Assessment of Abdominal Aortic Bifurcation Level in Pelvic Cancer Patients Undergoing Radiotherapy: A Retrospective CT-Based Analysis

ABSTRACT: Objective: This retrospective study aims to investigate the implications of the bifurcation of the abdominal aorta on radiation therapy planning for cervical cancer patients, within the broader context of assessing CT scans of various pelvic malignancies.

Methods: Patients who underwent radiotherapy for pelvic cancers between 2022 and 2024 were included in this retrospective study. The cohort comprised individuals diagnosed with cervical cancer, rectal cancer, and other pelvic malignancies. All patients underwent adequate immobilization in the supine position and received contrast-enhanced computed tomography (CT) simulation for radiotherapy planning, following a standardized bladder protocol. The level of division of the abdominal aorta into the right and left common iliac arteries, relative to the vertebral level, was determined and studied.

Results: In our study of 40 pelvic cancer patients, the division of the abdominal aorta into common iliac arteries primarily occurred above and at the level of the L3-L4 intervertebral space in 52.5% (21/40) of cases, in front of the body of the L4 vertebra in 25% (10/40) of cases, and at the L4-L5 intervertebral space in 22.5% (9/40) of cases.

Conclusion: The division of the abdominal aorta typically occurs at a higher level than the L4-L5 intervertebral space level in pelvic cancer patients. Our findings underscore the importance of utilizing CT scan-based planning for radiotherapy to accurately target treatment areas. However, in facilities where CT-based planning is unavailable, it is recommended to shift the upper border of the radiotherapy treatment portal above the L3-L4 intervertebral space for cervical cancers for optimal coverage of the iliac lymph node chain. These recommendations aim to ensure adequate radiation dose delivery while considering anatomical variations in pelvic cancer patients.

Keywords: Abdominal aorta, Common iliac arteries, Pelvic cancers, Radiotherapy planning, Anatomical variations.

INTRODUCTION: Pelvic cancers, particularly cervical cancer, present formidable challenges in treatment planning due to their intricate anatomical location and proximity to vital structures such as the abdominal aorta and iliac arteries. While radiotherapy remains pivotal in the management of cervical cancer, ensuring precise delineation of target volumes is imperative to optimize treatment outcomes and minimize radiation-related toxicities. The scope of external beam radiotherapy (EBRT) treatment for cervical cancer encompasses key anatomical structures including the uterus, cervix, vagina, parametrial tissue, and the network of draining pelvic lymph nodes, such as the obturator, internal iliac, external iliac, common iliac, and presacral nodes. Various modalities for EBRT delivery, such as two-dimensional conventional radiotherapy (2D RT), three-dimensional conformal radiotherapy (3D CRT), or intensity-modulated radiotherapy (IMRT), offer adaptable strategies tailored to individual patient needs.

In conventional X-ray-based planning, reliance on bony landmarks defines the target volume, with the traditional superior border of the radiation portal for cervical carcinoma typically set at the level of the L4-L5 intervertebral space to encompass the common iliac nodes (1). However, in evaluating pelvic malignancies, particularly cervical cancer cases, attention to the anatomical variations in the aortic bifurcation becomes paramount. Understanding the vascular anatomy of the pelvis, particularly variations in the division of the abdominal aorta into common iliac arteries and subsequent bifurcation into external and internal iliac arteries, is crucial for radiation therapy planning. Proposed strategies, such as utilizing pelvic blood vessels as surrogate targets for lymph node delineation (2), aim to address these challenges and enhance treatment planning accuracy. These challenges underscore the importance of precise delineation of target volumes and sparing of adjacent normal tissues to optimize treatment efficacy and minimize radiation-related toxicities.

In this study, we aim to investigate the anatomical variations in the aortic bifurcation among all pelvic cancer patients undergoing radiotherapy. By assessing these variations across the pelvic cancer patient population, we seek to establish a standard level of bifurcation that can serve as a landmark for treatment planning, particularly in cervical cancer patients. Given the high patient load in most centres in India, conventional X-ray-based planning, such as 2D RT, is preferred over more complex techniques like 3D RT/IMRT due to its ease of use and time efficiency. This data-driven approach will provide valuable insights into optimizing radiation therapy delivery and enhancing treatment outcomes in cervical cancer patients, ultimately informing the reconsideration of the superior border of the radiation portal during radiotherapy (RT) planning.

MATERIALS AND METHODS:

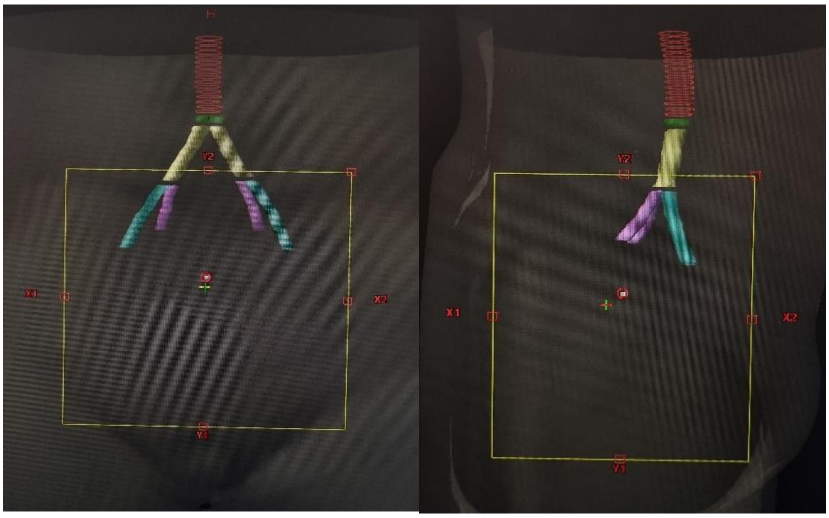
Study Design: This retrospective observational study was conducted in the Department of Radiotherapy and Oncology of Lakhimpur cancer centre, Assam, India. It aimed to investigate the implications of the bifurcation of the abdominal aorta on radiation therapy planning for newly diagnosed, histopathologically proven patients of carcinoma cervix, carcinoma rectum, and other pelvic cancers.

Patient Population: The study included newly diagnosed, histopathologically proven patients of carcinoma cervix, carcinoma rectum, and other pelvic cancers who received external beam radiotherapy (EBRT) between 2022 and 2024 at our hospital. Post-operative cases were excluded from the study.

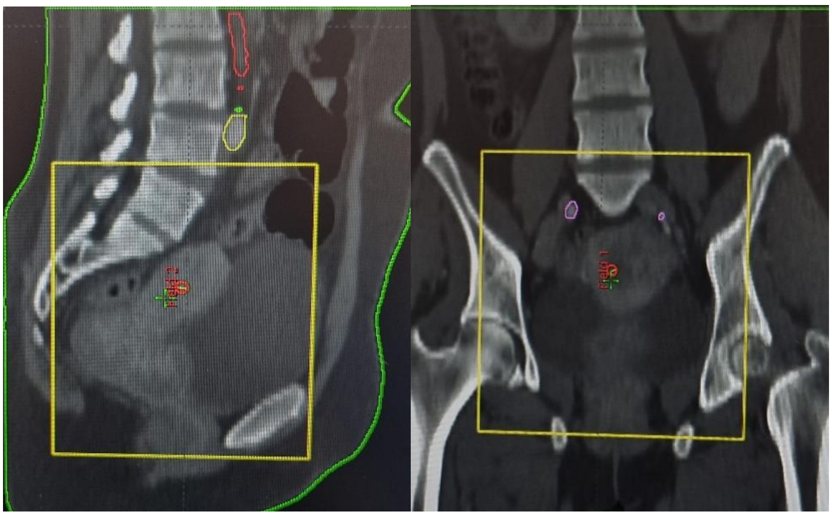
Data Collection: The medical records of patients with pelvic cancers who underwent EBRT during the specified period were reviewed. Patient demographics, clinical characteristics, and treatment details were collected for analysis.

Radiographic Evaluation: For EBRT planning, either non-contrast or contrast-enhanced images were acquired using a 16-slice wide-bore computed tomography (CT) simulator. CT sections were obtained at 3mm intervals. The acquired images were then transferred to the treatment planning system (TPS). Contouring and radiotherapy planning were performed using the ECLIPSE version 16.1 treatment planning system.

Evaluation of Aortic Bifurcation: The division of the abdominal aorta into the right and left common iliac arteries was evaluated on axial CT sections. Confirmation of aortic bifurcation was done in the coronal sections using partial slice trackers. The determined level of aortic bifurcation was then correlated with the corresponding vertebral level in sagittal sections. Images of radiotherapy planning were obtained for a selected patient, illustrating the contouring of the aorta, common iliac arteries, and the level of aortic bifurcation. If this same patient is undergoing 2D planning, the corresponding radiation portals on the anterior-posterior (AP) and right-left (RL) views were depicted. Notably, in this patient where the aortic bifurcation was observed at a lower border of L3, much higher than the conventionally set upper border at L4-L5, shown in images 1,2,3,4.



Images 1,2- CT images showing AP and RL Beam's Eye View (BEV) showing contouring of aorta(red), aortic bifurcation(green),common iliac vessels(yellow) and external iliac vessels (cyan), internal iliac vessels(pink)



Images 3,4- CT images showing RL and AP field borders, where upper border is kept at L4-L5 space.

Statistical Analysis: Descriptive statistics were used to summarize the distribution of the division of the abdominal aorta among the study population. The division levels were presented as percentages with corresponding vertebral levels.

RESULTS:

The minimum age observed was 32 years, while the maximum age recorded was 78 years. A total of 40 patients were included in the study, with a distribution of 15 (37.5%) carcinoma cervix, 10 (25%) carcinoma rectum, and 15 (37.5%) other pelvic cancers, summarized in table 1. The division of the abdominal aorta into common iliac arteries was predominantly observed at different vertebral levels among the study population. Specifically, 21 patients (52.5%) exhibited the division at and above L3-L4 intervertebral space, while 10 patients (25%) showed it in front of the L4 vertebral body. Additionally, 9 patients (22.5%) displayed the division at L4-L5 intervertebral space and below, illustrated in table 2. Further subdivision within these divisions revealed varying patterns, with the most common being 12 patients (30%) exhibiting division at the L3-L4 space, followed by 7 patients (17.5%) in the L4-L5 space. Further subdivisions within the division of the abdominal aorta are presented in Table 3.

These findings provide valuable insights into the anatomical variations of the abdominal aorta among pelvic cancer patients, highlighting the need for personalized treatment planning strategies in radiation therapy.

Table 1: Patient Characteristics

Cancer Type	Number of Patients	Percentage
Carcinoma Cervix	15	37.5%
Carcinoma Rectum	10	25%
Other Pelvic Cancers	15	37.5%

Table 2: Division of Abdominal Aorta

Division Level	**Number of Patients**	**Percentage**
At and above L3-L4 intervertebral space	21	52.5%
In front of L4 vertebral body	10	25%
At L4-L5 intervertebral space and below	9	22.5%

Table 3: Further Division of Abdominal Aorta

Division Level	Number of Patients	Percentage
L3 Upper	2	5%
L3 Lower	7	17.5%
L3-L4 Space	12	30%
L4 Upper	3	7.5%
L4 Mid	4	10%
L4 Lower	3	7.5%
L4-L5 Space	7	17.5%
L5 Upper	2	5%

DISCUSSION:

The age distribution of the patients in our study ranged from 32 to 78 years. Notably, we observed a wide age range within our study population, reflecting the diversity of pelvic cancer patients requiring radiotherapy intervention. The minimum age observed was 32 years, indicating that our study included relatively young individuals, while the maximum age recorded was 78 years, highlighting the inclusion of older patients as well.

A total of 40 patients were included in the study, representing a heterogeneous cohort of pelvic cancer cases undergoing radiotherapy. Among these, 37.5% had carcinoma of the cervix, 25% presented with carcinoma of the rectum, and the remaining 37.5% were diagnosed with other pelvic cancers. This distribution underscores the varied nature of pelvic malignancies encountered in clinical practice and emphasizes the importance of considering different cancer types in radiotherapy planning.

Our study investigated the division of the abdominal aorta into common iliac arteries and its relation to vertebral bony landmarks among pelvic cancer patients undergoing radiotherapy. The division of the abdominal aorta was predominantly observed at different vertebral levels within the study population. The historical practice of setting the upper border of the radiotherapy field at the L4-L5 intervertebral space, based on the assumption of aortic bifurcation at this level, has been challenged by our study findings. Previous anatomical descriptions from textbooks and limited surgical or cadaveric series suggested varying levels of aortic bifurcation, with discrepancies between studies. For instance, Gray's Anatomy and Hollinshead's textbook indicated the division at the lower border of the L4 vertebra (3,4), while Cunningham's manual and Moore's clinically oriented Anatomy reported it at the level of the L4 vertebral body (5). Additionally, Bergman et al. observed the division occurring predominantly at the L4-L5 interspace in 80% of cases (6), while an Indian study on cadaveric specimens found it at the level of the L4 body in 54% of cases (7). In a similar retrospective study, Rai et al. reported aortic bifurcation above the L4-L5 junction in 70.7% of patients (8). Mishra et al. observed that the aortic bifurcation was above the L4-L5 junction in 74.4% of cases (9). Additionally, Ponni et al. found that the aortic bifurcation occurred above the L4-L5 intervertebral space in 84.60%

of their patients (10). Notably, our study, based on live individuals and radiological imaging, demonstrated a higher prevalence of aortic division above and at the L3-L4 interspace (52.5%) compared to the L4-L5 interspace and below (22.5%).

The consequences of inaccurately defining the upper border of the radiotherapy field have significant clinical implications, particularly in terms of treatment efficacy and toxicity. Regional recurrences in cervical cancer patients often occur in the common iliac nodal area, which may be inadequately covered if the radiotherapy field is not appropriately adjusted to account for the observed level of aortic division. There is a dearth of data regarding the consequences of overlooking common iliac lymph nodes during radiotherapy for cervical cancer. However, studies by Beadle et al. and Tamaki et al. highlighted marginal recurrences occurring predominantly in the common iliac nodal area after radiotherapy for cervical cancer (11,12). In a retrospective study, Rai et al. assessed the patterns of recurrence in cervical cancer patients treated with pelvic nodal clinical target volume at L4–L5 junction instead of aortic bifurcation, revealing that maximum failures occurred in the common iliac region, even when only clinically node-negative patients were included (8). Our results offer a plausible explanation for this pattern of recurrence, suggesting that the conventional practice of setting the upper border of the radiotherapy field at the L4-L5 level may lead to inadequate coverage of the common iliac nodes. The incidence of subclinical involvement of common iliac nodes in carcinoma of the cervix (FIGO Stage IB2) is around 28%, which increases as the stage progresses (13). Therefore, it is essential not to miss this group of nodes in the radiotherapy portals, regardless of the technique used, for optimal therapeutic outcomes.

To ensure adequate coverage of common iliac nodes while minimizing toxicity, adjustments to radiotherapy planning strategies are warranted. Specifically, our findings suggest that the upper border of the radiotherapy field should be positioned above the L3-L4 interspace or at the lower border of the L2 vertebra. Most of our patients (77.5%) exhibited aortic bifurcation above the L4-L5 intervertebral space, further emphasizing the need for revised radiotherapy planning techniques. However, this may result in increased bowel volume within the radiation field and potential toxicity. Techniques such as the use of corner lead shields or conformal blocks can mitigate these effects. Therefore, whenever feasible, computed tomography-based radiotherapy planning should be employed for treating cervical cancer patients to optimize treatment outcomes. Our study adds to the existing literature on aortic bifurcation levels and underscores the importance of individualized treatment planning strategies based on accurate anatomical data.

Limitations: It is noteworthy that our study has some limitations, including its retrospective nature and small sample size. A prospective study with a larger sample size is warranted to validate our findings and further elucidate the optimal radiotherapy planning strategies for pelvic cancer patients. Additionally, while our study aimed to investigate the implications of aortic bifurcation specifically for cervical cancer radiotherapy planning, it is important to acknowledge that the cohort included patients with various pelvic malignancies. While this broad inclusion allowed for a comprehensive assessment of aortic bifurcation patterns, it also introduced heterogeneity into the study population. As different pelvic malignancies may exhibit variations in anatomical structures and treatment responses, the generalizability of our findings to cervical cancer patients specifically may be influenced by this heterogeneity.

CONCLUSION:

Based on our study's findings, we observed significant variability in the division of the abdominal aorta among pelvic cancer patients. Contrary to historical assumptions, our results indicate that most cases exhibited this division at the L3-L4 intervertebral space rather than the L4-L5 interspace. This anatomical variation has critical implications for radiation therapy planning, particularly in the treatment of cervical cancer patients. Incorporating this anatomical insight into radiotherapy planning is essential to ensure comprehensive coverage of the common iliac lymph node region, which is frequently involved in recurrences. Setting the upper border of the radiotherapy field at or above the L3-L4 interspace may provide more effective coverage of common iliac nodes, thereby optimizing treatment outcomes in cervical cancer patients. Additionally, our study underscores the importance of adopting computed tomography-based planning protocols whenever feasible, as they offer superior anatomical detail compared to conventional X-ray-based planning, ultimately enhancing treatment precision and efficacy. In conclusion, our findings advocate for a shift towards tailored radiotherapy planning strategies that account for the anatomical variability of the abdominal aorta. By integrating these insights into clinical practice, we can optimize treatment strategies and improve outcomes for patients with pelvic malignancies.

Ethical Considerations: This study was conducted in compliance with ethical guidelines and regulations. Approval was obtained from the institutional review board (IRB), with waiver of informed consent granted due to the retrospective nature of the study and anonymized patient data.

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