M.PHIL. RESEARCH PRESENTATION | MEDICAL PHYSICS

Dosimetric and Radiobiological Comparison of 3DCRT, IMRT and VMAT

in Post-Operative Prostate Cancer Radiotherapy

Muhammad Waseem Sajjad

M.Phil. Physics (Medical Physics) | 2024–2026
Supervisor: Dr. Gul Naz | Institute of Physics, The Islamia University of Bahawalpur

M.PHIL. VIVA VOCE

CANDIDATE PROFILE

Academic Background & Clinical Training

M.Phil. Physics — Medical Physics

The Islamia University of Bahawalpur
2024–2026

BS Physics

Emerson College, Bahauddin Zakariya University (BZU)
2019–2024

Research Internship — BINO

Bahawalpur Institute of Nuclear Medicine & Oncology
02 Sep 2025 – 30 Apr 2026

CLINICAL & TECHNICAL EXPOSURE

- Eclipse Treatment Planning System; 3DCRT and IMRT workflows
- Radiotherapy, dosimetry, daily QA and radiation safety
- CT image quality, DICOM/PACS and IndoQCT
- Tools: Excel, Word, PowerPoint, Python, C++ and Arduino

INTRODUCTION

Study Background & Rationale

Radiotherapy

Uses ionizing radiation to damage tumour-cell DNA while limiting dose to surrounding normal tissues.

Planning challenge

The prostate is close to the rectum, bladder and femoral heads; target coverage must be balanced against organ-at-risk (OAR) dose.

Why compare techniques?

3DCRT, IMRT and VMAT use different beam arrangements and intensity modulation, which can change dose distribution and predicted biological effects.

Research question

Which technique provides the most favourable balance between planning-target-volume (PTV) coverage, OAR sparing and model-based radiobiological outcomes?

STUDY AIM

Aim & Objectives

OVERALL AIM

To compare the dosimetric and radiobiological performance of 3DCRT, IMRT and VMAT in post-operative prostate cancer radiotherapy.

01 Target evaluation

Compare PTV coverage, dose homogeneity and conformity.

02 OAR evaluation

Assess rectum, bladder and left/right femoral-head doses using DVH parameters.

03 Radiobiological evaluation

Compare target EUD and TCP, and OAR NTCP using the LKB model.

TREATMENT TECHNIQUES

Techniques Compared in This Study

Technique	Planning approach	Beam arrangement	Key feature
3DCRT	Forward planning	5 fixed fields	Conformal fields; nearly uniform intensity
IMRT	Inverse planning	7 fixed beams	Intensity varies within each field
VMAT	Inverse planning	2 full arcs	Gantry rotates; MLC and dose rate vary dynamically

Common treatment-planning platform

Varian TrueBeam LINAC | 15 MV photons | AAA dose-calculation algorithm

All three techniques were planned for the same patients using the same CT data and contours.

METHODS

Study Design & Planning Workflow

01 10 patients

Retrospective paired comparison

02 CT & contouring

PTV, rectum, bladder and both femoral heads

03 Treatment planning

3DCRT, IMRT and VMAT for each patient

04 Prescription

76 Gy in 38 fractions (2 Gy/fraction)

05 DVH extraction

Target and OAR dose-volume parameters

06 Analysis

Dosimetry, EUD, TCP, NTCP and statistics

Each patient served as their own control, reducing inter-patient anatomical variation.

EVALUATION

Dosimetric & Radiobiological Endpoints

PTV metrics

D2%, D50%, D95%, D98%, Dmean, Dmax
Homogeneity index (HI)
Conformity index (CI)

OAR metrics

Rectum: Dmean, V50, V65, V75
Bladder: Dmax, Dmean, V50–V70
Femoral heads: Dmax and Dmean

Biological models

EUD: equivalent uniform dose
TCP: tumour control probability
NTCP: Lyman–Kutcher–Burman model

Statistical analysis

- One-way ANOVA for PTV parameters; repeated-measures ANOVA for OAR dosimetry.
- Friedman test for radiobiological indices; Cohen's d for pairwise effect size.
- Statistical significance: $p < 0.05$.

RESULTS

PTV Dosimetry: Modulated Plans Improved Uniformity

Parameter	3DCRT	IMRT	VMAT	p-value
D2% (Gy)	81.87	77.83	77.19	<0.0001
D95% (Gy)	72.12	73.65	73.60	0.0036
Dmean (Gy)	78.49	74.50	74.37	<0.0001
HI (lower is better)	0.15	0.09	0.08	<0.0001
D98% (Gy)	70.27	73.52	70.09	0.1843

Main finding

IMRT and VMAT reduced hot spots and improved dose homogeneity.

Interpretation

D95% increased; D98% showed no statistically significant difference.

HI improved from 0.15 (3DCRT) to 0.09 (IMRT) and 0.08 (VMAT).

RESULTS

OAR & Radiobiological Findings

Endpoint	3DCRT	IMRT	VMAT
Rectum V75 (%)	3.69	1.39	0.88
Bladder Dmax (Gy)	80.75	78.83	78.20
Bladder Dmean (Gy)	27.50	39.42	37.77
Left femoral Dmean (Gy)	27.46	17.62	14.27

Biological index	3DCRT	IMRT	VMAT
PTV TCP (%)	65.15	95.13	98.05
Bladder NTCP (%)	0.20	0.088	0.086
Rectum NTCP (%)	1.93	29.67	27.68
Femoral NTCP (R/L)	2.36 / 2.16	0.017 / 0.007	0 / 0

Potential advantages

VMAT reduced rectal V75, bladder Dmax and femoral-head doses; modelled TCP was highest.

Important trade-offs

Bladder mean dose increased, and modelled rectal NTCP was higher with IMRT/VMAT.

Radiobiological values are model-based estimates and require cautious interpretation.

CONCLUSION

Key Findings

- IMRT and VMAT produced more homogeneous PTV dose distributions than 3DCRT.
- VMAT showed favourable high-dose OAR sparing and the highest modelled TCP.
- Higher bladder mean dose and rectal NTCP remain important trade-offs.
- For this dataset, VMAT offered the best overall balance, followed by IMRT.

Limitations: 10-patient retrospective dataset, model-dependent radiobiology and no clinical outcome validation.

Thank You | Questions?