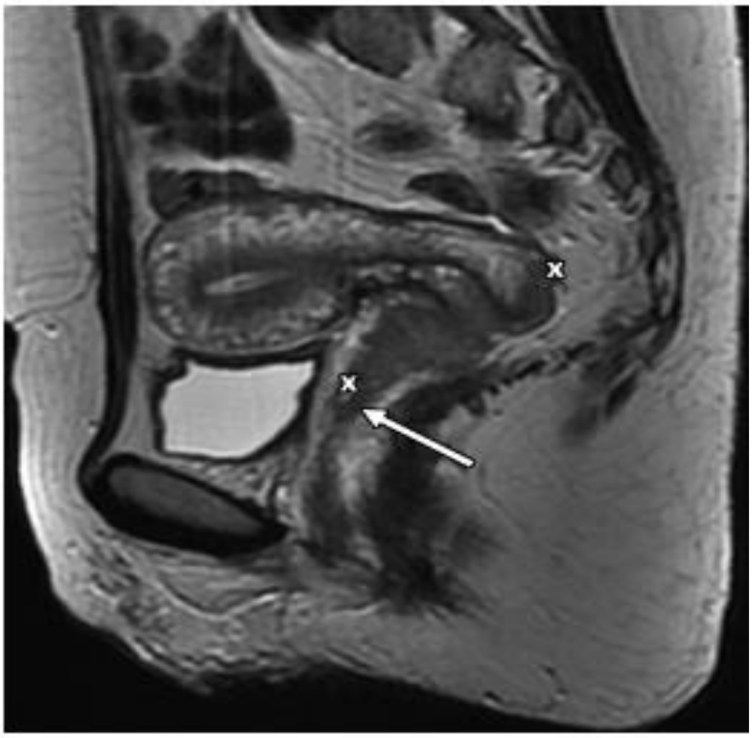
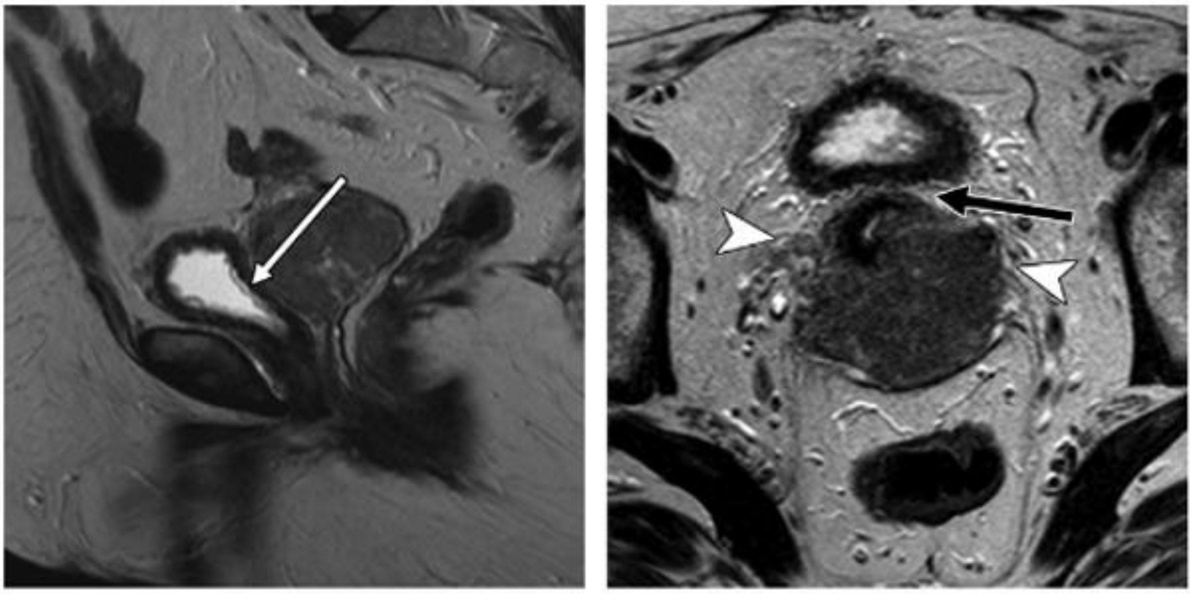


"Figure 7. 2018 FIGO stage IIA2 disease in a 50-year-old woman who presented with dyspareunia. Sagittal T2-weighted MR image shows a 6.1-cm intermediate signal intensity mass (calipers) centered on the cervix. There is loss of the normal low T2-weighted signal intensity of the anterior and posterior vaginal walls. The tumor extends to invade the upper vagina above the level of the bladder base (arrow). These imaging findings are consistent with 2018 FIGO stage IIA2 (unchanged from the 2009 FIGO classification)."

"Stage IIB: Parametrial Invasion"

"The parametrium comprises fat, lymphatics, and vessels located between the body of the uterus and the pelvic sidewall above the level of the ureters. At MRI, normal cervical stroma demonstrates low T2-weighted signal intensity. Focal or diffuse full-thickness disruption of this low T2-weighted signal intensity cervical stromal ring with tissue extending into the parametrial fat is highly sensitive for parametrial invasion. A 3-mm rim of circumferential low T2-weighted signal intensity cervical stroma (the hypointense rim sign) has been found to be 96%–99% specific in excluding parametrial invasion at MRI."[17]



"*Figure 8. 2018 FIGO stage IIB disease* with bullous edema in a 54-year-old woman who underwent staging MRI. Sagittal (a) and axial oblique (b) T2-weighted images show an inter-mediate T2-weighted signal intensity cervical tumor invading the posterior wall of the upper vagina with loss of the normal low T2-weighted signal intensity cervical stroma from 1-o'clock to 6-o'clock. There is extension of the tumor (arrowheads in b) into the parametrial tissues bilaterally with soft-tissue irregularity and extension into the parametrial fat. There is a hyper- intense layered appearance of the bladder wall (arrow in a) consistent with bullous edema. There is no intermediate T2-weighted signal intensity or nodularity within the bladder, and the separating fat plane (arrow in b) between the bladder and the cervical tumor is preserved, suggesting that there is no tumor invasion into the bladder. These imaging findings are consistent with 2018 FIGO stage IIB (unchanged from the 2009 FIGO classification)."

3. **Stage III:**

"Stage IIIA: Lower One-Third of the Vagina:"

"The lesion extends to the lower one-third of the vagina and is best appreciated with a sagittal sequence.Tumor demonstrates intermediate signal intensity at T2-weighted imaging and restricted diffusion."[17]

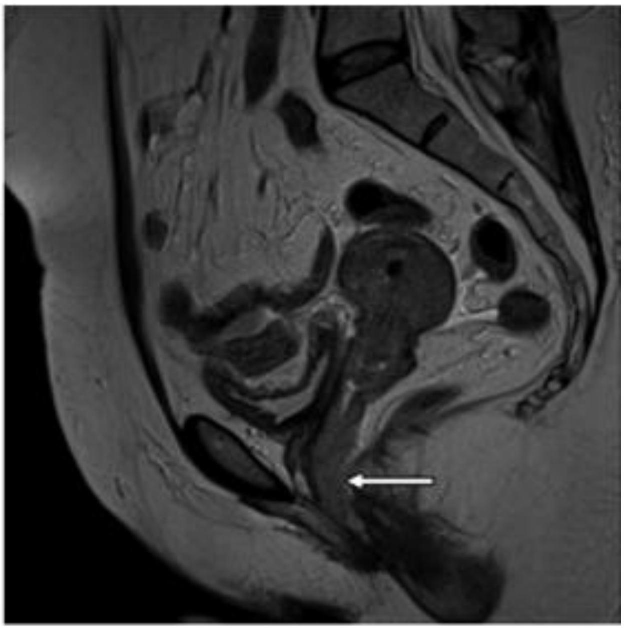
"Stage IIIB: Pelvic Sidewall Involvement"

"It can be diagnosed at imaging when the tumor is less than 3 mm from the pelvic wall."(17)

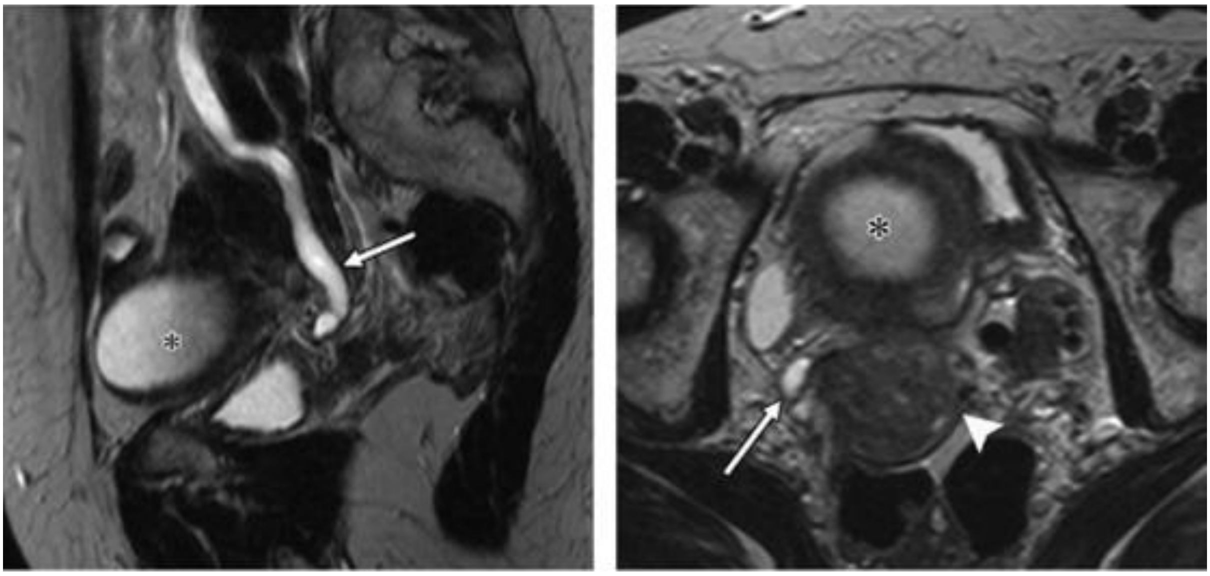
Hydronephrosis, hydroureter or a nonfunctioning kidney secondary to ureteric invasion is indicator of Stage IIIB disease.

"Stages IIIC1 and IIIC2: Pelvic and Para-aortic Lymph Node Involvement."

"There have been multiple studies showing an increase in disease recurrence in the presence of positive lymph nodes at various stages of local tumor extension, as well as a reduced overall survival."[17]



"Figure 9. 2018 FIGO stage IIIA disease in 58-year-old woman who presented with dyspareunia and blood-stained vaginal dis- charge. Sagittal T2-weighted MR image shows an intermediate T2-weighted signal intensity mass (arrow) centered on the cervix with intermediate T2-weighted signal intensity also extending to the myometrium and the lower one-third of the vagina, with loss of the normal low T2-weighted signal intensity of the vaginal walls below the level of the base of the bladder. These imaging findings are consistent with 2018 FIGO stage IIIA (un- changed from the 2009 FIGO classification)."



"Figure 10. 2018 FIGO stage IIIB disease in a 50-year-old woman who presented with right flank pain and was found to have right-sided hydronephrosis at US (not shown). Sagittal (a) and axial (b) T2-weighted MR images show a mass (arrowhead in b) centered on the cervix with right parametrial invasion extending to the right pelvic sidewall and causing right ureteric obstruction and distal right hydroureter (arrow). There is hematometra (*) secondary to cervical stenosis from the cervical tumor. These imaging findings are consistent with 2018 FIGO stage IIIB"

"Stage IV: Disease extending to adjacent organs or outside the true pelvis as metastatic disease is classified as 2018 FIGO stage IV."[17]

Stage IVA:

"Extension of the cervical tumor through the full thickness of the bladder wall anteriorly or rectal wall posteriorly and into the mucosa and lumen."[17]

"If there is loss of the normal separating fat plane between the cervix and the bladder or rectum, or the tumor breaches the normal low T2-weighted signal intensity of the bladder or bowel serosa but does not invade into the lumen, this is not stage IVA."[17]

Stage IVB:

"metastases to distant organs either by lymphatic spread to more distant lymph node groups—for example, the supraclavicular and inguinal regions or less commonly, by hematogenous spread to the bones and lungs"

Staging Change	Description of Change	Reasons and Evidence
Stage IA: definition altered	Width of lesion removed and only depth considered	To remove potential for artifactual error (4)
Stage IB: new categorization	Tumors subdivided into three subgroups: IB1: ≤2 cm IB2: >2 cm and ≤4 cm IB3: >4 cm	Using the National Cancer Institute's Surveillance, Epidemiology, and End Results database, Matsuo et al (5) found that patients with tumors <2 cm had a twofold increase in survival compared with those with tumors measuring between 2 cm and 4 cm.
Stage IIIC: new substages	Suspected nodal disease at imaging now included in FIGO staging	Nodal disease is the most important prognostic indicator of reduced 5-year survival at each stage in patients with positive nodes compared with those without (6). For example, patients with IB2 disease and negative nodes had an 83.3% rate of 5-year survival, compared with 72.1% in patients with positive nodes and IB2 tumors, in a validated study by Wright et al (3). Cross-sectional imaging has an established role in the depiction of lymph node disease. A meta-analysis assessing the diagnostic performance of FDG PET/CT, MRI, and CT for nodal involvement reported FDG PET/CT had pooled sensitivity of 82% and specificity of 95%, with CT 50% and 92%, and MRI 56% and 91%, respectively (7). A more recent systematic review of FDG PET/CT for nodal staging in cervical cancer (27 studies, 8507 cases, surgical pathology reference standard) reported a pooled sensitivity of 72% and specificity of 96% (8).

Table 2: Shows evidence of changes in the 2018 FIGO staging classification

Magnetic resonance imaging (MRI) is the main oncological imaging tool for early diagnosis of cervical cancer along with histopathological (HPE) analysis by regular PAP smears. MRI plays a crucial role in assessing tumor size, evaluating parametrial invasion, determining the depth of stromal infiltration, and detecting lymph node metastases. As a result, it is considered the most reliable imaging modality for initial staging, monitoring treatment response, follow-up evaluations, and identifying tumor recurrence.[11]

Additionally, deeper stromal invasion by the tumor correlates with a higher likelihood of nodal metastasis.[15]

Based on the FIGO staging of cervical cancer done by pathological and imaging findings which takes into consideration the size, location and spread of cancer. Based on this staging, the treatment is initiated to the patient, the treatment includes radical hysterectomy, concurrent chemotherapy and radiation therapy.

The main advantage of assessing the early treatment response, especially in radiation therapy as it allows for timely treatment escalation, including higher radiation dosing, combination chemotherapy, or trial participation. Besides, early assessment to treatment also helps in canceling ineffective treatment and in turn reducing treatment related toxicity and morbidity.[18] Identifying patients early who are less likely to achieve Complete Metabolic Resolution (CMR) could allow for the implementation of more aggressive local treatment strategies, which may ultimately enhance clinical outcomes.[19]

In cases of Early Cervical Cancer (ECC) with Pelvic Lymph Node Metastasis (PLNM), the European Society of Medical Oncology (ESMO) guidelines typically advocate concurrent chemoradiotherapy. Studies have shown that this approach yields comparable survival and recurrence outcomes to surgical management. Therefore, accurate preoperative assessment of pelvic lymph node involvement is crucial for developing the most effective treatment plans.[20]

The application of imaging techniques—especially magnetic resonance imaging (MRI)—in cervical cancer evaluation shows significant regional variability.[15]

Standard Treatment Approaches for Cervical Cancer:

Treatment choices for cervical cancer patients are determined based on the FIGO stage of the disease.[18]

Patients diagnosed with early-stage cervical cancer—where the tumor is confined to the cervix or measures less than 4 cm (FIGO stages IB1, IB2, and IIA1)—are generally managed with primary surgery including tumor resection and lymphadenectomy. Radical hysterectomy with lymphadenectomy is the standard treatment for Early Cervical Cancers (ECC) according to FIGO guidelines.[20] However, for individuals unsuitable for surgery or general anesthesia, concurrent chemoradiotherapy serves as an effective alternative.[11]

In these individuals unsuitable for surgery or general anesthesia concurrent chemoradiotherapy remains the established standard of care for managing cervical cancer cases classified as FIGO Stage IB through IVA.[11,19,21]

For radiotherapy, techniques like image-guided adaptive brachytherapy—particularly interstitial brachytherapy (ISBT)—enhance dose conformity, enable dose escalation, and contribute to better local tumor control.[19]

"Chemoradiation, the combination of chemotherapy and radiotherapy, has become a cornerstone in the management of various malignancies, notably in head and neck, cervical, and esophageal cancers. In the Indian clinical setting, concurrent chemoradiotherapy (CCRT) has shown improved survival outcomes compared to radiotherapy alone, particularly in locally advanced diseases".

"Chemotherapeutic agents such as cisplatin act as radiosensitizers, enhancing the cytotoxic effects of radiation on tumor cells. Several Indian studies have also emphasized the practicality and efficacy of CCRT protocols tailored to resource-constrained environments, achieving substantial tumor control with manageable toxicity profiles".

Even after staging and starting treatment for the patient 10–30% of cervical cancer patients do not achieve a Complete Metabolic Resolution (CMR).[19] To reduce the percentage of patients not achieving CMR, early prediction of treatment response after treatment is of utmost importance so that the treatment can be changed and also terminated if not showing promising results as continuation of the treatment in such cases causes toxic effects on the patients.[18]

Challenges in assessing treatment response:

Following radiation therapy (RT), a significant reduction or complete disappearance of the cervical tumor is observed in some cervical cancer patients. However, others show minimal regression or even an increase in tumor size, indicating possible resistance to RT. At present, no standardized methods exist to reliably forecast treatment response, leaving many patients dependent on post-therapy imaging to assess outcomes.[18] Therefore, developing a standardized approach for evaluating treatment response in cervical cancer patients is essential to overcome this challenge.

Imaging in Cervical Cancer:

Importance of imaging in diagnosing and planning treatment:

Historically, the staging of cervical cancer relied exclusively on clinical examination; however, since 2018, radiological imaging has been officially included as part of the staging criteria.[11] Compared to Computed Tomography (CT), Magnetic Resonance Imaging (MRI) provides superior soft tissue contrast and more detailed anatomical visualization, demonstrates strong correlation with the evaluation of parametrial invasion, and plays a vital role in guiding treatment planning.[11]

MRI outperforms clinical examination in assessing tumor size and location, enhancing the accuracy of FIGO staging by as much as 96%.[15] For tumors classified above FIGO stage IB2, MRI is the preferred imaging technique because of its high accuracy in assessing the extent of tumor invasion. It is also currently the primary non-invasive method for evaluating pelvic lymph node metastasis (PLNM).[20]

A standard MRI protocol for cervical cancer includes T2-weighted imaging of the pelvis in various planes. Axial and coronal images are obtained in an oblique orientation along the cervical canal to improve visualization of tumor boundaries and evaluate parametrial invasion. Furthermore, T1- and T2-weighted sequences covering the full abdomen and pelvis are advised for detecting possible lymph node metastases.[15]

Table 3: Essential MRI Sequences for Staging Cervical Cancer

Sequence	Plane	Coverage	Matrix (mm × mm)	Section Thickness (mm)	Rationale
T2W	Sagittal	To cover the uterus and parametrium, ideally including pelvic sidewall	260 × 230	4	For size and local staging Vaginal involvement
T2W	Perpendicular to the cervix	To cover uterus and vagina	200 × 180	3.5	For local staging Parametrial and pelvic sidewall involvement
T2W	Axial	From renal hila to pubic symphysis	300 × 260	5	For disease outside the cervix Para-aortic nodes
T1W	Axial	From renal hila to pubic symphysis	300 × 260	5	For disease outside the cervix Para-aortic nodes
DWI	Axial	From renal hila to pubic symphysis	300 × 260	5	Identifying small masses, lymph nodes, and unexpected bone metastases

Sources.—References 17 and 18.
Note.—T1W = T1-weighted, T2W = T2-weighted.

Table 3: Essential MRI sequences for staging cervical cancer

Sequence planning:

MRI sequences are oriented with respect to the cervical canal's long axis. The axial images are acquired perpendicular to this axis, while the coronal images are obtained parallel to it.

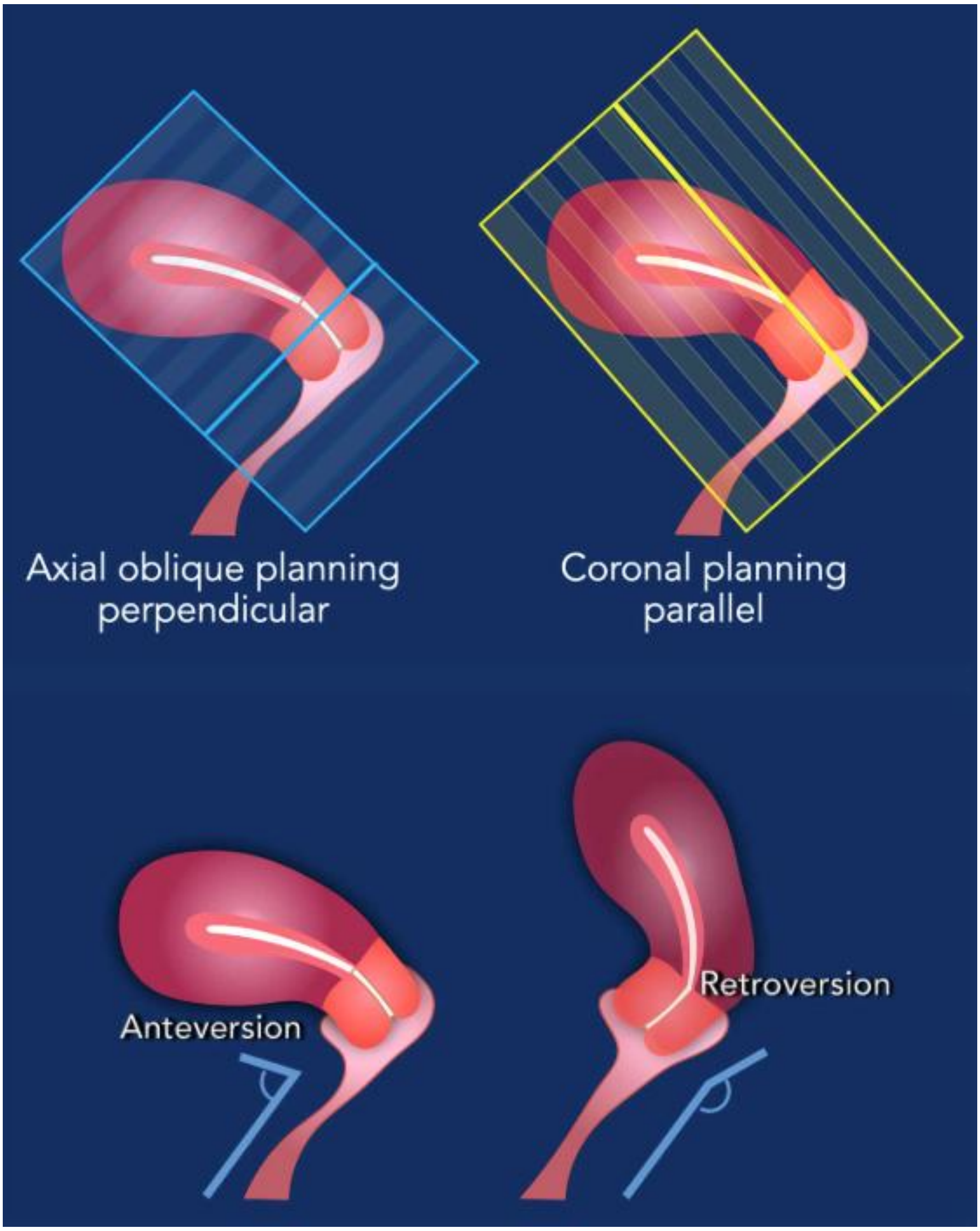


Figure 11 shows the diagrammatic representation of sequence planning in MRI pelvis for cervical imaging

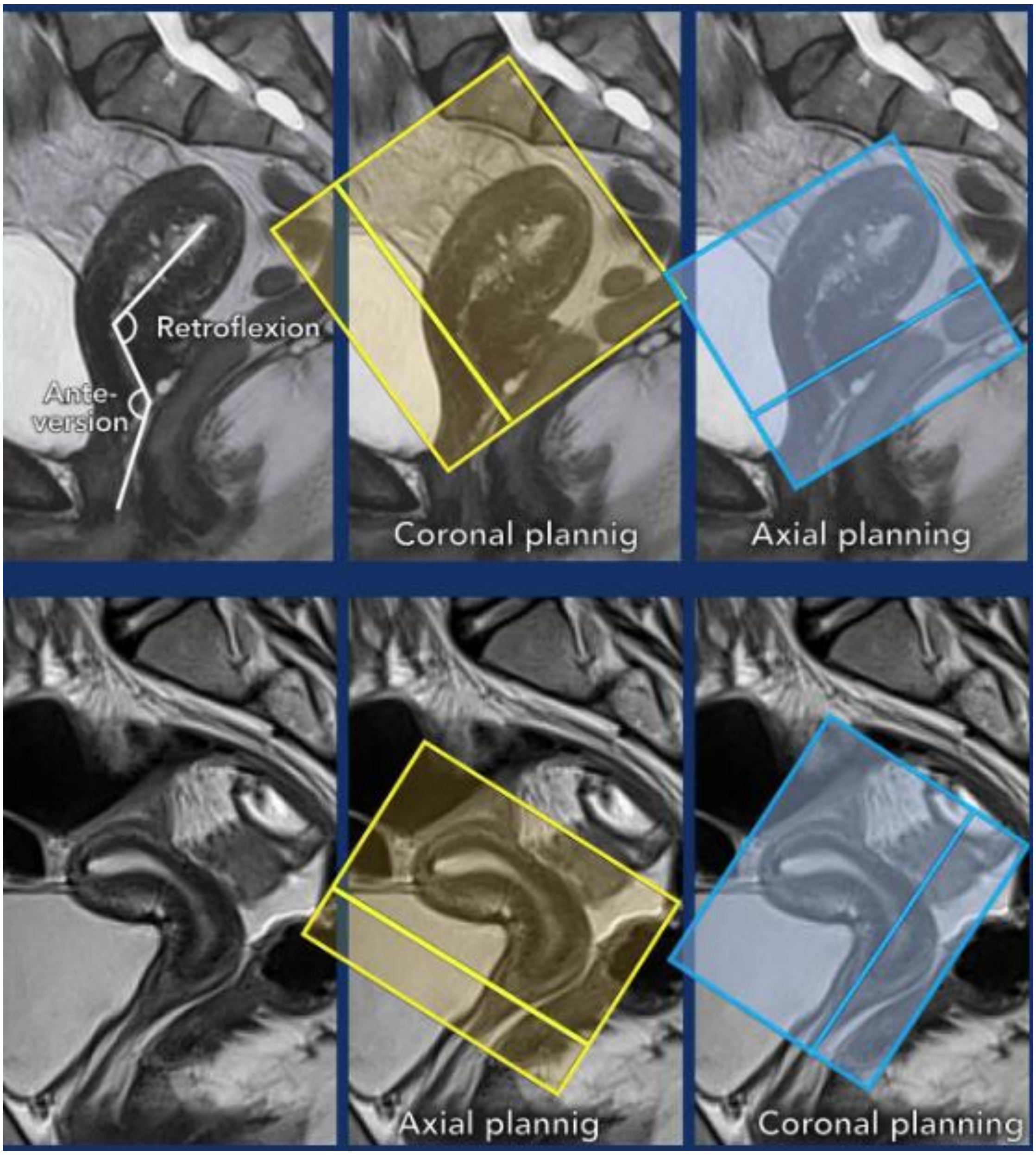


Figure 12 shows the MRI sequence planning in MRI pelvis for cervical imaging in axial and coronal planes.

PET-CT also plays a role in evaluating the complete metabolic response in cervical cancer, which is associated with better patient outcomes.[19]

A Phase III randomized trial proposed an alternative approach of neoadjuvant chemoradiotherapy (CRT) followed by radical surgery. This method demonstrated comparable response rates to those achieved with definitive CRT alone, while offering additional prognostic insights. Patients who attained a pathological complete response after neoadjuvant CRT experienced improved disease-free and overall survival compared to those with only a partial response. In this context, identifying a noninvasive biomarker to detect partial response after neoadjuvant CRT in patients with locally advanced cervical cancer (LACC) is a significant clinical need. Having imaging modalities capable of accurately assessing residual disease would be crucial for selecting patients who might either avoid surgery altogether or undergo a more individualized surgical approach.[21]

Besides, early assessment to treatment also helps in canceling ineffective treatment and in turn reducing treatment related toxicity and morbidity.[18] Early detection of patients unlikely to achieve a complete metabolic response (CMR), who might benefit from intensified local therapy, could help enhance outcomes for this patient subgroup.[19]

Limitations of conventional imaging techniques (e.g., USG & CT, MRI without DWI):

The effectiveness of conventional MRI, which relies on morphological features to detect pelvic lymph node metastasis (PLNM), remains limited because of challenges posed by inflammatory hyperplasia and micrometastatic lymph nodes.[20]

In earlier studies, we individually investigated several quantitative and semi-quantitative parameters from different imaging modalities, including vascular indices and contrast-enhanced features from transabdominal ultrasound (TUS), morphological parameters from TUS, MRI-derived tumor volume, MRI-DWI signal intensity and mean apparent diffusion coefficient (ADC), along with ^18F-FDG-PET/CT metrics such as maximum standardized uptake value (SUVmax), mean SUV, metabolic tumor volume (MTV), and total lesion glycolysis (TLG). Our findings indicated that, at various points before, during, and after neoadjuvant CRT, certain parameters significantly differed between patients with residual disease (partial responders) and those without residual disease (complete responders) on histopathology. Nevertheless, no single parameter demonstrated a high diagnostic accuracy on its own.[21]

MRI is not useful for assessing stage IA cervical cancer, as it cannot reliably detect microscopic disease.[15]

Diffusion-Weighted MRI (DW- MRI):

Introduction:

Diffusion-weighted MRI (DWI-MRI) has emrged as a focal point of interest as a noninvasive method that offers information about the tumor's cellular environment by assessing water molecule diffusion within tissues.[19]

DWI is a vital component of the MRI protocol in carcinoma evaluation, enhancing tumor detection, staging accuracy, and assessment of therapeutic response.[11] Tumors generally show increased signal intensity on DWI and lower apparent diffusion coefficient (ADC) values relative to adjacent normal tissues.[11]

Diffusion-Weighted MRI and ADC: Principles and Tumor Characterization:

DW-MRI is a sophisticated imaging method that assesses tissue microstructure by capturing the in vivo random movement of water molecules, called Brownian motion.[22] In a DW-MRI sequence, strong gradient pulses (so-called b-values) are applied; water molecules that diffuse freely during these gradients lead to signal attenuation on the resulting images. Tissues with impeded or restricted diffusion retain higher signal on DWI at high b-values. By acquiring images with at least 2 different b-values, one can quantify the degree of water diffusivity in tissues through the ADC.[23] The ADC is calculated from the signal decay between b-value images and is expressed in units of mm^2/s, representing how rapidly water diffuses within the tissue microenvironment.[23] On ADC maps (parametric images of diffusion), areas of restricted diffusion appear dark (low ADC values), whereas regions with free diffusion appear bright (high ADC values).

The relevance of DW-MRI to tumor characterization stems from the fact that tumors often have altered tissue architecture. Most malignant tumors are hypercellular, with densely packed cells, enlarged nuclei, and abundant macromolecules — all of which impede water motion. Consequently, high-cellularity tumors cause more restriction to water diffusion, resulting in lower ADC values.[24] Numerous studies have demonstrated an inverse correlation between tumor ADC and cellular density.[22] In practical terms, this means aggressive or cellular tumors typically show high signal on DW-MRI (especially at high b-values) and low ADC values on the corresponding maps, compared to normal tissues or less cellular lesions. DW-MRI thereby adds a functional dimension to cancer imaging: it can highlight tumors that might be inconspicuous on routine scans and can provide quantitative metrics (ADC values) that reflect tumor biology. For example, in carcinoma cervix, integrating DW-MRI with conventional MRI improves tumor delineation against surrounding tissues and aids in detecting involved lymph nodes.[25] By measuring ADC, radiologists can non-invasively infer tumor characteristics; a very low ADC in a carcinoma cervix lesion suggests dense tumor cellularity, while a higher ADC may indicate necrosis or less aggressive behavior. Thus, DW-MRI serves as a tumor biomarker imaging tool, complementing anatomical imaging by revealing microstructural information that is highly relevant for diagnosis, grading and even prognostication.[22]

Importance of cellular diffusion in cancerous tissues: Unlike traditional clinical and pathological prognostic indicators, this functional imaging technique may more accurately reflect the distinct biological characteristics of tumors in vivo by assessing water molecule diffusion within cancerous tissue, serving as a valuable imaging biomarker.[18]

Advantages of DW-MRI over other imaging techniques:

An increasing number of studies support the role of Diffusion-weighted imaging (DWI) in predicting treatment response across different types of cancer. Research on nasopharyngeal carcinoma, breast cancer, and locally advanced rectal cancer has shown that lower pre-treatment ADC values are linked to poorer therapeutic outcomes.[18]

Functional imaging techniques like diffusion-weighted imaging (DWI) are increasingly recognized as useful biomarkers for assessing and predicting cancer treatment responses.[18]

Diffusion-weighted imaging (DWI) offers insights into cellular density and membrane integrity, thereby serving as a valuable adjunct in differentiating benign from malignant lymph nodes(20). Diffusion-weighted imaging (DWI) can be performed without the use of contrast agents, making it suitable for patients with impaired kidney function.[15]

Apparent Diffusion Coefficient (ADC) in Tumor Assessment

Studying the microenvironment of tumors through functional imaging parameters and analyzing its association with tumor invasiveness can enhance the accuracy of evaluating MRI techniques as dependable diagnostic tools.[20]

Tissues characterized by high cellularity, such as tumors, lymph nodes, and fibrotic regions, generally display reduced apparent diffusion coefficient (ADC) values. In cases of pelvic cancers—such as prostate, bladder, rectal, and cervical malignancies—ADC assessments can help identify patients who are at higher risk for disease recurrence or poor outcomes. Additionally, evaluating changes in ADC values before and after treatment can provide an effective method for tracking the response to chemoradiotherapy.[11]

How ADC values correlate with tissue cellularity and its potential applications in monitoring treatment response of tumor:

Measurements of the Apparent Diffusion Coefficient (ADC) obtained through diffusion-weighted imaging (DWI) offer a quantitative means of evaluating tumor cellularity and the extent of necrosis after treatment.[19]

Water diffusion is limited in tissues with high cellular density by cell membranes, leading to reduced diffusivity. Malignant tumors typically exhibit lower ADC values due to their dense cellular architecture. Following chemotherapy or radiotherapy, tumor necrosis often results in elevated ADC values, making ADC a valuable parameter for evaluating therapeutic response.[19]

Reduced ADC values have been associated with increased tumor aggressiveness across different types of tumors.[15]

Research has demonstrated that ADC values are useful in predicting malignancy and important clinical outcomes across various cancer types.[19]

This study aims to investigate the potential of ADC values as early biomarkers for treatment response, with the goal of minimizing dependence on post-treatment imaging for outcome prediction. It also seeks to determine whether pre-treatment and follow-up ADC measurements can effectively distinguish between complete and partial responders to chemoradiotherapy.

MATERIALS
& METHODS

MATERIALS AND METHODS

Study Design:

Research Type: This was a prospective study conducted in the Department of Radio-diagnosis, R.L.Jalappa Hospital and Research Center attached to Sri Devaraj Urs Medical College, Kolar after approval by institutional ethical committee.

Duration of study: Conducted for a period of 18 months.

Sample size: 30

Materials:

Source of data is done based on the following two criterias:

- Inclusion criteria
- Exclusion criteria

MRI Equipment

- MRI scan was performed on SIEMENS MAGNETOM AVANTO 1.5 Tesla, 18 channel MRI machine.

Contrast Agents

- No contrast agents were used in this study.

Methods:

Pre-Imaging Procedures:

The procedure is thoroughly explained to the patient, and informed consent is obtained.

Proper patient preparation is essential for high-quality pelvic MRI imaging. Individuals are advised to empty both their bladder and rectum approximately 30 minutes prior to the scan. This practice ensures a partially filled bladder, which helps maintain an optimal uterine position and reduces image artifacts caused by overdistension. Additionally, diffusion-weighted imaging (DWI) of the pelvis can be compromised by distortion related to residual rectal gas.

Although no conclusive evidence currently supports the routine use of bowel preparation for cervical cancer MRI, studies have indicated that microenemas can reduce the frequency and intensity of rectal gas artifacts in prostate DWI.

Imaging Protocols:

In this study, MRI scans were performed following a standardized protocol using a 1.5 Tesla system equipped with a pelvic phased-array coil, with patients positioned supine. Initial imaging included sagittal T2-weighted sequences of the pelvis, followed by high-resolution, small field-of-view (FOV) sequences aligned perpendicular to the cervix's long axis. These high-resolution sequences were critical for precise local tumor staging, capturing the morphology of the primary lesion and assessing parametrial and vaginal involvement.

Additionally, large FOV axial T1-weighted and T2-weighted images were obtained, extending from the renal hila to the pubic symphysis. Large FOV imaging was essential for evaluating disease spread beyond the cervix, including para-aortic lymph node enlargement, hydronephrosis, and osseous metastases. Notably, large FOV T1-weighted sequences offered superior soft-tissue contrast, facilitating the differentiation of lymph nodes from adjacent fat and identifying fatty hila within lymph nodes.

Chemoradiation treatment:

Eligible participants included adults diagnosed with locally advanced malignancies, primarily squamous cell carcinomas, who were scheduled to undergo CCRT with cisplatin-based regimens. "Radiotherapy was administered using a conventional fractionation schedule (2 Gy per fraction, 5 days a week), alongside concurrent cisplatin at a dose of 40 mg/m^2 weekly, adhering to standard Indian oncology protocols. Patient selection, treatment planning, toxicity assessment, and response evaluation followed the guidelines recommended by the Indian Council of Medical Research (ICMR) to ensure uniformity and reproducibility in outcomes. Ethical clearance was obtained prior to study initiation, and informed consent was secured from all participants".

Cervical tumors commonly exhibit restricted diffusion, axial diffusion-weighted imaging (DWI) of the pelvis was conducted using b-values of 50, 400, and 800.

Table 3: Essential MRI Sequences for Staging Cervical Cancer					
Sequence	Plane	Coverage	Matrix (mm × mm)	Section Thickness (mm)	Rationale
T2W	Sagittal	To cover the uterus and parametrium, ideally including pelvic sidewall	260 × 230	4	For size and local staging Vaginal involvement
T2W	Perpendicular to the cervix	To cover uterus and vagina	200 × 180	3.5	For local staging Parametrial and pelvic sidewall involvement
T2W	Axial	From renal hila to pubic symphysis	300 × 260	5	For disease outside the cervix Para-aortic nodes
T1W	Axial	From renal hila to pubic symphysis	300 × 260	5	For disease outside the cervix Para-aortic nodes
DWI	Axial	From renal hila to pubic symphysis	300 × 260	5	Identifying small masses, lymph nodes, and unexpected bone metastases

Sources.—References 17 and 18.
Note.—T1W = T1-weighted, T2W = T2-weighted.

Table 4: Shows essential MRI sequences for staging cervical cancer.

Data Collection Procedures

The data after the MRI was performed was sent to Synapse 3D workstation for reporting the staging of cervical cancer according to FIGO Classification 2018.The findings were recorded in the proforma.

Figure 13 shows SIEMENS MAGNETOM Avanto 1.5 Tesla Machine

RESULTS

Table 5:- Subject distribution according to age group

	Frequency	Percentage
51-60yrs	12	40.0
61-70yrs	12	40.0
71-80yrs	6	20.0
Total	30	100.0

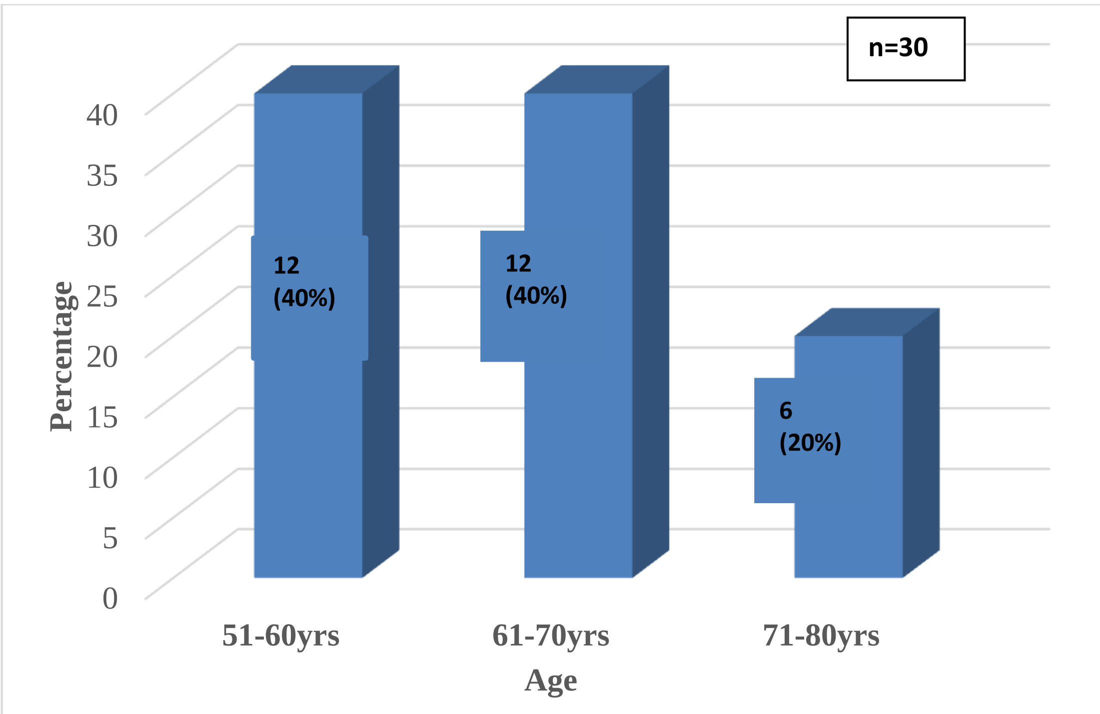


Figure 14:- Bar diagram with subject distribution according to age group. The majority of subjects belonged to 51-60 and 61-70 years age group. Very few subjects were observed in the older age group i.e., 71-80 years.

Table 6:- Subject distribution according to T1

	Frequency	Percentage
Hypo intense	7	23.3
Isointense	23	76.7
Total	30	100.0

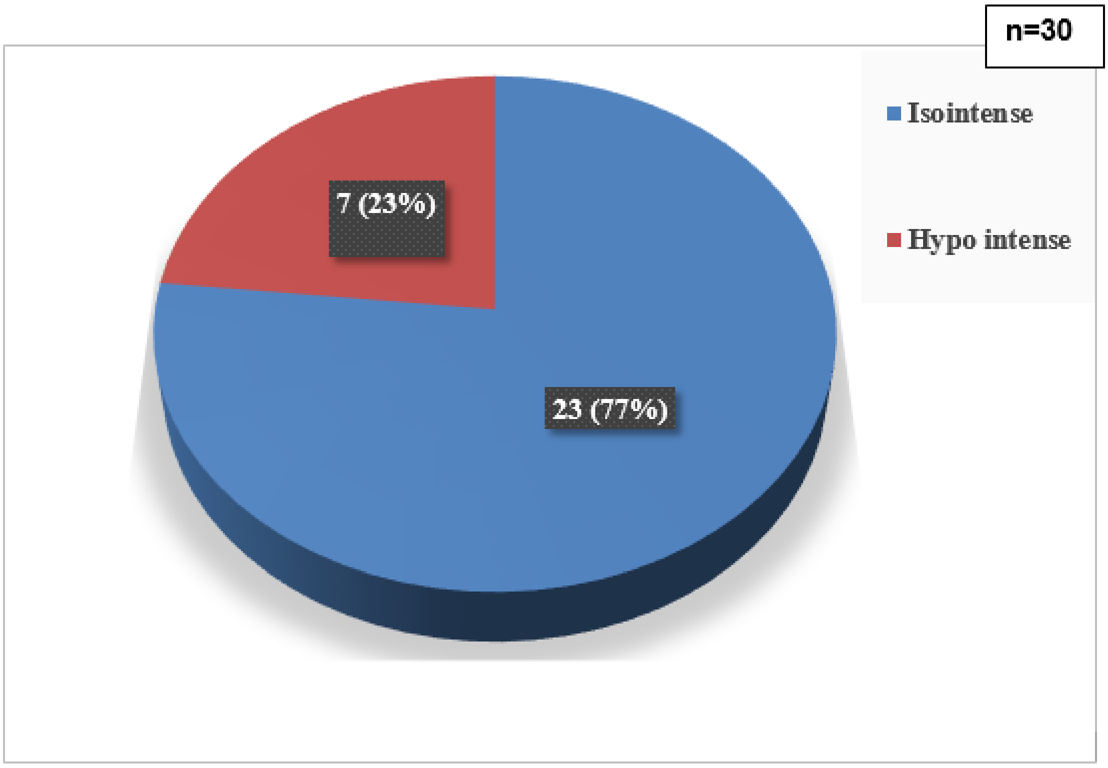


Figure 15:- Pie chart with subject distribution according to T1. The majority of subjects (77%) showed isointense signal intensity on T1 Weighted imaging.

Table 7:- Subject distribution according to T2 and T1 Post contrast

	Frequency	Percentage
Homogeneous	0	0
Heterogeneous	30	100.0
Total	30	100.0

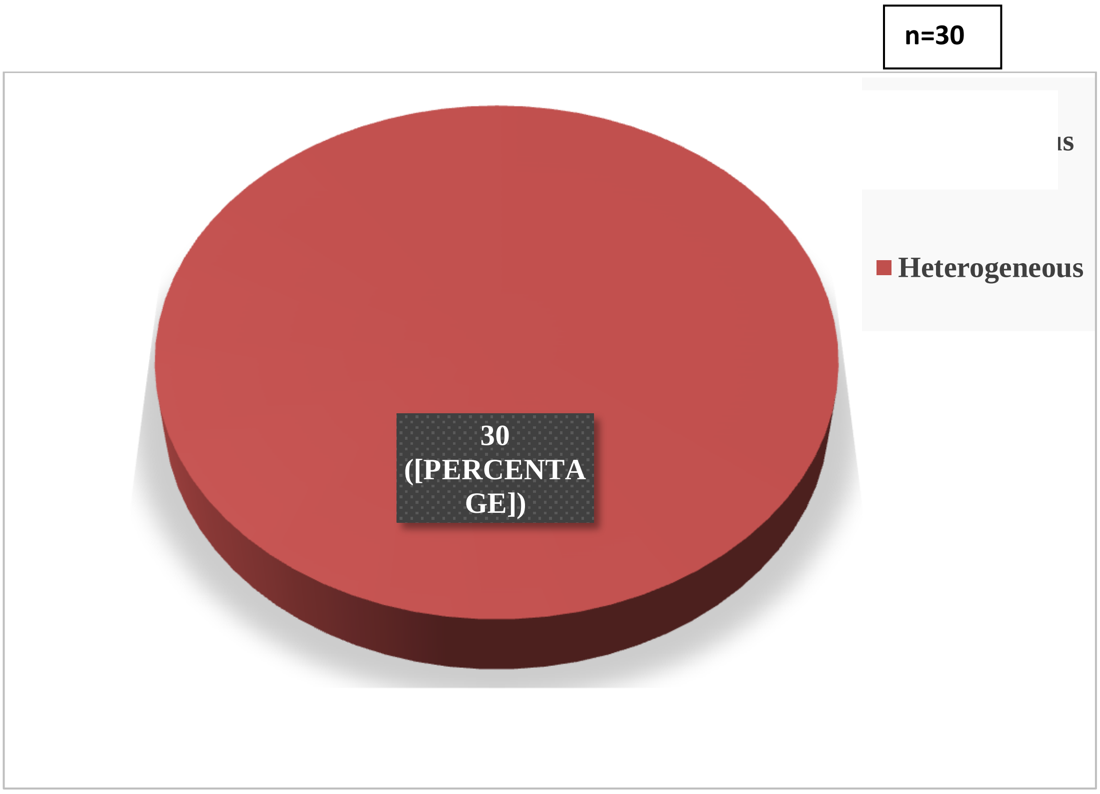


Figure 16:- Pie chart with subject distribution according to T2 and T1 Post contrast. All subjects showed heterogeneous signal intensity on T2 Weighted imaging.

Table 8:- Subject distribution according to DW1 Restriction

	Frequency	Percentage
Homogeneous	22	73.3
Patchy	8	26.7
Total	30	100.0

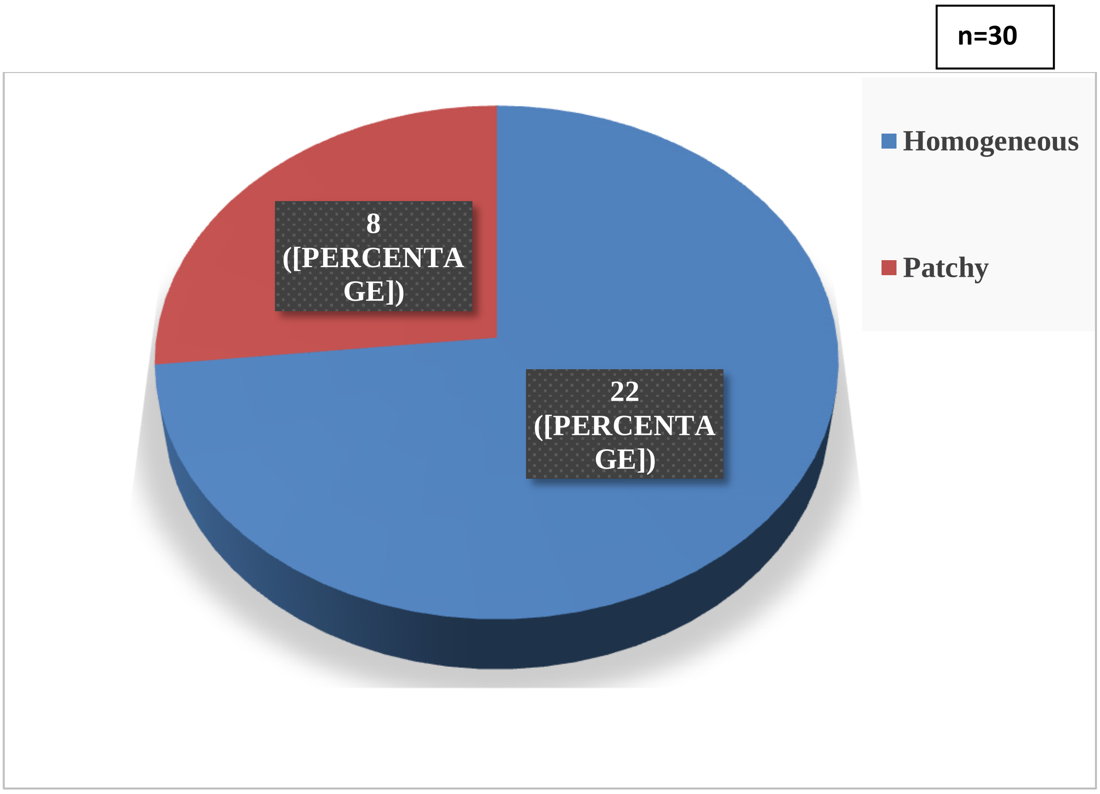


Figure 17:- Pie chart with subject distribution according to DW1 Restriction. The majority of subjects (73%) showed homogenous restriction, while minority of subjects (27%) showed patchy area of restriction.

Table 9:- Subject distribution according to Hydroureteronephrosis

	Frequency	Percentage
Absent	25	83.3
Present	5	16.7
Total	30	100.0

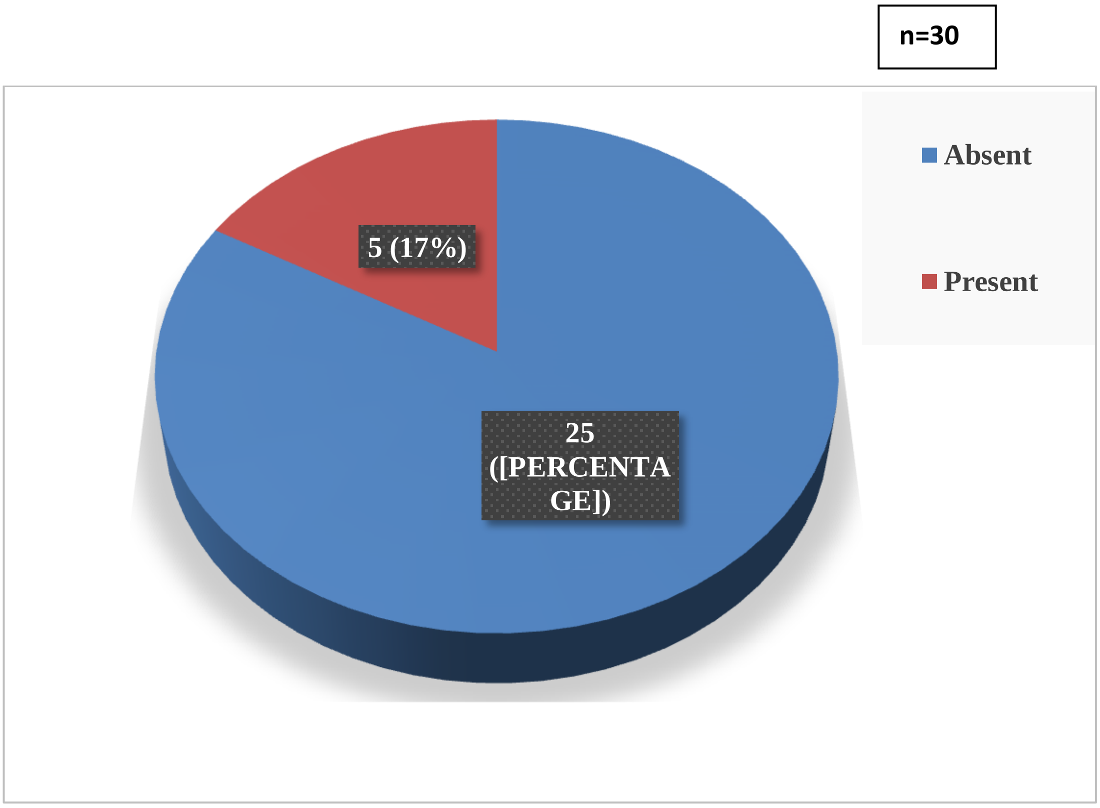


Figure 18:- Pie chart with subject distribution according to subjects having Hydroureteronephrosis. 83% had Hydroureteronephrosis, few subjects (17%) did not have Hydroureteronephrosis.

Table 10:- Subject distribution according to Enlarged lymph nodes

	Frequency	Percentage
Absent	18	60.0
Present	12	40.0
Total	30	100.0

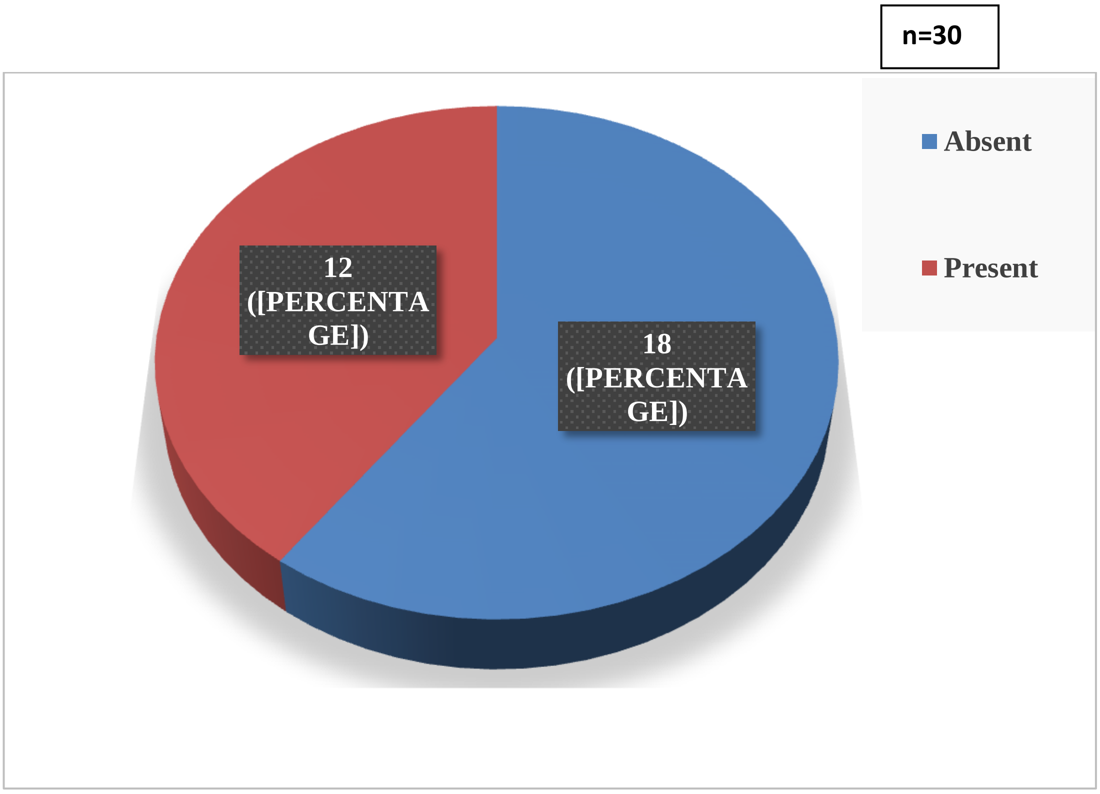


Figure 19:- Pie chart with subject distribution according to enlarged lymph nodes. The majority of subjects (60%) had enlarged lymph nodes, few subjects (40%) did not have any enlarged lymph nodes.

Table 11:- Subject distribution according to Pyometra

	Frequency	Percentage
Absent	18	60.0
Present	12	40.0
Total	30	100.0

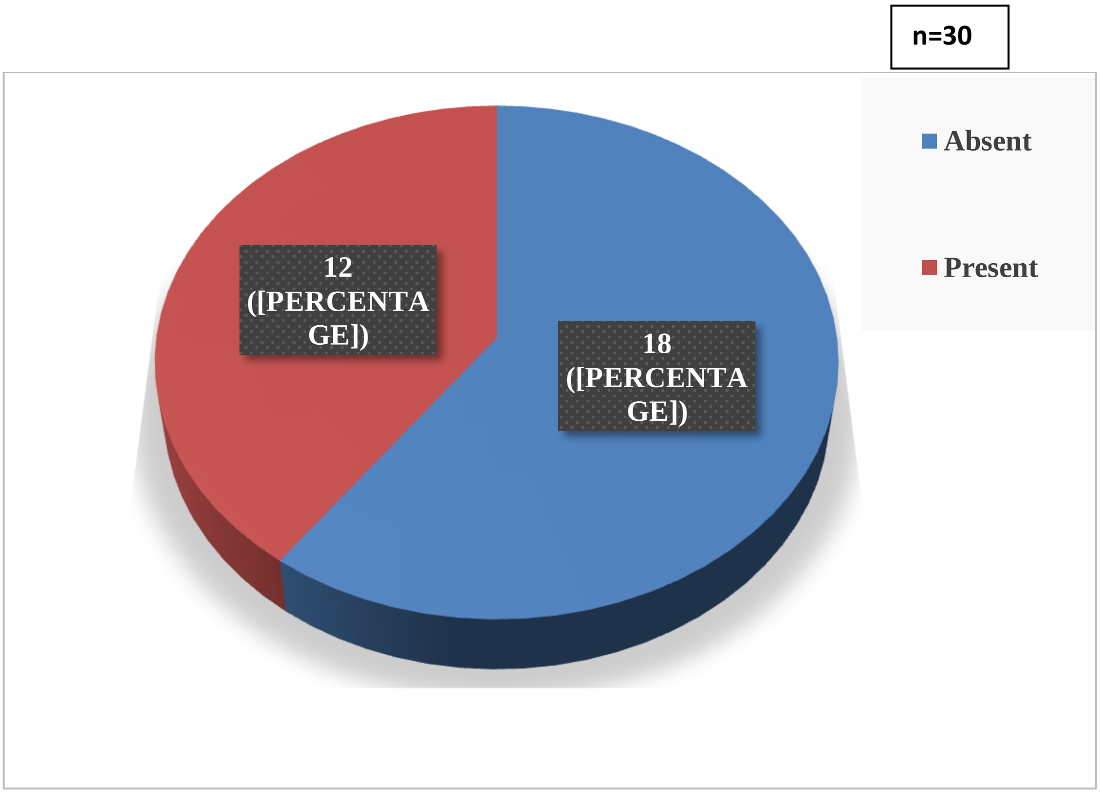


Figure 20:- Pie chart showing subject distribution according to Pyometra. 60% of subjects had pyometra, while 40% did not have pyometra.

Table 12:- Subject distribution according to FIGO Staging

	Frequency	Percentage
IIA	3	10.0
IIB	8	26.7
IIIA	6	20.0
IIIC	11	36.7
IVA	1	3.3
IVB	1	3.3
Total	30	100.0

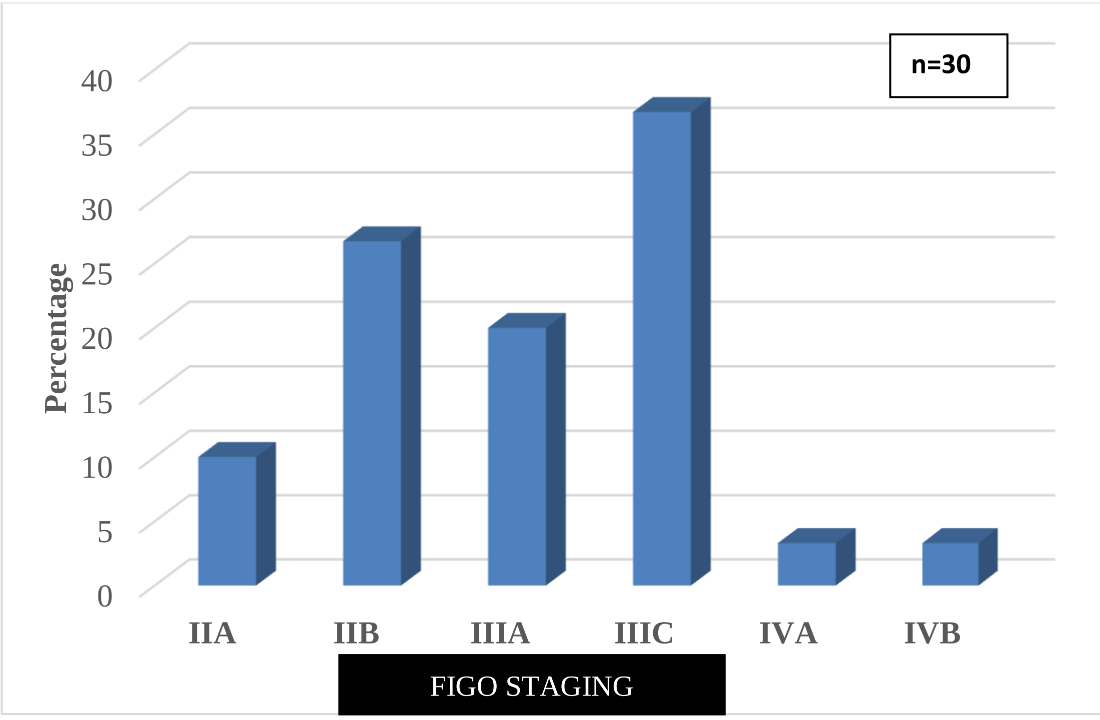


Figure 21:- Bar diagram with subject distribution according to FIGO Staging. In our study most common staging the subjects had fallen under is IIIC (36.7%). Other staging's are IIB (26.7%), IIIA (20%), IIA (10%), IVA (3.3%) and IVB (3.3%).

Table 13:- Comparison of mean size of carcinoma cervix, Pre-treatment vs Post-treatment

	Mean	Std. Deviation	P Value
Pre-treatment	3.85	1.35	<0.01
Post-treatment	3.03	1.1	

Carcinoma cervix mean size Pre-treatment was 3.85± 1.35 and Post-treatment was 3.03± 1.1. A statistically significant difference was observed between pre-treatment and post-treatment measurements.

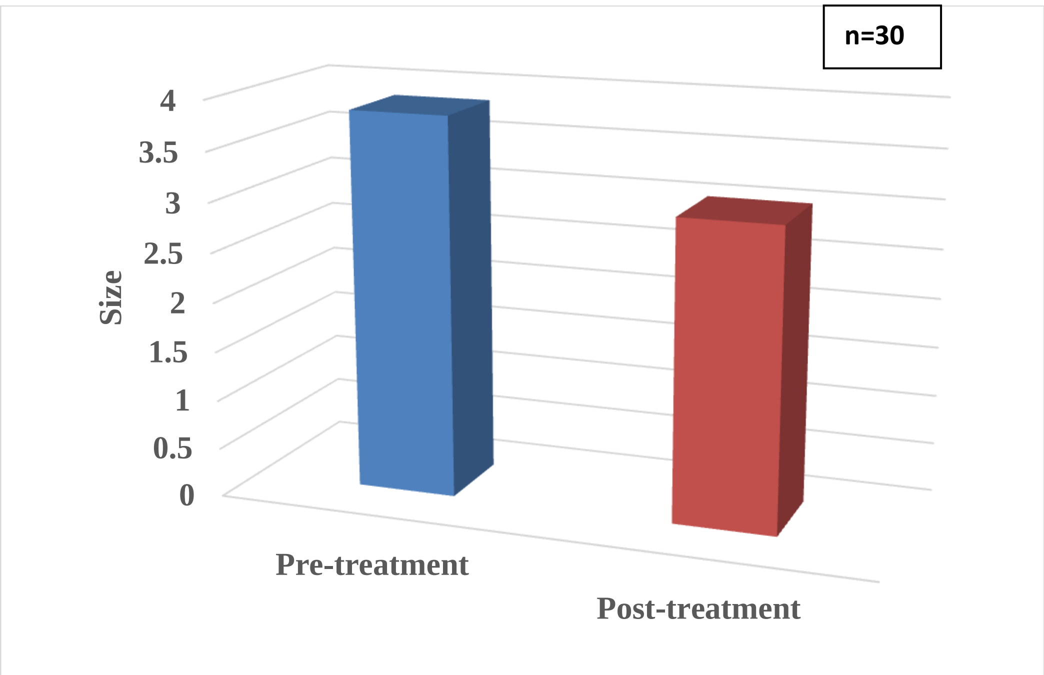


Figure 22:- Graph showing Comparison of mean size of carcinoma cervix, Pre-treatment vs Post-treatment. The mean size of the mass was 3.5 cm in pre-treatment and it reduced to mean size to 2.8 cm in post-treatment.

Table 14:- Comparison of mean ADC Values of carcinoma cervix, Pre-treatment vs Post-treatment

	Mean	Std. Deviation	P Value
Pre-treatment	0.659	0.147	<0.01
Post-treatment	1.447	0.21	

Mean ADC Values Pre-treatment was 0.659± 0.147 and Mean ADC Values Post-treatment was 1.447± 0.21 . A statistically significant difference was observed between Pre-treatment and Post-treatment with respect to ADC Values

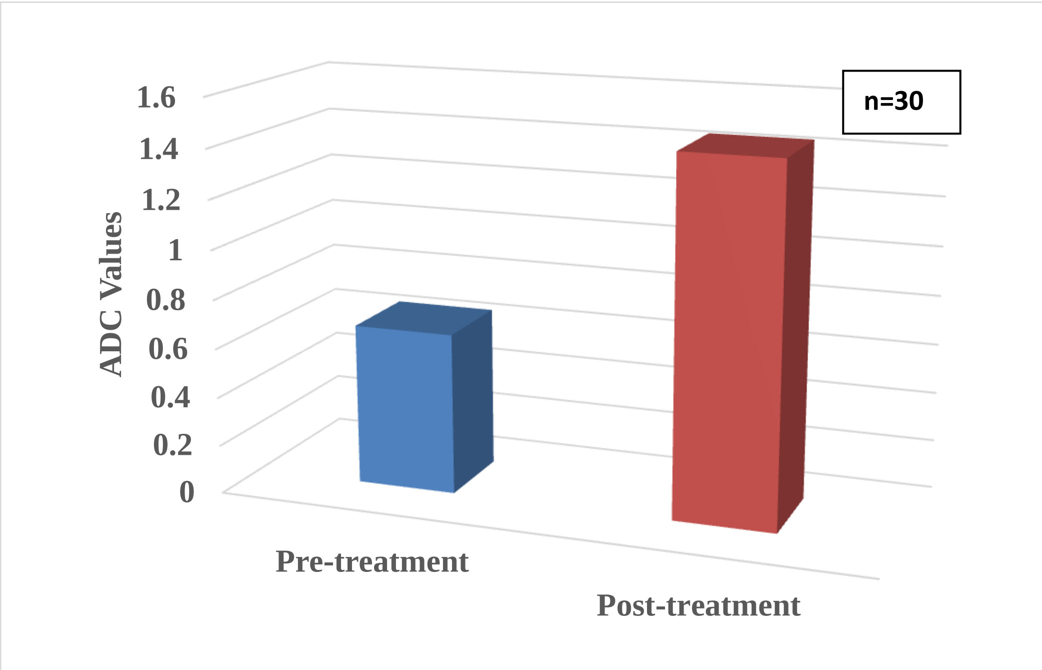


Figure 23:- Graph showing Comparison of mean ADC Values Carcinoma cervix, Pre-treatment vs Post-treatment. The mean ADC was 0.6 in pre-treatment and it increased to mean ADC of 1.4 in post-treatment.

CASE 1

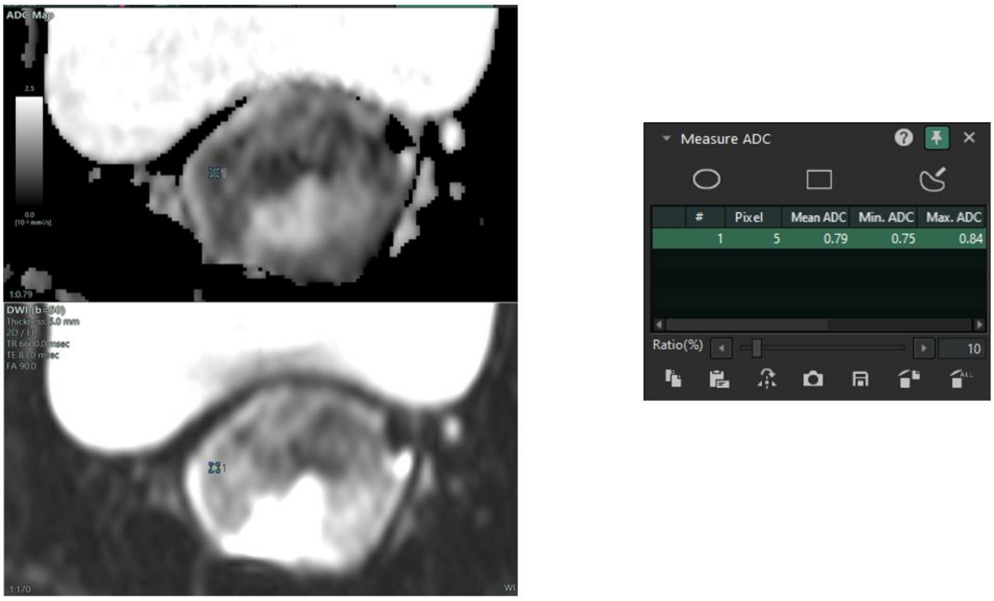


Figure 24: A patient with carcinoma cervix (pre-treatment) shows the DWI (b=50) and corresponding ADC image in a patient with a ROI of 5 pixel (1.3 mm) showing mean ADC of 0.79.

CASE 1 (POST CHEMORADIATION)

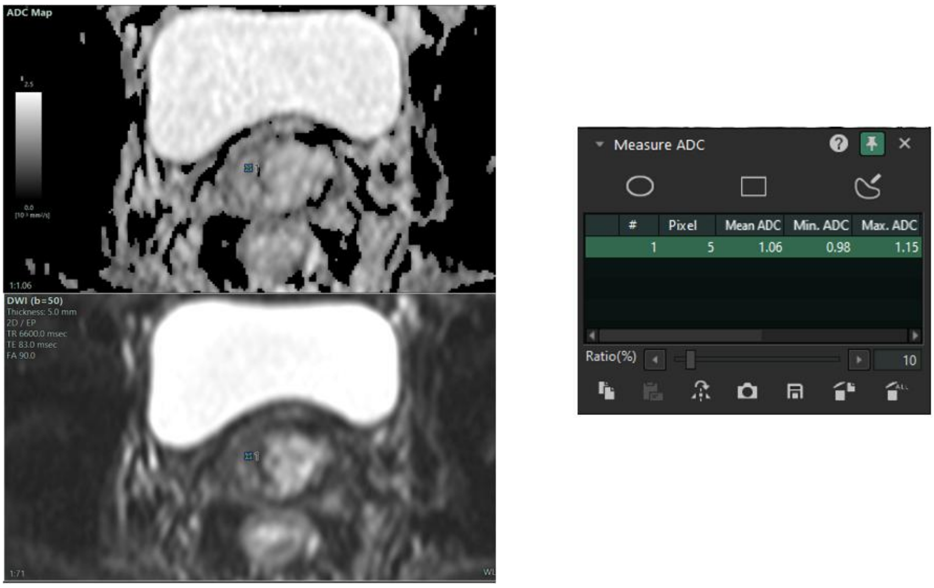


Figure 25: A patient with carcinoma cervix (post-treatment) shows the DWI (b=50) and corresponding ADC image in a patient with a ROI of 5 pixel (1.3 mm) showing mean ADC of 1.0.

CASE 2

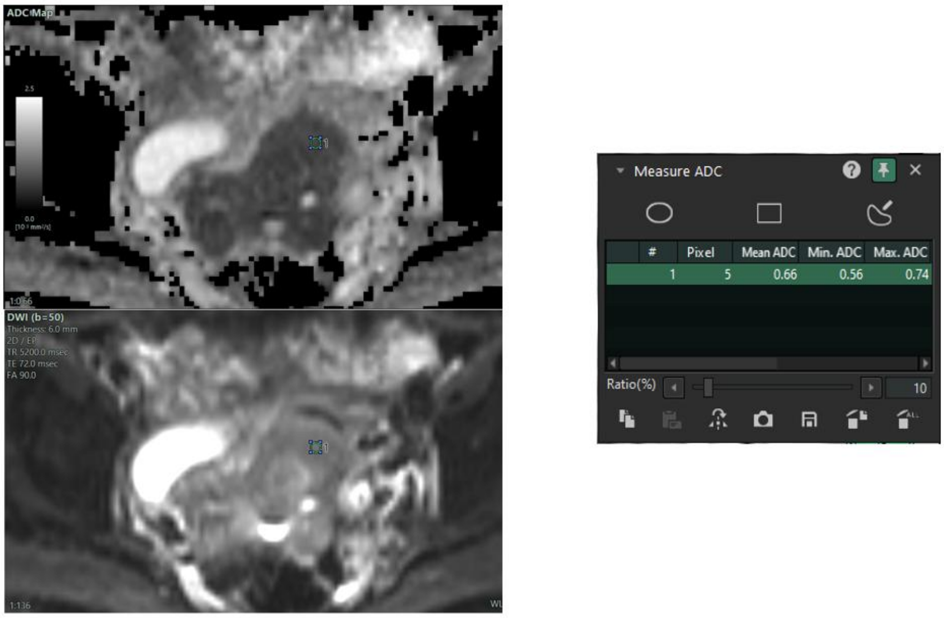


Figure 26: A patient with carcinoma cervix (pre-treatment) shows the DWI (b=50) and corresponding ADC image in a patient with a ROI of 5 pixel (1.3 mm) showing mean ADC of 0.66.

CASE 2 (POST CHEMORADIATION)

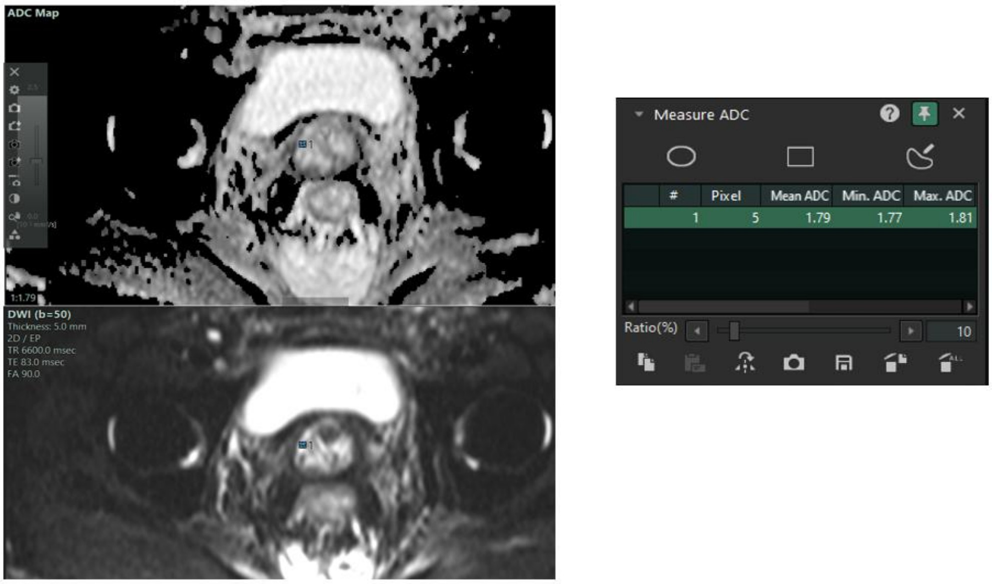


Figure 27: A patient with carcinoma cervix (post-treatment) shows the DWI (b=50) and corresponding ADC image in a patient with an ROI of 5 pixel (1.3 mm) showing mean ADC of 1.79.

CASE 3

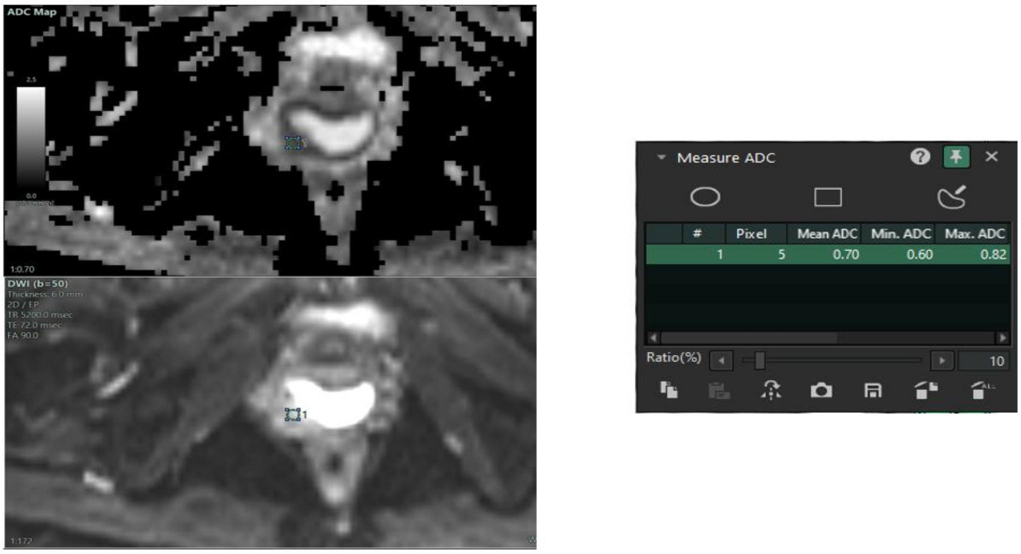


Figure 28: A patient with carcinoma cervix (pre-treatment) shows the DWI (b=50) and corresponding ADC image in a patient with an ROI of 5 pixel (1.3 mm) showing mean ADC of 0.70.

CASE 3 (POST CHEMORADIATION)

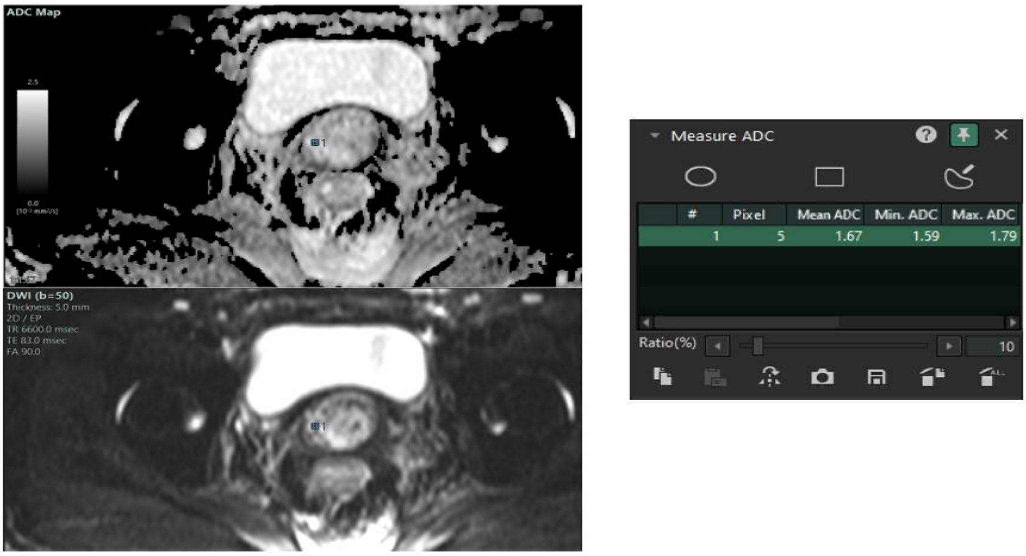


Figure 29: A patient with carcinoma cervix (post-treatment) shows the DWI (b=50) and corresponding ADC image in a patient with an ROI of 5 pixel (1.3 mm) showing mean ADC of 1.67

DISCUSSION

DISCUSSION

Our study demonstrated the clinical relevance of diffusion-weighted MRI (DW-MRI) and apparent diffusion coefficient (ADC) measurements in cervical cancer, especially to predict and evaluate the response to chemoradiotherapy. A significant finding was the marked rise in tumor ADC values from the pre-treatment phase to the early stages of treatment. Tumor ADC's increased markedly within the first few weeks of therapy compared to baseline, reflecting reduced cellularity as the tumor responded. This increase was statistically significant, indicating that even in the early phase of chemoradiation, cervical tumors undergoing effective treatment show measurably higher ADC values. For example, prior literature has noted that complete responders can exhibit an average ADC increase on the order of 0.6×10−3 mm2/s (roughly a 50% relative rise) in the early treatment period, whereas non-responders show a much smaller change.[26,27]

Consistent with such trends, our study's cohort demonstrated a clear upward shift in mean ADC after initiation of therapy, underlining DW-MRI's sensitivity to microstructural tumor changes before any gross anatomical shrinkage becomes apparent. This early ADC elevation was correlated with treatment response – patients whose tumors had larger ADC increases were more likely to achieve substantial tumor regression by the end of chemoradiation. The data support that DW-MRI can detect beneficial treatment effects in cervical carcinoma at an early stage, as evidenced by significant ADC value increase between the pre-therapy and interim scans.

Our findings align with increasing literature emphasizing the role of DW-MRI in cervical cancer treatment monitoring. It is well established that cervical tumors generally exhibit restricted water diffusion (low ADC) compared to normal tissue, due to high cell density, and that successful treatment reverses this effect.[11,28–31] Multiple studies have documented that ADC values significantly increase during and after chemoradiation in cervical cancer, reflecting therapy-induced necrosis/apoptosis. For example, ***Fu et al.*,** in a meta-analysis, found that post-treatment mean ADC values were significantly elevated compared to pre-treatment measurements, indicating that ADC serves as an effective tool for assessing treatment outcomes.[32]

Holopainen *et al.* likewise demonstrated intratumoral ADC values rise substantially over the course of chemoradiotherapy; in their study ADC increased immediately after external beam radiotherapy (EBRT) and remained elevated during brachytherapy, with the ADC post-EBRT significantly higher than baseline ($p < 0.001$).[32] They further observed that these diffusion changes have prognostic significance: patients with greater ADC increases between the pretreatment and mid-treatment scans had better overall survival rates.[32] These results reinforce our finding that early ADC changes are indicative of tumor response. Notably, our study's detection of a significant ADC rise in the early phase of therapy is in line with prior reports that responders show an approximately two to three fold greater ADC increase than non-responders by the end of treatment.[27]

Although increased ADC generally indicates treatment response in cervical tumors, the prognostic significance of pretreatment ADC values remains debated. A low pretreatment ADC typically reflects a densely cellular and aggressive tumor due to restricted water diffusion.[18]

Erbay *et al*. reported significantly lower baseline ADC values in patients with tumor recurrence, suggesting highly cellular tumors may resist treatment.[11] Additionally, lower ADC values have been associated with poorly differentiated cervical cancers, indicating higher tumor aggressiveness.[33] These findings suggest baseline DW-MRI can reflect tumor aggressiveness. However, not all studies agree; **Somoye *et al*.** found no significant correlation between initial ADC and prognosis.[11]

A meta-analysis published in PLOS. One journal in the year 2023 concluded that pretreatment ADC alone is not a reliable predictor of chemoradiotherapy outcome in cervical cancer.[11] Our results resonate with this latter view – while baseline ADC provides useful characterization of tumor biology, it was the change in ADC that more strongly signaled response. We observed that tumors with similar starting ADCs could have very different outcomes depending on how their ADC evolved during treatment.

The early changes in ADC during therapy have emerged as a more robust indicator of response across many studies, which is in agreement with our findings. **Bae *et al.*** demonstrated that the change in tumor ADC from pre-treatment to mid-treatment (at 4 weeks) was significantly associated with treatment outcome, whereas the pretreatment ADC was not.[34] In their cohort, patients whose tumors showed greater rises in ADC by mid-therapy had a significantly lower recurrence rate, and ADC change was an independent predictor of recurrence-free survival on multivariate analysis.[34]

Similarly, a 2021 meta-analysis by **Harry *et al.*** found that ADC values obtained within the first 2–3 weeks of chemoradiation correlated strongly with eventual treatment response, and responders had a much larger percentage increase in ADC (nearly 50% on average) compared to non-responders (~20%).[26] This meta-analysis confirmed that early-treatment ADC measurements have prognostic value, even though pretreatment ADC does not.[26] Our study reinforces this pattern: we detected significant ADC increases early on in treatment among patients who went on to have good clinical response.

Another study by **Fliedner FP *et.al*** in BMC cancer have demonstrated that the absolute values of ADC measured in the early stage of therapy, as well as the change in ADC from before treatment to early stage of treatment both have a significant correlation with therapeutic outcomes.[44]

Beyond mean ADC, advanced DW-MRI techniques such as histogram or texture analysis have been explored for cervical cancer. Histogram parameters, like the 10th or 90th percentile ADC, capture intratumoral heterogeneity and can predict recurrence risk after chemoradiation.[35] Additionally, multiparametric MRI combining DW-MRI with dynamic contrast-enhanced MRI (DCE-MRI) or MR spectroscopy has been investigated to assess tumor perfusion, oxygenation, and cellular density.[36,37] These combined strategies are designed to detect poorly perfused tumors that are more likely to exhibit resistance to radiation early during treatment. Overall, our findings align with literature supporting DW-MRI's value for early monitoring of cervical cancer treatment, emphasizing dynamic ADC changes over baseline measurements as stronger indicators of therapeutic response.[11,34]

The findings of this study highlight the potential of ADC values as a non-invasive imaging biomarker for evaluating tumor aggressiveness and forecasting therapeutic outcomes in cervical cancer. This could have significant implications for personalized treatment planning, enabling early intervention strategies for non-responders and reducing unnecessary toxicities in patients likely to benefit from chemoradiation.

Strengths:

• Longitudinal assessment of pre- and post-treatment ADC values, enabling assessment of treatment response.

• Inclusion of a well-characterized patient cohort with histopathologically confirmed squamous cell type of carcinoma cervix.

CONCLUSION

CONCLUSION

Our prospective study in a developing country adds to the growing body of evidence supporting DW-MRI as a critical component of modern carcinoma cervix imaging—offering deeper biological insight and enhancing the precision of treatment monitoring.

Our study underscores the clinical value of Diffusion-Weighted Magnetic Resonance Imaging (DW-MRI) and Apparent Diffusion Coefficient (ADC) measurements in the management of cervical carcinoma. Through serial imaging before and post chemoradiation, a clear trend of rising ADC values in responding tumors compared to pre chemoradiation with mean age of the patients with 63.5 years was observed.

As imaging techniques and treatment paradigms evolve, DW-MRI stands out as a functional tool with diagnostic relevance in cervical cancer.

This non-invasive imaging biomarker reflects underlying treatment-induced cellular changes, offers a powerful adjunct to conventional MRI, enabling early identification of therapeutic response prior to visible tumor shrinkage.

Hence, incorporating DW-MRI into standard radiologic follow-up protocols may facilitate earlier clinical decision-making, such as treatment escalation for poor responders or de-escalation strategies in favorable cases, thus advancing the principles of personalized oncology.

Furthermore, the implementation of DW-MRI and ADC mapping in routine clinical practice could lead to significant improvements in patient outcomes by reducing the time to treatment modification in non-responders.

SUMMARY

SUMMARY

The present prospective study was conducted to evaluate the role of Diffusion-Weighted Magnetic Resonance Imaging (DW-MRI) and Apparent Diffusion Coefficient (ADC) values in patients with carcinoma of the cervix, specifically focusing on assessing their response to concurrent chemoradiation therapy (CCRT). The study had two primary objectives:

1. To perform and assess Diffusion Weighted Magnetic Resonance Imaging and Apparent Diffusion Coefficient values in carcinoma cervix before and after chemoradiation.

2. To evaluate the efficacy of Diffusion Weighted Magnetic Resonance Imaging and Apparent Diffusion Coefficient values in predicting response to chemoradiation.

A total of 30 patients with biopsy-proven cervical cancer underwent DW-MRI scans at two time points: prior to initiation of treatment and during early therapy (approximately 4–6 weeks).

A statistically significant rise in mean ADC values was observed from pre-treatment to early post-treatment scans, with initial ADC measurements averaging below 1.0×10^{-3} mm^2/s and post-treatment values rising above 1.0×10^{-3} mm^2/s in responders.

The ADC increase corresponded to a positive clinical and radiological response, suggesting its utility as an early biomarker for treatment efficacy. Tumors that responded well to chemoradiation demonstrated a more substantial rise in ADC values compared to those with suboptimal response, supporting the inverse relationship between ADC and tumor cellularity.

These results align with international literature showing that early ADC changes are a more reliable predictor of treatment response than static pre-treatment values.

The results of this study reinforce the clinical value of DW-MRI and ADC mapping in the early evaluation of cervical cancer response to chemoradiotherapy. A notable rise in ADC values during the initial phase of treatment may act as a non-invasive, radiation-free biomarker for assessing therapeutic effectiveness. Incorporating DW-MRI into standard imaging protocols for cervical cancer has the potential to facilitate early identification of non-responders, allowing for timely treatment modifications and more personalized care strategies.

Nonetheless, this study has certain limitations. The modest sample size and single-center setting may restrict the broader applicability of the results. Additionally, variations in imaging protocols and scanner parameters across institutions could influence ADC measurements, highlighting the need for standardized imaging protocols. Larger multicentric studies with a longer follow-up period are warranted to validate these preliminary findings and confirm the prognostic value of early ADC changes.

Future research should also explore integrating DW-MRI and ADC values with other advanced imaging modalities, such as dynamic contrast-enhanced MRI (DCE-MRI) or PET/CT, to improve diagnostic accuracy and treatment monitoring. Investigating the role of machine learning algorithms in analyzing imaging data could further enhance predictive capabilities and streamline clinical workflows. As imaging technology continues to evolve, the integration of functional imaging biomarkers like ADC into routine oncologic care may significantly improve outcomes in cervical cancer management.

LIMITATIONS

LIMITATIONS

Despite promising results, DW-MRI and ADC for evaluating cervical carcinoma response to chemoradiation have limitations, including technical challenges like reduced signal-to-noise ratio and susceptibility distortions inherent to echo-planar imaging.[38] The cervix is surrounded by bowel loops and air-filled structures, causing motion and susceptibility artifacts despite patient preparation, leading to inconsistent ADC measurements.

Limited spatial resolution of DWI can result in partial volume averaging, especially in small or shrinking tumors, complicating accurate ADC assessment. ROI placement for ADC measurement becomes challenging as tumors shrink or become indistinct on DW-MRI.[11] This scenario is a double-edged sword: while a vanishing tumor is a good clinical sign, it limits the ability of DW-MRI to quantify ADC changes (potentially excluding the best responders from ADC analysis). Therefore, DW-MRI is most useful for early and mid-treatment evaluation, before tumors completely disappear; scanning too late (when little tumor remains) can reduce the method's utility.

Lack of standardization in ADC measurement and analysis for cervical tumors is another limitation. Different studies often use different b-value combinations, MRI field strengths, and ROI drawing methods (some use the whole tumor, others sample small portions with the most restricted diffusion).[11] This can lead to variability in reported ADC values and cut-offs. There is currently no universally accepted threshold or ΔADC percentage that definitively indicates a responder.

Our study, like others, chose an arbitrary or empirically determined cutoff for analysis, but results can vary with technique. A recent meta-analysis highlighted the need to establish an ideal ADC cut-off or range for predicting response.[39] Lack of standardized sequence parameters and analysis methods complicates clinical translation of ADC findings. ADC values may be influenced by inflammation, edema, hemorrhage, or necrosis, independently of tumor viability. Histological variations, such as higher ADC in mucinous adenocarcinomas, also affect interpretation. Thus, ADC changes must be contextually interpreted, as the significance of ADC shifts can differ between individuals.

It’s also worth noting that our study’s follow-up was focused on short-term imaging response; the ultimate validation of DW-MRI’s utility would be how well early ADC changes predict long-term outcomes (local control, survival). While initial results are encouraging, longer follow-up is needed to confirm that patients flagged as good responders by DW-MRI truly have superior long-term tumor control. Furthermore, the single-institution setting and relatively small sample size of this study may restrict the generalizability of its findings. Multi-center trials with larger patient cohorts would help verify that the observed ADC-response relationship holds across different scanners and populations.

In our study, we successfully recruited more than 30 patients, meeting the required sample size. However, a few participants discontinued the treatment prematurely, and some did not return for the follow-up scan scheduled 4–6 weeks after treatment initiation. These confer to the limitations for this type of study, potentially affecting the completeness and robustness of the outcome data.

RECOMMENDATIONS

RECOMMENDATIONS

The encouraging findings of this study pave the way for several future directions in imaging and response assessment for cervical cancer. One important avenue is the refinement and enhancement of DW-MRI techniques. Advanced diffusion MRI models such as intravoxel incoherent motion (IVIM) and diffusion kurtosis imaging (DKI) could provide more detailed information than the conventional ADC. IVIM, for example, separates perfusion-related diffusion from true molecular diffusion and might detect changes in tumor vascularity during treatment in addition to cellularity.[37,40]

Implementing IVIM-DWI in cervical cancer has the potential to improve early response assessment, as changes in the perfusion fraction or true diffusion coefficient may serve as additional biomarkers for treatment efficacy. Higher field MRI (3.0 Tesla) and emerging sequences (like readout-segmented or turbo spin-echo DWI) can improve resolution and reduce distortions, making quantitative ADC assessment more reliable in the pelvis. These technical improvements will likely address some of the current limitations, enabling DW-MRI to be used more routinely for adaptive treatment strategies.

Beyond diffusion, multi-parametric MRI approaches are on the horizon for monitoring therapy. Combining DW-MRI with dynamic contrast-enhanced MRI (DCE-MRI) could allow simultaneous assessment of tumor cellularity (via ADC) and tumor perfusion/hypoxia (via contrast uptake kinetics). Since tumors that respond poorly often exhibit hypoxia and poor perfusion, DCE-MRI might identify these features, and together with ADC mapping, clinicians could get a more comprehensive picture of tumor status during treatment.[41]

MR spectroscopy, though still investigational in cervical cancer, may complement DWI by detecting metabolite changes like choline peaks. Future improvements involve integrating modalities, exemplified by PET/MRI, which combines PET's metabolic data with MRI's anatomical and functional insights. PET/MRI could enable simultaneous evaluation of metabolic activity and ADC changes during treatment, potentially enhancing diagnostic accuracy in gynecologic cancers.[42] Such combined modalities could potentially detect residual disease more sensitively and guide early salvage therapies. For instance, a persistent hypermetabolic region on PET with low ADC on MRI mid-treatment might prompt a boost in radiation dose to that region.

An emerging area of interest is the use of radiomics and artificial intelligence (AI) in cervical cancer imaging. Radiomics focuses on extracting numerous quantitative features from medical images (including DW-MRI ADC maps, T2-weighted MRI, etc.) that are not apparent to the naked eye. These features, which capture tumor texture, shape, and intensity patterns, can be used to build predictive models for treatment response. Recent studies have shown that MRI-based radiomic features can stratify patients by likelihood of response or even predict pathological complete response before treatment begins.[41,43]

In the future, a radiomics model could take a patient's pre-treatment MRI (including diffusion images) and output a probability of treatment success, aiding in personalized therapy planning. Likewise, AI algorithms, including machine learning and deep learning models, can be trained on MRI datasets to automatically distinguish between responders and non-responders early during chemoradiotherapy. These approaches might incorporate not just ADC values but the entire image voxel data, potentially catching complex patterns of tumor change that single parameters miss. Our study's results contribute a piece of data that could be used in such models – the degree of ADC change – and future work could integrate this with other imaging markers.

Prospective trials exploring adaptive therapy based on early DW-MRI findings are needed. Patients showing minimal ADC change might benefit from intensified therapy, such as dose escalation or adjunct chemotherapy, while excellent early responses could cautiously inform potential treatment de-escalation to reduce toxicity. Establishing precise ADC thresholds and optimal imaging time-points through multi-center studies is essential. Integrating other biomarkers, like circulating tumor DNA, could further enhance early response evaluation. Overall, advanced imaging (IVIM, DKI), combined modalities (DCE-MRI, PET/MRI), and analytical approaches (radiomics/AI) will refine personalized cervical cancer management by enabling timely adjustments based on non-invasive imaging biomarkers.

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ANNEXURE

ANNEXURE I - PATIENT PROFORMA

“ROLE OF DIFFUSION WEIGHTED MAGNETIC RESONANCE IMAGING AND APPARENT DIFFUSION COEFFICIENT VALUE IN CARCINOMA CERVIX AND TO EVALUATE ITS RESPONSE TO CHEMORADIATION”

PROFORMA

- Name:
- Age:
- Address:
- Hospital ID:
- MRI NO:
- Mobile No:
- Clinical features:
- Past history:
- Family history:
- Personal history:
- Menstrual history:
- General physical examination:

    1. HR:
    2. Wt:
    3. PR:
    4. BP:

5. RR:

6. TEMP:

- Systemic examination:

- Local examination:

    1. Per vaginal findings:

    2. Per speculum findings:

- PAP smear:

- Biopsy findings:

- Other investigations:

    1. CBC –
    2. LFT –
    3. RFT –
    4. Serum creatinine -

- Allergic to contrast: Yes No

- **MRI FINDINGS PRE-TREATMENT:**

Pre - treatment	ROI (mm)	Mean ADC value	Minimum ADC value	Maximum ADC value

- FIGO STAGING:

MRI FINDINGS POST - TREATMENT:

Post - treatment	ROI (mm)	Mean ADC value	Minimum ADC value	Maximum ADC value

PATIENT RESPONSE TO TREATMENT: (AFTER 6 WEEKS OF CHEMORADIATION)

1. Disease free/ Complete remission
2. Residual disease/ Partial remission
3. No response to treatment

ANNEXURE II - INFORMED CONSENT

Study title:_ROLE OF DIFFUSION WEIGHTED MAGNETIC RESONANCE IMAGING AND APPARENT DIFFUSION COEFFICIENT VALUES IN CARCINOMA CERVIX AND TO EVALUATE ITS RESPONSE TO CHEMORADIATION.

Chief researcher/ PG guide name: Dr. ANIL KUMAR SAKALECHA

PG co-guide name: Dr. MANJUNATH G.N

Principal investigator: Dr. DODDALA VAMSI VENKAT.

Name of the subject:

Age :

Gender :

a. I have been informed in my own language that this study involves MRI as a part of procedure. I have been explained thoroughly and I understood the procedure.
b. I understand that the medical information produced by this study will become part of institutional record and will be kept confidential by the said institute.
c. I understand that my participation is voluntary and may refuse to participate or may withdraw my consent and discontinue participation at any time without prejudice to my present or future care at this institution.
d. I agree not to restrict the use of any data or results that arise from this study provided such a use is only for scientific purpose(s).
e. I confirm that Dr. DODDALA VAMSI VENKAT / Dr. ANIL KUMAR SAKALECHA. (chief researcher/ name of PG guide)/ Dr. MANJUNATH G.N (name of PG co-guide) has explained to me the purpose of research and the study procedure that I will undergo and the possible risks and discomforts that I may experience, in my own language. I hereby agree to give valid consent to participate as a subject in this research project.

Participant's signature/thumb impression

Signature of the witness: Date:

1)

2)

I have explained to ____________________________ (subject) the purpose of the research, the possible risk and benefits to the best of my ability.

Chief Researcher/ Guide signature Date:

ANNEXURE – III PATIENT INFORMATION SHEET

ROLE OF DIFFUSION WEIGHTED MAGNETIC RESONANCE IMAGING AND APPARENT DIFFUSION COEFFICIENT VALUES IN CARCINOMA CERVIX AND TO EVALUATE ITS RESPONSE TO CHEMORADIATION.

Patient Information Sheet

Principal Investigator: Dr. DODDALA VAMSI VENKAT / Dr. ANIL KUMAR SAKALECHA/ Dr. MANJUNATH G.N

I, Dr. Doddala Vamsi Venkat**,** post-graduate student in Department of Radio-Diagnosis at Sri Devaraj Urs Medical College. I will be conducting a study titled "ROLE OF DIFFUSION WEIGHTED MAGNETIC RESONANCE IMAGING AND APPARENT DIFFUSION COEFFICIENT VALUES IN CARCINOMA CERVIX AND TO EVALUATE ITS RESPONSE TO CHEMORADIATION" for my dissertation under the guidance of Dr. Anil Kumar Sakalecha, Professor and HOD, Department of Radiodiagnosis and under the co-guidance of Dr. Manjunath G.N, Associate professor, Department of Radiotherapy. In this study, we will assess the role of Diffusion weighted MRI and ADC values in evaluation of response to chemoradiation. You would have to undergo DWI - MRI before entering the study. The study will not add any financial burden to you if you are part of the study. You will not be paid any financial compensation for participating in this research project.

All of your personal data will be kept confidential and will be used only for research purpose by this institution. You are free to participate in the study. You can also withdraw from the study at any point of time without giving any reasons whatsoever. Your refusal to participate will not prejudice you to any present or future care at this institution.

Name of the Principal Investigator: DODDALA VAMSI VENKAT

Mobile number of Principal Investigator: 7032008811

Date:

MASTER CHART

KEY TO MASTER CHART

1. **S.No** – Serial number
2. **UHID** – Unique Health Identification
3. **T1C+ -** T1 Post contrast
4. **DWI** – Diffusion Weighted Imaging
5. **ADC** – Apparent Diffusion Coefficient

S.No	UHID	Size of the lesion (Pre treatment)	Age group	T1	T2	T1C+	DWI Restriction	ADC Values (Pre-treatment)	Hydroureter onephrosis	Enlarged lymph nodes	Pyometra	Staging	Size of the lesion (Post treatment)	ADC Values (Post-treatment)	Response (Yes/No)
1	350838	4.2	54	Isointense	Heterogeneous	Heterogeneous	Patchy	0.79	Absent	Absent	Absent	IVB	3.2	1.06	Yes
2	353489	2.9	53	Isointense	Heterogeneous	Heterogeneous	Patchy	0.5	Present	Present	Present	IIIC	2.2	1.61	Yes
3	353833	4.6	65	Isointense	Heterogeneous	Heterogeneous	Homogeneous	0.66	Present	Present	Absent	IIIC	3.5	1.79	Yes
4	360474	2.5	56	Isointense	Heterogeneous	Heterogeneous	Patchy	0.7	Absent	Absent	Absent	IIIA	1.9	1.67	Yes
5	354470	4.5	59	Isointense	Heterogeneous	Heterogeneous	Homogeneous	0.8	Absent	Present	Present	IIIC	3.6	1.32	Yes
6	361317	6.2	64	Isointense	Heterogeneous	Heterogeneous	Homogeneous	0.6	Absent	Present	Absent	IIIC	5	1.45	Yes
7	358883	2.1	74	Isointense	Heterogeneous	Heterogeneous	Homogeneous	0.53	Absent	Present	Absent	IIB	1.2	1.23	Yes
8	370295	4.8	72	Hypointense	Heterogeneous	Heterogeneous	Homogeneous	0.63	Absent	Absent	Absent	IIB	3.2	1.03	Yes
9	369690	5.3	64	Isointense	Heterogeneous	Heterogeneous	Homogeneous	0.8	Absent	Present	Absent	IIIC	3.6	1.45	Yes
10	372381	5	55	Isointense	Heterogeneous	Heterogeneous	Homogeneous	0.74	Absent	Absent	Absent	IIA	4.2	1.89	Yes
11	373225	4.8	52	Isointense	Heterogeneous	Heterogeneous	Homogeneous	0.69	Present	Absent	Absent	IVA	3.5	1.45	Yes
12	534218	5.3	59	Isointense	Heterogeneous	Heterogeneous	Homogeneous	0.5	Absent	Present	Absent	IIIC	4.2	1.2	Yes
13	563452	3.5	61	Isointense	Heterogeneous	Heterogeneous	Homogeneous	0.7	Absent	Present	Present	IIIC	2.9	1.35	Yes
14	565316	3.6	64	Isointense	Heterogeneous	Heterogeneous	Homogeneous	0.63	Absent	Present	Present	IIIC	2.5	1.33	Yes
15	563074	1.9	52	Isointense	Heterogeneous	Heterogeneous	Homogeneous	0.8	Absent	Absent	Present	IIB	1	1.45	Yes
16	562379	2	51	Isointense	Heterogeneous	Heterogeneous	Homogeneous	0.53	Absent	Absent	Absent	IIB	1.5	1.21	Yes
17	553941	3.9	65	Isointense	Heterogeneous	Heterogeneous	Patchy	0.64	Absent	Absent	Absent	IIIA	3	1.42	Yes
18	559011	2.5	51	Isointense	Heterogeneous	Heterogeneous	Homogeneous	0.7	Present	Absent	Absent	IIA	1.6	1.52	Yes
19	558808	2.2	58	Isointense	Heterogeneous	Heterogeneous	Homogeneous	0.56	Absent	Absent	Absent	IIB	1.6	1.63	Yes
20	545025	4.2	72	Isointense	Heterogeneous	Heterogeneous	Homogeneous	0.74	Absent	Absent	Present	IIIA	3.2	1.75	Yes
21	541269	1.9	65	Isointense	Heterogeneous	Heterogeneous	Homogeneous	0.9	Absent	Absent	Present	IIB	1.2	1.3	Yes
22	514569	4.5	63	Isointense	Heterogeneous	Heterogeneous	Patchy	0.56	Absent	Present	Present	IIIC	3.3	1.67	Yes
23	524968	5.1	62	Isointense	Heterogeneous	Heterogeneous	Homogeneous	0.73	Absent	Absent	Present	IIIA	4.1	1.45	Yes
24	512469	2.6	70	Isointense	Heterogeneous	Heterogeneous	Patchy	0.2	Absent	Absent	Absent	IIB	2	1.3	Yes
25	322841	2.3	71	Hypointense	Heterogeneous	Heterogeneous	Homogeneous	0.84	Present	Absent	Absent	IIA	1.6	1.45	Yes
26	323753	4.2	66	Hypointense	Heterogeneous	Heterogeneous	Homogeneous	0.54	Absent	Present	Absent	IIIC	3.3	1.5	Yes
27	326911	1.9	62	Hypointense	Heterogeneous	Heterogeneous	Patchy	0.95	Absent	Absent	Present	IIB	1	1.75	Yes
28	329699	4	59	Hypointense	Heterogeneous	Heterogeneous	Homogeneous	0.63	Absent	Absent	Present	IIIA	2.9	1.4	Yes
29	339456	3.2	79	Hypointense	Heterogeneous	Heterogeneous	Homogeneous	0.51	Absent	Present	Present	IIIC	2.5	1.6	Yes
30	345676	4.3	72	Hypointense	Heterogeneous	Heterogeneous	Patchy	0.68	Absent	Absent	Absent	IIIA	2.6	1.2	Yes