

Dosimetric and Radiobiological Comparison of Volumetric Modulated Arc Therapy versus Intensity-Modulated Radiotherapy in Locally Advanced Cervical Cancer: A Retrospective Single-Center Study

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ABSTRACT Background: Cervical cancer is the second most common cancer among Moroccan women. IMRT and VMAT are both used routinely as intensity-modulated techniques, but when patient enrollment for this study began, a radiobiologically informed comparison of the two had not yet been reported for a North African population.

Purpose: To compare VMAT and IMRT dosimetrically and radiobiologically in locally advanced cervical cancer (LACC).

Methods: Forty-five patients treated with definitive concurrent chemoradiotherapy (FIGO IB2–IVA) were included retrospectively; twenty-three received VMAT and twenty-two received IMRT. Plans were recalculated with the Acuros XB algorithm (Eclipse v16.1). DVH parameters were extracted for the PTV and pelvic organs at risk. TCP was modeled with the Poisson linear-quadratic formalism, and NTCP with the Lyman–Kutcher–Burman model, using literature-derived parameters. Because the two groups were independent, between-group comparisons used the Mann–Whitney U test.

Results: PTV coverage was equivalent between techniques (D95: 97.8% vs 97.5%, $p = 0.38$). VMAT significantly reduced dose to the rectum, bladder, small bowel, and femoral heads ($p \leq 0.021$). Modeled TCP was comparable between groups (78.4% vs 76.9%, $p = 0.38$), while modeled NTCP for grade ≥ 2 proctitis, cystitis, and enteritis was lower with VMAT ($p < 0.01$). Monitor units decreased by 30.4% and beam-on time by 63.2% with VMAT.

Conclusion: VMAT improved modeled organ-at-risk sparing without compromising tumor coverage. These findings are consistent with the international literature and support a clinical interest in VMAT in this Moroccan setting. Prospective confirmation with clinical toxicity data remains necessary before generalization.

Keywords: VMAT; IMRT; Cervical cancer; Dosimetry; TCP; NTCP; LKB model; Acuros XB; North Africa; Pelvic radiotherapy

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INTRODUCTION

Cervical cancer is a major cause of cancer death among women in low- and middle-income countries. In Morocco, it is the second most frequent cancer in women. The age-standardized incidence is about 13.4 per 100,000 women per year [1]. Most patients present with locally advanced disease (FIGO stage IIB–IVA). The standard treatment is platinum-based concurrent chemoradiotherapy followed by a brachytherapy boost [2,3].

3D-CRT was historically the standard technique for pelvic irradiation in LACC. Its ability to spare nearby organs is limited by geometric constraints. These organs include the rectum, bladder, small bowel, and femoral heads. IMRT changed this. It uses inverse optimization to shape non-uniform dose distributions around the target. Several studies show that IMRT reduces acute and late gastrointestinal and genitourinary toxicity compared with 3D-CRT [4,5].

VMAT extends IMRT by modulating gantry speed, dose rate, and MLC shape during a continuous arc, which gives access to more beam angles than fixed-field IMRT. In principle this yields more homogeneous dose distributions with steeper dose gradients, and delivery is generally faster as well. Several studies report dosimetric advantages of VMAT over IMRT specifically in LACC, including better rectal and bowel sparing, fewer monitor units, and shorter treatment times [6–8].

The reported magnitude of these advantages varies across studies, likely reflecting differences in pelvic anatomy, BMI, planning systems, and dose-volume constraints. While this manuscript was in preparation, a Moroccan single-center series compared 3D-CRT, IMRT, and VMAT dosimetry in ten cervical cancer patients, using a different linear accelerator platform and dose-calculation algorithm and without radiobiological modeling [19]. When patient enrollment for the present study began, a larger, radiobiologically informed comparison of VMAT and IMRT specifically was, to our knowledge, still lacking for this population.

A purely dosimetric comparison does not directly reflect clinical outcome, whereas TCP and NTCP models offer a mechanistic link between dose-volume data and predicted outcome [9]. That link is particularly relevant for LACC, where late rectal, bladder, and bowel toxicity strongly affect long-term quality of life, and where

retreatment options are often limited in resource-constrained settings.

We conducted a retrospective dosimetric and radiobiological comparison of VMAT and IMRT for LACC at a Moroccan tertiary center. We hypothesized that VMAT would reduce OAR dose without compromising PTV coverage.

MATERIALS AND METHODS

Patient Selection and Ethical Framework

This retrospective study received approval from our Institutional Ethics Committee and was conducted in accordance with the Declaration of Helsinki. Because the design was retrospective and the data were anonymized, individual patient consent was waived. We screened patients with confirmed LACC who had received definitive EBRT between January 2021 and December 2023. Patients were included if they met the following criteria: (i) 2018 FIGO stage IB2–IVA; (ii) squamous, adeno-, or Aden squamous histology; (iii) complete simulation CT and DICOM-RT data; and (iv) curative-intent definitive concurrent chemoradiotherapy. We excluded patients with prior pelvic irradiation, a treatment gap exceeding 5 days due to toxicity, or a PTV D95 below 93% on the approved plan.

Forty-five patients met all criteria. Twenty-three received VMAT and twenty-two received IMRT (Figure 1). Technique choice followed institutional preference and machine scheduling. There was no formal randomization, which is a limitation discussed in Section 4.

CT Simulation and Contouring

All patients had CT simulation supine, with a full-bladder protocol (500 mL oral fluid, 60-minute wait). Slice thickness was 3 mm. Immobilization used a Vac-Lok™ cushion. Intravenous contrast was used in 84% of cases. One senior radiation oncologist contoured all structures, following the EMBRACE II protocol [10]. The CTV included the GTV, uterus, cervix, parametria, upper two-thirds of the vagina, and regional nodes (common, external, internal iliac, obturator, presacral to S2–S3). The PTV used a 7 mm isotropic margin, reduced to 3 mm posteriorly at the rectal interface. OARs included the rectum, bladder, small bowel, sigmoid colon, and bilateral femoral heads.

A single contouring observer limits inter-observer variability but does not allow its estimation. This is acknowledged as a study limitation.

Treatment Planning

All plans were recalculated with Acuros XB (v16.1.0, Eclipse, Varian, Palo Alto, CA, USA). Dose grid resolution was 2.5 mm. Acuros XB solves the Linear Boltzmann Transport Equation. It is more accurate than the Anisotropic Analytical Algorithm in tissue heterogeneities. IAEA TRS-483 recommends it for advanced techniques [11].

IMRT used 7–9 coplanar fixed beams (step-and-shoot), optimized with PRO3. VMAT used two full coplanar arcs (360°, both directions), with 10° and 350° collimator angles to reduce tongue-and-groove effects, optimized with the Photon Optimizer. One

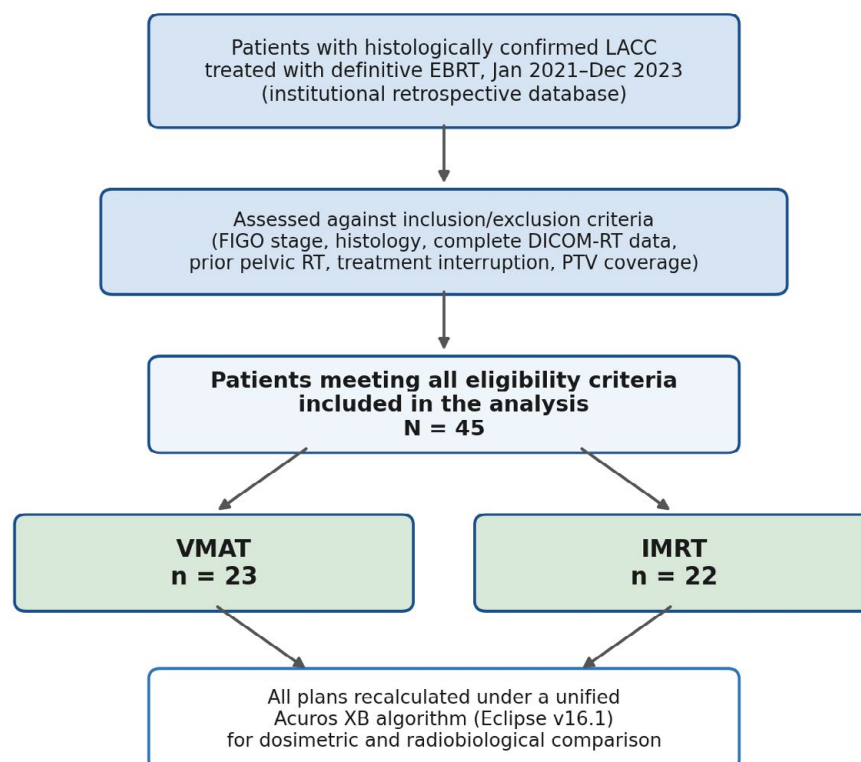


Figure 1: Patient selection and allocation. Numbers reflect the confirmed cohort described in Section 2.1; VMAT and IMRT groups are independent (non-paired), as technique assignment followed institutional scheduling rather than randomization.

experienced dosimetrist (≥ 5 years IMRT/VMAT) planned all cases. Beam energy was 6 MV.

Prescribed dose was 45 Gy in 25 fractions to the PTV. Eight patients with bulky nodes received a simultaneous integrated boost to 50.4 Gy in 28 fractions. Dose objectives followed QUANTEC and EMBRACE II: rectum V40Gy<80%, V50Gy<65%; bladder V40Gy<80%, V50Gy<65%; small bowel V45Gy<195 cm³, Dmax<51 Gy; femoral heads V30Gy<50%.

Dosimetric Analysis

DVH data were extracted from DICOM-RT files with custom Python scripts (pydicom v2.4, dicompyler-core v0.5.5). For the PTV, we recorded D95, D98, D2, Dmax, Dmean, and the homogeneity index (D2/D98). For OARs, we extracted Vx and Dmean per QUANTEC metrics. Monitor units and beam-on time were recorded as delivery-efficiency indices.

Radiobiological Modeling

Tumor Control Probability

TCP was modeled with the Poisson-LQ formalism [12]:

$$\text{TCP} = \exp[-\rho \cdot V \cdot \text{SF}(d,n)], \text{SF}(d,n) = \exp[-(\alpha d + \beta d^2) \cdot n]$$

Here $\rho = 107$ clonogens/cm³ is clonogen density, V is GTV volume, d is dose per fraction, and n is fraction number. For cervical squamous carcinoma, we used $\alpha = 0.30$ Gy⁻¹ and $\alpha/\beta = 10$ Gy, as reported by Bentzen and Joiner [13]. For SIB cases, a weighted mean equivalent dose was used. Because these are population-level literature values rather than parameters fitted to our own patients, the resulting TCP estimates reflect a modeling assumption rather than a measured property of this cohort.

Normal Tissue Complication Probability

NTCP was calculated with the LKB model [14,15]:

$$\text{NTCP} = \Phi[(\text{EUD} - \text{TD50}(1)) / (m \cdot \text{TD50}(1))]$$

Φ is the cumulative normal distribution. EUD is the generalized equivalent uniform dose. TD50(1) is the dose for a 50% complication probability in a uniformly irradiated organ, and m sets the slope of the dose-response curve.

The LKB parameters used for each organ are taken from the literature, not re-fitted to our institutional outcomes. For the rectum, we used the QUANTEC pooled estimate for grade ≥ 2 late toxicity: TD50 = 76.9 Gy, m = 0.13, n = 0.09 [16]. QUANTEC does not provide fitted LKB parameters for bladder, small bowel, or femoral head. For these organs we used the classic Emami/Burman compilation [17,18], summarized in (Table 1). These

values reflect population-level tolerance data from older cohorts and different treatment eras. For this reason, the absolute NTCP values reported here are best read as model estimates that allow a fair comparison between VMAT and IMRT under identical assumptions, rather than as complication rates actually observed in our patients.

Statistical Analysis

Analyses used Python 3.11 (SciPy v1.11, statsmodels v0.14, pingouin v0.5.3). The Shapiro–Wilk test showed non-normal distributions for dosimetric parameters. VMAT and IMRT patients form two independent, unpaired groups, since each patient received only one technique. Continuous variables were therefore compared with the Mann-Whitney U test, not the paired Wilcoxon signed-rank test. Categorical variables (Table 2) were compared with the chi-square test, or Fisher's exact test when an expected cell count was below 5. Effect sizes used the rank-biserial correlation (r): 0.1 small, 0.3 medium, 0.5 large. Bland–Altman plots assessed agreement for selected DVH parameters. Significance was set at two-sided p<0.05.

RESULTS

Patient and Plan Characteristics

Forty-five consecutive eligible patients were included (Figure 1). Groups were balanced (Table 2). Mean age was 52.4 $\pm$ 11.7 years. Mean BMI was 26.8 $\pm$ 4.3 kg/m². FIGO stage, histology, and prescription did not differ between groups (all p>0.3). Weekly cisplatin (40 mg/m²) was given to 84.4% of patients.

Plan Dosimetric Quality — PTV Coverage

PTV coverage was equivalent between techniques for all metrics (Table 3). D95 was 97.8 $\pm$ 1.1% vs. 97.5 $\pm$ 1.3% (p=0.38, r=0.14). D98 was 95.6 $\pm$ 1.4% vs. 95.2 $\pm$ 1.6% (p=0.32, r=0.16). Dmean was 47.1 $\pm$ 0.9 Gy vs. 47.0 $\pm$ 1.0 Gy (p=0.71, r=0.06). The homogeneity index showed a non-significant trend favoring VMAT (1.054 $\pm$ 0.012 vs. 1.061 $\pm$ 0.015, p=0.07). Tumor coverage was therefore non-inferior with VMAT.

Plan Dosimetric Quality — OAR Sparing

VMAT reduced dose to all evaluated OARs (Table 3, Figure 2). For the rectum, V40Gy fell from 51.7 $\pm$ 10.4% to 42.3 $\pm$ 9.8% (p<0.001, r=0.58). V50Gy fell from 25.4 $\pm$ 7.1% to 18.1 $\pm$ 6.2% (p<0.001, r=0.62). Dmean fell from 39.2 $\pm$ 5.8 Gy to 34.7 $\pm$ 5.1 Gy (p=0.004, r=0.44). For the bladder, V40Gy fell from 55.3 $\pm$ 12.0% to 47.6 $\pm$ 11.2% (p=0.021). V50Gy fell from 29.1 $\pm$ 8.8% to 22.4 $\pm$ 7.9% (p=0.008). Dmean fell from 43.1 $\pm$ 6.9 Gy to 38.4 $\pm$ 6.3

Table 1: LKB model parameters used for NTCP calculation. Values are literature-derived and were not re-fitted to the present cohort.

Organ	Endpoint	TD50(1) (Gy)	m	n	Source
Rectum	Grade ≥ 2 proctitis / bleeding	76.9	0.13	0.09	[16]
Bladder	Grade ≥ 2 cystitis (whole organ)	80	0.11	0.50	[17,18]
Small bowel	Grade ≥ 2 enteritis (obstruction/perforation)	55	0.15	0.15	[17,18]
Femoral heads	Grade ≥ 2 necrosis	65	0.25	0.25	[17,18]

Abbreviations: TD50(1) = dose for 50% complication probability, uniform whole-organ irradiation; m = slope parameter; n = volume parameter. Rectum parameters from the QUANTEC pooled analysis [16]; other organs from the Emami [17] / Burman [18] tolerance-dose compilation, as no QUANTEC-fitted LKB parameters are available for these organs.

Table 2: Patient and treatment characteristics by radiotherapy technique. Continuous variables as mean $\pm$ SD; categorical variables as n (%).

Characteristic	All patients (N = 45)	VMAT group (n = 23)	IMRT group (n = 22)	p-value
Age, years — mean $\pm$ SD	52.4 $\pm$ 11.7	51.9 $\pm$ 12.1	53.0 $\pm$ 11.4	0.67
BMI, kg/m ² — mean $\pm$ SD	26.8 $\pm$ 4.3	27.1 $\pm$ 4.5	26.5 $\pm$ 4.1	0.61
Pelvic width, cm — mean $\pm$ SD	13.2 $\pm$ 1.4	13.4 $\pm$ 1.5	13.0 $\pm$ 1.3	0.34
FIGO stage — n (%)				
IB2–IIA	11 (24.4%)	6 (26.1%)	5 (22.7%)	0.88
IIB	22 (48.9%)	11 (47.8%)	11 (50.0%)	
IIIB–IVA	12 (26.7%)	6 (26.1%)	6 (27.3%)	
Histology: squamous cell carcinoma — n (%)	40 (88.9%)	21 (91.3%)	19 (86.4%)	0.59
Prescribed dose, Gy — median (range)	45.0 (45–50.4)	45.0 (45–50.4)	45.0 (45–50.4)	—
Number of fractions — median (range)	25 (25–28)	25 (25–28)	25 (25–28)	—
Concurrent chemotherapy — n (%)	38 (84.4%)	19 (82.6%)	19 (86.4%)	0.72
GTV volume, cm ³ — median (IQR)	41.3 (28–67)	43.1 (30–68)	39.5 (26–65)	0.51

Abbreviations: BMI = body mass index; IQR = interquartile range. Continuous variables were compared with the Mann-Whitney U test. Categorical variables were compared with the chi-square test, except for FIGO stage, for which Fisher's exact test was used because one expected cell count was below 5. No significant difference was observed between groups (all $p > 0.30$).

Table 3: Dosimetric comparison of VMAT and IMRT plans. Significant differences ($p < 0.05$) marked with an asterisk (*). Effect size r : small ≥ 0.10 , medium ≥ 0.30 , large ≥ 0.50 .

Parameter	VMAT (mean $\pm$ SD)	IMRT (mean $\pm$ SD)	p-value	Effect size (r)
PTV COVERAGE				
D95 (%)	97.8 $\pm$ 1.1	97.5 $\pm$ 1.3	0.38	0.14
D98 (%)	95.6 $\pm$ 1.4	95.2 $\pm$ 1.6	0.32	0.16
Dmean (Gy)	47.1 $\pm$ 0.9	47.0 $\pm$ 1.0	0.71	0.06
HI (D2/D98)	1.054 $\pm$ 0.012	1.061 $\pm$ 0.015	0.07	0.28
RECTUM				
V40Gy (%)	42.3 $\pm$ 9.8	51.7 $\pm$ 10.4	< 0.001 *	0.58
V50Gy (%)	18.1 $\pm$ 6.2	25.4 $\pm$ 7.1	< 0.001 *	0.62
Dmean (Gy)	34.7 $\pm$ 5.1	39.2 $\pm$ 5.8	0.004 *	0.44
BLADDER				
V40Gy (%)	47.6 $\pm$ 11.2	55.3 $\pm$ 12.0	0.021 *	0.36
V50Gy (%)	22.4 $\pm$ 7.9	29.1 $\pm$ 8.8	0.008 *	0.41
Dmean (Gy)	38.4 $\pm$ 6.3	43.1 $\pm$ 6.9	0.015 *	0.38
SMALL BOWEL				
V15Gy (cm ³)	182.4 $\pm$ 45.3	234.6 $\pm$ 52.8	< 0.001 *	0.56
V45Gy (cm ³)	28.7 $\pm$ 12.4	41.3 $\pm$ 15.6	0.003 *	0.47
Dmean (Gy)	22.6 $\pm$ 6.1	28.4 $\pm$ 7.2	0.001 *	0.50
FEMORAL HEADS (bilateral mean)				
V30Gy (%)	12.8 $\pm$ 5.6	19.4 $\pm$ 6.9	< 0.001 *	0.53
Dmean (Gy)	18.3 $\pm$ 4.1	23.7 $\pm$ 5.2	< 0.001 *	0.55
DELIVERY EFFICIENCY				
Monitor units (MU/fraction)	782 $\pm$ 98	1,124 $\pm$ 142	< 0.001 *	0.78
Beam-on time (min)	3.2 $\pm$ 0.5	8.7 $\pm$ 1.2	< 0.001 *	0.83

Abbreviations: HI = homogeneity index (D2/D98); MU = monitor units. * $p < 0.05$ (Mann-Whitney U test, independent samples). Effect size r = rank-biserial correlation coefficient.

Gy ($p=0.015$). Small bowel V45Gy fell from 41.3 $\pm$ 15.6 cm³ to 28.7 $\pm$ 12.4 cm³ ($p=0.003$, $r=0.47$). V15Gy fell from 234.6 $\pm$ 52.8 cm³ to 182.4 $\pm$ 45.3 cm³ ($p<0.001$, $r=0.56$). Bilateral femoral head V30Gy fell from 19.4 $\pm$ 6.9% to 12.8 $\pm$ 5.6% ($p<0.001$, $r=0.53$). All OAR reductions had medium-to-large effect sizes ($r\geq 0.36$).

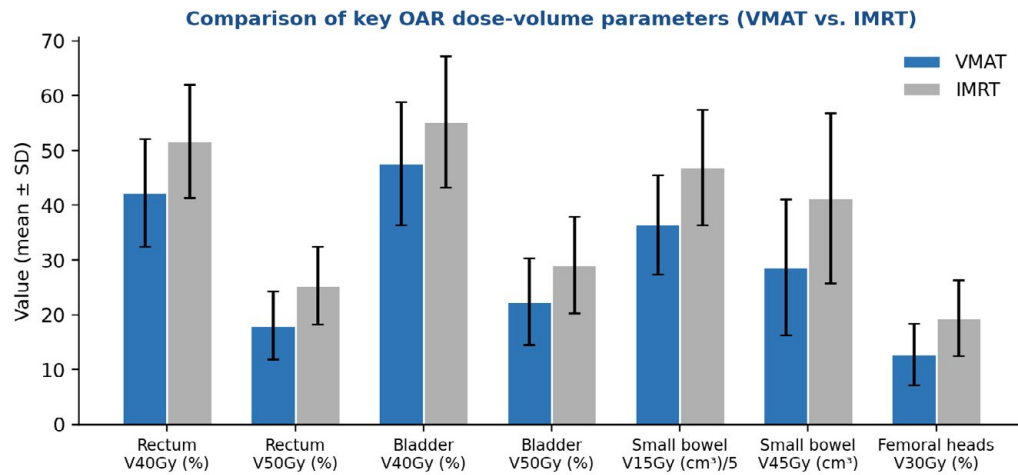
Delivery Efficiency

VMAT delivery was more efficient than IMRT. Mean MU per fraction was 782 $\pm$ 98 vs. 1,124 $\pm$ 142 (–30.4%, $p<0.001$, $r=0.78$).

Mean beam-on time was 3.2 $\pm$ 0.5 vs. 8.7 $\pm$ 1.2 minutes (–63.2%, $p<0.001$, $r=0.83$). Over 25 fractions, this is a saving of about 137.5 machine-minutes per patient. This is a planning-level estimate and does not include setup, imaging, or quality-assurance time.

Radiobiological Analysis

Modeled TCP was equivalent between VMAT and IMRT (78.4 $\pm$ 6.2% vs. 76.9 $\pm$ 6.8%, $p=0.38$; (Table 4), (Figure 3)). Modeled NTCP was lower with VMAT for every endpoint. Grade



Small bowel V15Gy divided by 5 for axis scaling; original values reported in Table 2.

Figure 2: Comparison of key OAR dose-volume parameters (mean ± SD), plotted from the values reported in Table 3. Small bowel V15Gy is divided by 5 for axis scaling; original values are in Table 3.

Table 4: Radiobiological comparison using TCP (Poisson-LQ model) and NTCP (LKB model, parameters in Table 1). Significant differences marked with an asterisk (*). Δ (pp) = VMAT minus IMRT.

Radiobiological parameter	VMAT (mean ± SD)	IMRT (mean ± SD)	p-value	Δ (pp)
TCP — Poisson-LQ model (%)	78.4 ± 6.2	76.9 ± 6.8	0.38	+ 1.5
NTCP Rectum — grade ≥ 2 proctitis (%)	8.4 ± 3.1	14.7 ± 4.2	< 0.001 *	- 6.3
NTCP Bladder — grade ≥ 2 cystitis (%)	5.2 ± 2.4	9.8 ± 3.3	0.002 *	- 4.6
NTCP Small bowel — grade ≥ 2 enteritis (%)	11.3 ± 4.7	18.6 ± 5.9	< 0.001 *	- 7.3
NTCP Femoral heads — grade ≥ 2 necrosis (%)	1.8 ± 0.9	4.3 ± 1.6	0.001 *	- 2.5

Abbreviations: TCP = tumor control probability; NTCP = normal tissue complication probability; LQ = linear-quadratic; LKB = Lyman-Kutcher-Burman; pp = percentage points. * p < 0.05 (Mann-Whitney U test).

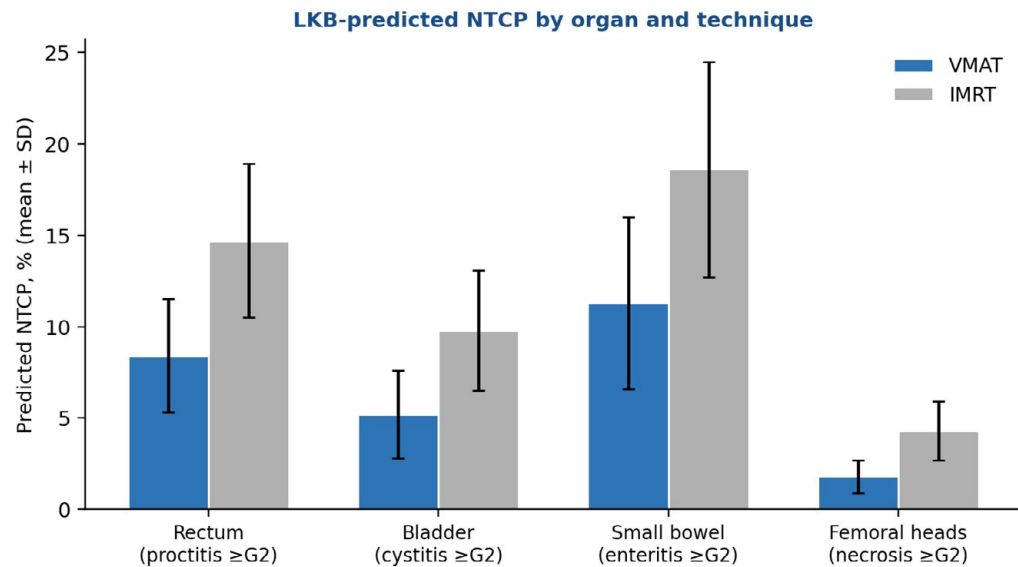


Figure 3: LKB-predicted NTCP by organ and technique (mean ± SD), plotted from Table 4. Values are model estimates based on the literature-derived parameters in Table 1, not directly measured complication rates.

≥2 proctitis NTCP was 8.4±3.1% vs. 14.7±4.2% (Δ=-6.3 pp, p<0.001). Grade ≥2 cystitis NTCP was 5.2±2.4% vs. 9.8±3.3% (Δ=-4.6 pp, p=0.002). Grade ≥2 enteritis NTCP was 11.3±4.7% vs. 18.6±5.9% (Δ=-7.3 pp, p<0.001). Grade ≥2 femoral head necrosis NTCP was 1.8±0.9% vs. 4.3±1.6% (Δ=-2.5 pp, p=0.001).

DISCUSSION

To our knowledge, this is among the first dosimetric and radiobiological comparisons of VMAT and IMRT for LACC conducted in Morocco. A smaller Moroccan series recently

reported 3D-CRT, IMRT, and VMAT dosimetry in ten patients treated on a different linac platform with a Monte Carlo dose engine, but did not include radiobiological modeling [19]; our cohort is larger, uses Acuros XB dose calculation, and adds TCP/NTCP modeling, so the two studies should be compared with these differences in mind rather than treated as directly equivalent. In our data, VMAT reduced dose to every evaluated pelvic OAR, with medium-to-large effect sizes for the rectum, bowel, and femoral heads, while target coverage remained unaffected. These dosimetric gains should nonetheless be interpreted with the limitations of a single-center, retrospective, modest-sized study in mind.

Rectal dose reductions in our cohort (V40Gy: -9.4 pp; V50Gy: -7.3 pp; Dmean: -4.5 Gy) are consistent with prior reports; a systematic review by Yin et al. [7] found pooled rectal Dmean reductions of 3–8 Gy with VMAT across 11 studies, and our results fall within that range. The 12.6 cm³ reduction in small bowel V45Gy (p=0.003) may also be clinically relevant, since severe acute GI toxicity can interrupt concurrent chemoradiotherapy—a risk that may be greater where nutritional reserve or supportive care access is limited.

Bladder sparing was significant but more modest than rectal or bowel sparing, which fits with the anatomy involved: the posterior bladder wall lies close to the cervical CTV, especially when parametrial disease is bulky, and this geometric proximity limits achievable sparing with any IMRT-based technique.

The femoral head dose reduction (V30Gy: 12.8% vs. 19.4%, Δ =-6.6 pp, r =0.53) deserves comment. Radiation-induced femoral head necrosis is uncommon (lifetime incidence 3–10%). It is nonetheless a disabling late complication. Many Moroccan LACC patients are pre- or peri-menopausal, and some receive concurrent hormonal therapy. A lower femoral head dose may therefore carry real clinical value, even though absolute predicted NTCP is low.

The radiobiological analysis adds to prior, purely dosimetric comparisons, but it has an important limitation. As noted in the Methods, the LKB parameters in Table 1 come from the literature rather than from our own outcome data, so the absolute NTCP and TCP figures remain estimates rather than measured

complication rates. We consider the relative comparison between VMAT and IMRT, computed under the same set of assumptions for both arms, more robust than any single absolute value, and it is the main basis for our conclusions.

VMAT also reduced monitor units (-30.4%) and beam-on time (-63.2%), which could carry workflow implications for centers with limited LINAC capacity, a common constraint in North Africa. A shorter mean delivery time per fraction could, in principle, free up machine time, although total daily patient throughput also depends on setup, imaging, and quality-assurance steps that fall outside the scope of this analysis. Any estimate of added daily capacity should therefore be treated as indicative only, not as a guaranteed operational gain.

Several limitations should be noted. The retrospective, non-randomized design may carry selection bias. The sample size, while larger than some prior series, remains modest for subgroup analyses. Contouring was performed by a single observer, so inter-observer variability could not be assessed. LKB parameters were not specific to this population. No clinical toxicity or quality-of-life data were available to validate the modeled NTCP estimates.

CONCLUSIONS

In this Moroccan cohort of patients with LACC, VMAT reduced dose to the rectum, bladder, small bowel, and femoral heads while keeping PTV coverage equivalent to IMRT. Radiobiological modeling showed comparable tumor control (TCP) between techniques, together with lower predicted normal-tissue complication probabilities (NTCP) across all evaluated organs at risk with VMAT. VMAT also reduced monitor units and beam-on time relative to IMRT.

These findings support a preference for VMAT in this clinical setting, where it is available. They do not, on their own, establish VMAT as a mandatory standard of care. The retrospective design, modest sample size, single-center setting, and use of literature-derived NTCP parameters all limit generalization. Prospective studies with clinical toxicity outcomes, quality-of-life data, and independently validated radiobiological parameters are needed to confirm these findings.

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