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Impact of body contouring changes on dosimetric accuracy in volumetric modulated arc cherapy (VMAT) for cervical cancer: A method to identify target dose deviations beyond 5%

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► ***Original article***

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#Zhen Cao and Weibing Xu contributes equally.

ABSTRACT

Background: This study evaluates the impact of body contouring changes on delivered dose and proposes a method to identify target dose deviations exceeding 5%. ***Materials and Methods:*** Five CT datasets were created by simulating body contouring reductions of 3mm, 6mm, 9mm, 12mm, and 15mm from the original planning CT. Using the same iso-center and Volumetric Modulated Arc Therapy (VMAT) plan, new plans (P3, P6, P9, P12, P15) were generated for new five CT datasets (body contouring reductions of 3mm, 6mm, 9mm, 12mm, and 15mm) respectively. Dose distributions and changes in dosimetric parameters for the Planning Target Volume (PTV) and Organs at Risk (OARs), including the small intestine, rectum, bone marrow, femoral head, and bladder, were analyzed. ***Results:*** Progressive weight loss increased doses to PTVs and OARs. PTV D50 increased by 1.32%, 2.35%, 3.62%, 5.18%, and 6.24% for 3mm, 6mm, 9mm, 12mm, and 15mm reductions, respectively. The small intestine V45 exceeded 195cc and the rectum V50 surpassed 50% at 12mm and 15mm. Bone marrow doses remained below the V40 threshold of 37%. When reductions reached 12mm and 15mm, regions with dose deviations >5% (250cGy) covered 31.81% and 178.08% of the PTV. ***Conclusion:*** Weight loss-induced body contouring reductions significantly affect PTV and OAR doses. Re-scanning and re-planning are recommended when contour reductions exceed 12mm or waist circumference decreases by >75mm.

INTRODUCTION

Volumetric Modulated Arc Therapy (VMAT) is an advanced radiotherapy technique that delivers highly conformal dose distributions by using a rotating accelerator gantry with continuous adjustments in gantry speed, multileaf collimator (MLC) positions, and dose rate [1]. This allows for improved dose conformity and uniformity for Planning Target Volumes (PTVs) and effective sparing of Organs at Risk (OARs), making VMAT a widely utilized technology for various cancer treatments [2]. However, the steep dose gradients and conformal dose distribution inherent in VMAT make it highly sensitive to anatomical changes or setup uncertainties during treatment, potentially leading to underdosing of the PTV and overdosing of the surrounding OARs [3].

This issue is particularly pronounced in cervical cancer patients, who often undergo radiotherapy combined with chemotherapy [4, 5]. During the approximately 5-week treatment course, patients frequently experience significant weight loss due to gastrointestinal mucosal damage, which impairs nutrient intake, digestion, and absorption [6-8]. Weight loss primarily affects the waist, abdomen, and buttocks, leading to a reduction in body contouring, a factor that current clinical imaging techniques, including Image-Guided Radiation Therapy (IGRT), are unable to fully compensate for. Such reductions in body contouring can result in alterations to the dose distribution, reducing the attenuation of adipose tissue to the radiation dose, which in turn may cause overdosing of the PTV and OARs, including the small intestine, rectum, bladder, and bone marrow [9-11]. This can lead to severe toxicities such as radiation enteritis, cystitis, and myelosuppression if the dose to these organs exceeds recommended limits [12-14]. According to the International Commission on Radiological Units (ICRU), it is essential that the dose

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error in the primary tumor's radical dose remains within ±5% to ensure effective radiotherapy [15, 16].

Traditional methods, such as tissue phantom ratios (TPR), have been employed to correct for body contouring changes in 3D Conformal Radiotherapy (3D-CRT) and Intensity-Modulated Radiation Therapy (IMRT), but these methods are not directly applicable to VMAT due to its more complex treatment geometry. Physicians and physicists typically use cone-beam CT (CBCT) for dose recalculations, but challenges such as inaccurate electron density conversion curves and poor image quality can undermine its reliability. Moreover, offline replanning is often limited by available resources.

The novelty of this study lies in its focus on the dosimetric impact of weight loss-induced body contouring changes in VMAT treatment plans for cervical cancer, a topic with limited prior investigation. Furthermore, this study proposes a simple and empirical method to detect treatment plans with dose deviations exceeding 5%, offering a practical and efficient solution for mitigating overdose risks in PTVs and OARs. This approach not only addresses a critical clinical gap but also enhances the safety and efficacy of VMAT for cervical cancer patients.

MATERIALS AND METHODS

Patient selection

This retrospective study included 20 female patients diagnosed with cervical cancer who underwent radiotherapy combined with chemotherapy between January 1, 2021, and January 1, 2022. The study was approved by the Ethics Committee of Zhongnan Hospital of Wuhan University (Approval Number: 2022220K, Date: November 15, 2022). The inclusion criteria required patients to have a body mass index (BMI) ≥25 kg/m^2 (classified as overweight or obese by WHO standards) and no significant comorbidities affecting weight changes. The patients' age ranged from 38 to 72 years, with a median age of 53 years. The BMI ranged from 25.1 to 32.8 kg/m^2, with a mean ± standard deviation of 28.5 ± 2.9 kg/m^2. Regarding FIGO 2018 staging, 20% (n=4) were classified as stage IB1, 15% (n=3) as stage IB2, 20% (n=4) as stage IC, 25% (n=5) as stage IIA, and 20% (n=4) as stage IIIB. All patients completed a prescribed course of radiotherapy (VMAT) and chemotherapy without interruptions.

For each patient, the Clinical Target Volume (CTV) was delineated by experienced radiation oncologists based on diagnostic imaging and clinical guidelines. The CTV was expanded isotropically by a 10 mm margin to generate the Planned Target Volume (PTV). The average PTV volume was 1154.18 ± 142.5 cc. Organs at Risk (OARs) included the small intestine, rectum, bone marrow, femoral head, and bladder, which were delineated following standardized contouring protocols. Dose constraints for these OARs were defined based on established guidelines to minimize radiation-induced toxicity.

Treatment planning

Each patient had a VMAT plan designed with 6MV X-ray and double full arcs, referred to as P0. In P0, the control points spacing, treatment couch angle, and dose rate were set to 2 degrees, 0 degrees, and 500 MU/min, respectively. Anisotropic Analytical Algorithm (AAA) was used for dose calculation with a grid size of 2.5 mm. The PTV's prescription dose was 50Gy in 25 fractions, with D95%≥50Gy and D2%≤ 55Gy. The dose limits for OARs were defined according to specific criteria. All treatment plans were created using the Eclipse treatment planning system (Eclipse,Varian Medical Systems, USA), a widely used platform for radiotherapy plan optimization and dose calculation.

Body contouring changes simulation

To simulate varying degrees of body contour changes from weight loss, five new CT images (CT1 to CT5) were generated from the original CT image. The original CT images were acquired using the CT simulator (SOMATOM Sensation Open, Siemens, Germany). Contouring was regenerated with inner margins of 3mm, 6mm, 9mm, 12mm, and 15mm on CT1 to CT5 using the Eclipse treatment planning system. Subsequently, new VMAT plans were performed and analyzed. It's important to note that anatomical changes in targets and organs at risk due to weight loss were not considered in this study.

Dosimetric parameters assessment

The assessment of dosimetric parameters to PTVs and OARs was conducted by comparing P3, P6, P9, P12, and P15 to P0 as per the ICRU83 report (2010). Specific parameters were analyzed for PTVs, and comparisons were made for OARs, such as small bowel, rectum, bone marrow, femoral head, and bladder. To gauge absolute dose distribution changes, calculations were performed to identify differences in dose changes in 3D anatomical space.

Statistical methods

Data analysis for this study was carried out using GraphPad Prism 5.0 (Prism, GraphPad Software, USA). The results were presented as mean ± standard deviation. A difference percentage calculation and paired T-test were executed for each parameter among various treatment plans. A P-value of less than 0.05 was considered statistically significant.

RESULTS

The study investigated the dose parameters of

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PTV and OARs in 20 patients diagnosed with cervical cancer. These parameters were measured at six different points: P0, P3, P6, P9, P12, and P15, as displayed in table 1. A comparison was conducted between the dose parameters of P3, P6, P9, P12, and P15 with P0. The results, including the difference percentage (diff) and paired T-test, are presented in table 2. The formula used for calculating diff, diff = (Pa-P0) ×100/P0, where "a" is one of the following values: 3, 6, 9, 12, 15. Figure 2 illustrates the absolute dose distribution changes in 3D anatomical space for each plan. Figure 3 highlights instances where the absolute dose changes exceeded 250 cGy (corresponding to 5% changes in prescription dose). Table 3 contains details of the absolute volume of dose changes exceeding 250 cGy in P3, P6, P9, P12, and P15.

The analysis revealed that the P3, P6, and P9 plans did not display areas with a dose change greater than 250 cGy. Only the P12 plan began to exhibit a substantial range of dose changes, as depicted in figure 3. A 2D dose distribution of five slices from different positions within P12 was selected for further examination, and these are shown in figure 4. The dose volume histograms (DVH) of OARs for P0, P3, P6, P9, P12, and P15 are demonstrated in figures 5-8.

Table 1. Absolute dose parameters (including D2, D50, D95, and D98) for the Planning Target Volume (PTV) and Organs at Risk (OARs), such as the small intestine, rectum, bladder, femoral head, and bone marrow, of 20 cervical cancer patients at different body contouring reductions (P0, P3, P6, P9, P12, and P15). The plans of P0, P3, P6, P9, P12, P15 represent the body contouring reductions of 0mm, 3mm, 6mm, 9mm, 12mm, and 15mm, respectively.

Structure	Parameter	Plan					
		P0 (Mean±SD)	P3 (Mean±SD)	P6 (Mean±SD)	P9 (Mean±SD)	P12 (Mean±SD)	P15 (Mean±SD)
PTV	D2	5367.12±43.76	5437.34±43.98	5496.19±42.9	5565.69±45.58	5631.59±46.56	5710.35±47.2
	D50	5178.13±43.65	5246.33±44.07	5299.79±44.36	5365.51±44.03	5451.06±45.73	5501.32±45.99
	D95	5055.29±27.65	5120.97±27.96	5173.02±26.93	5235.02±26.4	5294.56±28.15	5362.06±26.9
	D98	5026.48±20.96	5091.57±20.82	5143.03±18.99	5205.9±21.20	5265.69±23.38	5332.03±23.99
	HI	0.0596±0.0063	0.0603±0.0049	0.061±0.0044	0.0617±0.0055	0.0624±0.0042	0.0643±0.0048
	CI	0.8844±0.0206	0.8707±0.0171	0.8545±0.0138	0.8352±0.0249	0.8172±0.0148	0.798±0.0152
Small intestine	V45(cc)	167.80±26.83	174.33±25.79	178.87±24.94	185.47±23.72	198.48±23.21	208.13±22.34
	Dmax	5306.87±32.61	5385.77±36.71	5452.13±47.37	5518.84±27.47	5594.93±32.55	5696.32±39.05
	Dmean	2639.56±483.82	2670.97±487.19	2694.2±497.30	2723.89±507.84	2752.01±514.37	2783.15±520.82
Rectum	V50(%)	40.90±10.12	44.39±13.82	47.38±12.24	48.74±10.36	50.81±11.42	53.35±10.46
	Dmax	5324.25±107.14	5390.03±95.77	5448.3±97.61	5518.72±99.24	5581.03±88.52	5661.26±64.21
	Dmean	3762.9±366.43	3809.87±370.93	3846.82±375.42	3890.97±381.21	3933.25±386.25	3982.1±392.05
Bone marrow	V40(%)	34.15±3.67	34.40±3.75	34.56±4.30	34.75±5.01	34.92±5.10	34.97±5.13
	Dmean	2847.24±91.45	2880.84±91.85	2907.32±91.47	2934.44±92.50	2958.28±91.85	2979.92±93.04
Right femoral head	V30(%)	11.87±11.53	11.93±11.61	11.98±11.65	12.03±11.78	12.08±11.73	12.12±11.75
	Dmax	4868.33±456.28	4932.24±444.47	4976.12±431.38	5043.63±486.57	5114.94±495.26	5167.66±459.4
	Dmean	1448.33±169.9	1462.74±172.35	1473.39±173.48	1486.54±172.58	1498.44±175.15	1510.96±175.86
Left femoral head	V30(%)	11.21±7.95	11.28±7.94	11.33±7.94	11.39±7.91	11.44±7.89	11.49±7.87
	Dmax	5015.32±136.53	5090.43±128.95	5161.79±114.62	5200.35±132.71	5250.78±133.39	5358.45±119.77
	Dmean	1563.37±283.42	1579.32±286.54	1588.85±289.82	1603.16±291.86	1614.96±293.88	1630.91±295.99
Bladder	V40(%)	44.98±14.41	45.6±13.47	46.07±12.72	46.6±15.57	47.1±14.98	47.61±13.01
	Dmean	3609.02±622.15	3653.77±633.99	3692.39±646.61	3737.86±663.33	3779±671.81	3828.09±686.15

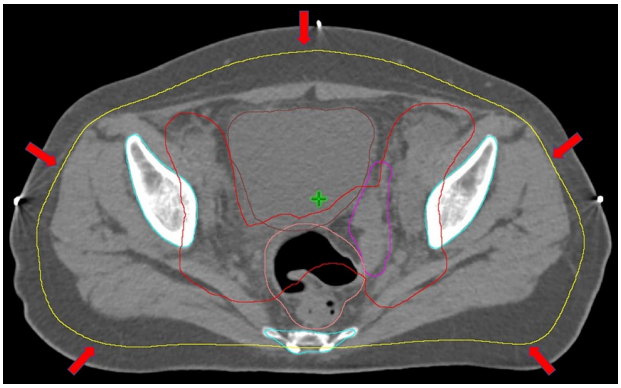

Figure 1. The description of body contouring changes simulation, the yellow outline is the regenerated body contouring.

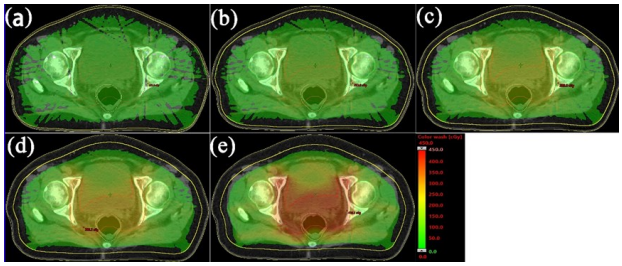

Figure 2. The absolute dose distribution changes in 3D anatomy space for each plan (P3, P6, P9, P12, and P15). **(a-e)**, The 3D spatial distribution of dose differences for plans P3, P6, P9, P12, and P15. These maps highlight the spatial effects of contour changes on dose delivery to the PTV and OARs. The plans of P0, P3, P6, P9, P12, P15 represent the body contouring reductions of 0mm, 3mm, 6mm, 9mm, 12mm, and 15mm, respectively.

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Table 2. Results of difference percentage (diff) and paired T-test analysis for the PTV and OARs (small intestine, rectum, bladder, femoral head, and bone marrow) of 20 cervical cancer patients at various body contouring reductions (P0, P3, P6, P9, P12, and P15), including statistical significance (P < 0.05). The plans of P0, P3, P6, P9, P12, P15 represent the body contouring reductions of 0mm, 3mm, 6mm, 9mm, 12mm, and 15mm, respectively.

Structure	Parameter	*diff* (%)				
		P0 vs P3 (Mean±SD)	P0 vs P6 (Mean±SD)	P0 vs P9 (Mean±SD)	P0 vs P12 (Mean±SD)	P0 vs P15 (Mean±SD)
PTV	D2	1.31±0.03**	2.41±0.05**	3.7±0.03**	5.13±0.07**	6.39±0.06**
	D50	1.32±0.04**	2.35±0.04**	3.62±0.09**	5.18±0.12**	6.24±0.12**
	D95	1.3±0.06**	2.33±0.06**	3.55±0.11**	5.03±0.14**	6.07±0.15**
	D98	1.3±0.05**	2.32±0.09**	3.57±0.11**	5.06±0.13**	6.08±0.17**
	HI	1.187±0.198	2.408±0.051	3.5458±0.053	5.258±0.044*	7.955±0.042*
	CI	-1.558±0.213	-3.385±0.443**	-4.5145±0.609**	-6.599±0.619**	-9.778±0.699**
Small intestine	V45(CC)	3.89±2.86**	6.60±3.58**	10.53±3.61**	13.85±4.07**	19.39±4.88**
	Dmax	1.49±0.27**	2.74±0.69**	3.99±0.34**	5.43±0.53**	7.34±1.04**
	Dmean	1.19±0.14	2.07±0.09	3.2±0.18	4.26±0.25*	5.44±0.28**
Rectum	V50(%)	8.54±4.07**	15.85±4.52**	19.45±5.71**	23.84±6.25**	30.43±7.3**
	Dmax	1.24±0.32*	2.33±0.46*	3.66±0.24**	4.83±0.49**	6.35±1.23**
	Dmean	1.25±0.07	2.23±0.13	3.4±0.2	4.52±0.23*	5.82±0.3*
Bone marrow	V40(%)	0.72±0.13	1.20±0.17	1.76±0.15	2.25±0.13*	2.41±0.21*
	Dmean	1.18±0.09	2.11±0.1*	3.06±0.28*	3.9±0.51*	4.66±1.02*
Right femoral head	V30(%)	0.54±0.16	0.92±0.29	1.39±0.51*	1.77±0.57*	2.13±0.71*
	Dmax	1.34±0.45	2.27±0.84*	3.6±0.37*	5.04±0.75**	6.19±0.72**
	Dmean	0.99±0.1	1.73±0.17	2.65±0.17	3.46±0.18*	4.33±0.52*
Left femoral head	V30(%)	0.65±0.36	1.07±0.55	1.57±0.97	2.06±1.2*	2.52±1.46*
	Dmax	1.51±0.65	2.93±1.03*	3.7±0.18**	4.7±0.32**	6.85±1**
	Dmean	1.02±0.25	1.63±0.16	2.55±0.16	3.3±0.26*	4.32±0.16*
Bladder	V40(%)	1.24±1.06	2.09±1.88*	2.55±3.15*	3.25±3.78*	4.26±4.8**
	Dmean	1.24±0.14	2.31±0.27	3.07±0.42*	4.11±0.51**	4.97±0.67**

* Represents P<0.05, **represents P<0.0001.

Table 3. Absolute volume of dose changes exceeding 250 cGy for PTV and OARs (small intestine, rectum, bladder, femoral head, and bone marrow) in 20 cervical cancer patients, across different body contouring reductions (P3, P6, P9, P12, and P15), showing the proportion of PTV affected by these dose changes. The plans of P0, P3, P6, P9, P12, P15 represent the body contouring reductions of 0mm, 3mm, 6mm, 9mm, 12mm, and 15mm, respectively.

Parameter	P3 (Mean±SD)	P6 (Mean±SD)	P9 (Mean±SD)	P12 (Mean±SD)	P15 (Mean±SD)
Absolute volume (cm^3)	0.16±0.05	0.27±0.12	1.15±0.43	367.15±37.74	2054.40±326.59

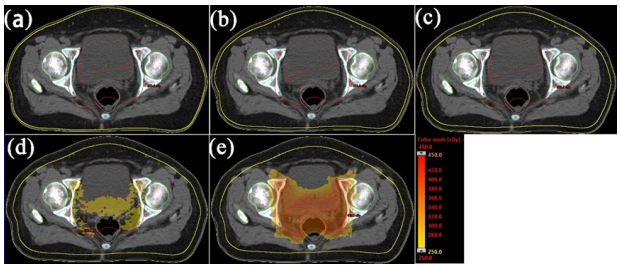

Figure 3. The absolute dose changes exceeding 250 cGy (5% of the prescription dose) for each plan (P3, P6, P9, P12, and P15), **(a-e)** Regions with dose deviations greater than 250 cGy for plans P3, P6, P9, P12, and P15. These regions correspond to significant dose alterations due to anatomical changes. The plans of P0, P3, P6, P9, P12, P15 represent the body contouring reductions of 0mm, 3mm, 6mm, 9mm, 12mm, and 15mm, respectively.

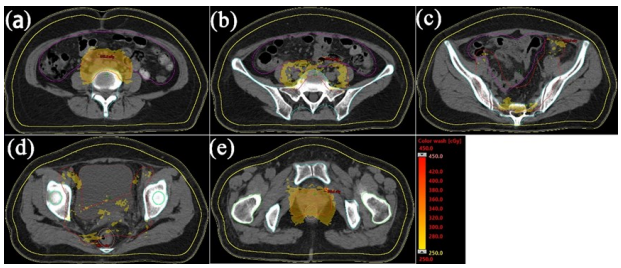

Figure 4. 2D dose distribution of five slices located in different position from P12. **(a-e)** Dose distributions for five different slices along the superior-inferior axis, with positions measured from the P12 plan. Each slice demonstrates the dose coverage and heterogeneity in relation to the contour changes in these anatomical planes. The plans of P0, P3, P6, P9, P12, P15 represent the body contouring reductions of 0mm, 3mm, 6mm, 9mm, 12mm, and 15mm, respectively.

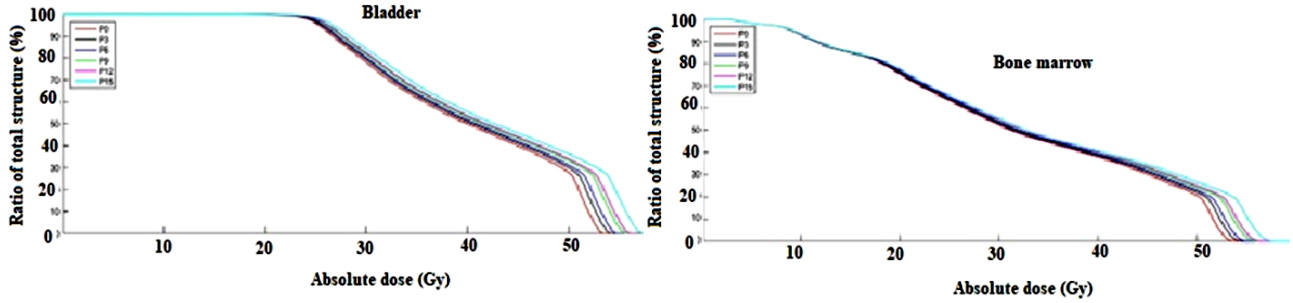

Figure 5. Dose-volume histograms (DVHs) for bladder and bone marrow across all plans (P0, P3, P6, P9, P12, and P15), showing the effect of anatomical variations on dose sparing. The plans of P0, P3, P6, P9, P12, P15 represent the body contouring reductions of 0mm, 3mm, 6mm, 9mm, 12mm, and 15mm, respectively.

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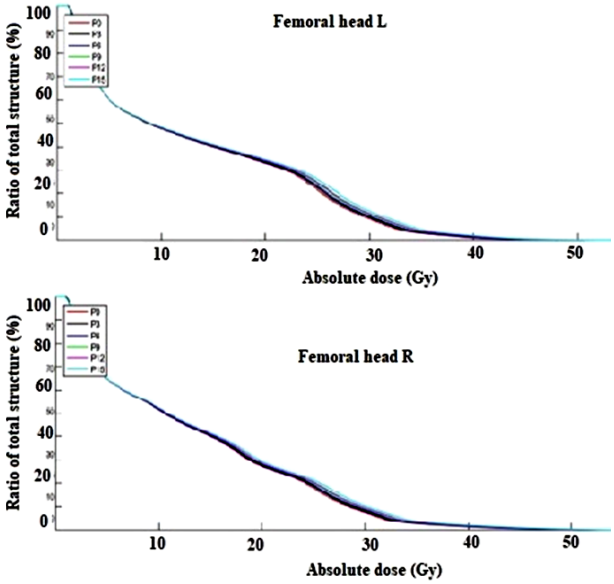

Figure 6. Dose-volume histograms (DVHs) for femoral head L and femoral head R across all plans (P0, P3, P6, P9, P12, and P15), showing the effect of anatomical variations on dose sparing. The plans of P0, P3, P6, P9, P12, P15 represent the body contouring reductions of 0mm, 3mm, 6mm, 9mm, 12mm, and 15mm, respectively.

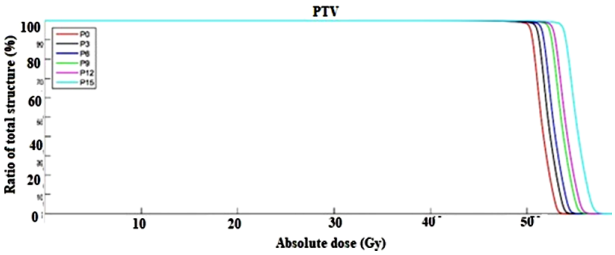

Figure 8. Dose-volume histograms (DVHs) for PTV across all plans (P0, P3, P6, P9, P12, and P15). The plans of P0, P3, P6, P9, P12, P15 represent the body contouring reductions of 0mm, 3mm, 6mm, 9mm, 12mm, and 15mm, respectively.

DISCUSSION

This study investigates the significant dosimetric effects of weight loss-induced body contouring changes in cervical cancer patients undergoing Volumetric Modulated Arc Therapy (VMAT). Weight loss is a common occurrence during radiotherapy, especially for cervical cancer patients undergoing concurrent chemotherapy, due to treatment-related gastrointestinal toxicity and metabolic changes. These changes alter body contouring, leading to variations in dose attenuation and increases in doses delivered to the Planning Target Volume (PTV) and adjacent Organs at Risk (OARs). The findings highlight the necessity of monitoring body contouring changes and implementing timely interventions to maintain optimal dose delivery.

Our findings align with previous studies on the impact of body contouring changes on radiotherapy dosimetry. Chow [17] observed that a 2cm reduction in body contouring in prostate cancer patients led to a 5% increase in dose to PTVs and OARs. Similarly,

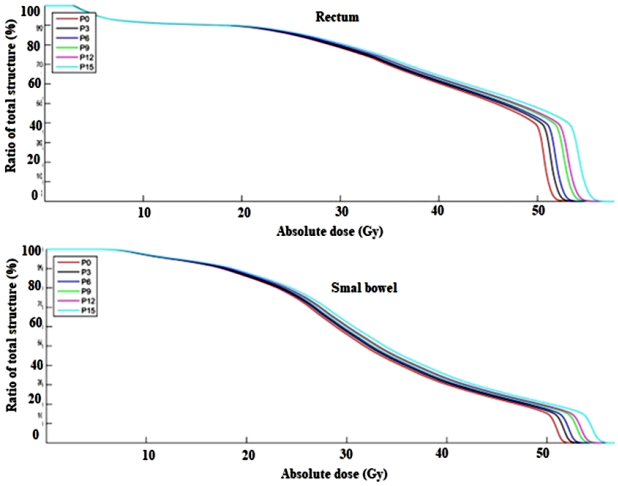

Figure 7. Dose-volume histograms (DVHs) for rectum and small intestine across all plans (P0, P3, P6, P9, P12, and P15), showing the effect of anatomical variations on dose sparing. The plans of P0, P3, P6, P9, P12, P15 represent the body contouring reductions of 0mm, 3mm, 6mm, 9mm, 12mm, and 15mm, respectively.

Pair [18] recommended re-scanning for prostate cancer patients when source-to-skin distance (SSD) deviations exceeded 1cm. In head and neck and prostate cancers, Sun [19] reported that unilateral contouring changes of less than 2cm or overall changes of less than 1cm may not require re-planning. For nasopharyngeal carcinoma, Moallim [20] and Chen [21] highlighted significant dose deviations to critical OARs like the brainstem and spinal cord due to weight loss. However, few studies have specifically evaluated these effects in cervical cancer, a disease where weight loss predominantly affects the waist and abdomen, resulting in more pronounced dose variations.

This study uniquely identifies a 12mm reduction in body contouring as a critical threshold for initiating re-scanning and re-planning. Reductions beyond this threshold resulted in dose deviations exceeding the International Commission on Radiological Units (ICRU) recommended ±5% limit for PTV doses, increasing the risk of radiation-induced toxicities [22]. Kavanagh [23] recommended that the small intestine volume receiving more than 45Gy (V45) should be less than 195cc and the rectum V50 should be less than 50%. At reductions of 12mm and 15mm, small intestine V45 exceeded 195cc, and rectum V50 surpassed 50%, indicating a heightened risk of gastrointestinal complications. To enhance the rigor of this study, we examined the impact of reducing the body contour by 10 mm and 11 mm, in addition to the previously tested 3 mm increments. The results showed that reducing the contour by 10 mm and 11 mm led to an average increase in D50 of 4.08% and 4.43%, respectively. In terms of OARs, the average V45 of the small intestine was 189.71cc and 183.63cc, and the average V50 of the rectum was 49.22% and 49.85%. However, these changes were within the clinically acceptable limit.

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The results also highlight the complexities of dose adjustments in VMAT compared to traditional radiotherapy techniques. Unlike Intensity-Modulated Radiotherapy (IMRT), where dose changes are more localized, VMAT delivers doses via continuous gantry rotation, making it more sensitive to global body contouring changes. This sensitivity necessitates the use of effective correction strategies. Although Cone-Beam Computed Tomography (CBCT)-based dose recalculations are commonly employed, they are limited by image quality and resource availability. Our proposed empirical method offers a simple, efficient alternative to identify high-risk plans, particularly in resource-constrained settings.

By quantifying the dosimetric impact of body contouring reductions and defining a practical intervention threshold, this research provides actionable insights for radiation oncologists and physicists. The patient's body contouring appears elliptical or circular due to varying degrees of obesity. The perimeter formulas for an ellipse and circle are $L=2\pi b+4(a-b)$ and $C=2\pi r$, where a and b represent half of the long and short axes of the ellipse, and c represents the radius of the circle. Through formula derivation, we have found that a reduction in body contouring leads to changes in the perimeters of the ellipse and circle, denoted by $\triangle L=2\pi\triangle b$ and $\triangle C=2\pi\triangle r$ respectively. We assume $\triangle b$ and $\triangle r$ are equal to 12mm, resulting in $\triangle L$ and $\triangle C$ being equal to 75mm. This implies that if a patient's waist circumference decreases by approximately 75mm (equivalent to a 12mm reduction in body contouring), re-scanning and re-planning should be strongly considered to mitigate risks associated with dose escalation.

The findings also highlight the need for integrating advanced imaging and adaptive radiotherapy techniques into clinical workflows. Real-time imaging and auto-contouring tools could enable more precise monitoring of body contouring changes, facilitating dynamic adjustments to treatment plans. Furthermore, incorporating machine learning algorithms could enhance the predictive capability of empirical models, identifying patients at risk of significant dose deviations based on weight loss trajectories and other clinical parameters.

However, this study has limitations. The simulated uniform reductions in body contouring may not fully represent the heterogeneous weight loss patterns observed in clinical practice, where changes may vary across anatomical regions such as the abdomen, waist, and back. Additionally, the sample size of 20 patients limits the generalizability of the findings. Future research should aim to validate these findings in larger, more diverse cohorts and investigate the impact of non-uniform contour changes.

CONCLUSION

Body contour changes due to weight loss during treatment can increase doses to both the target area and nearby OARs. Physicians should closely monitor cervical cancer patients' body contour changes with CT or CBCT scans. A 12mm reduction in body contouring may lead to overdoses to the small intestine, rectum, and OARs at the ends of the PTVs, thus requiring re-scanning and re-planning. Patients should track waist circumference changes during radiotherapy and report if changes exceed 75mm. Weight, as a simple indicator of nutritional status, should also be monitored, with nutritional support provided as needed.

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***Author contributions*:** Z.C. and W.X. contributed to the conceptualization and design of the study, conducted data analysis, and drafted the manuscript. J.S. was responsible for data collection and interpretation, as well as revising the manuscript for important intellectual content. L.L., H.L. and C.C. provided critical feedback on the study design and methodology and helped with the final editing of the manuscript. All authors read and approved the final manuscript.

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