Dosimetric Comparison Of Rapidarc Dynamic and Rapidarc for Prostate Cancer: A Paired Planning Study

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ABSTRACT

This study compared RapidArc Dynamic (RAD) with conventional RapidArc (RA) for prostate cancer radiotherapy, focusing on organ-at-risk sparing, target dose quality, and delivery efficiency. Seven patients were replanned using four RAD configurations—1arc1S, 1arc3S, 1arc5S, and 3arc1S—and a conventional three-full-arc RA technique. Dose–volume histogram parameters for the rectum, bladder, and bowel were evaluated. Target quality was assessed using conformity index (CI) and homogeneity index (HI), while total monitor units and beam-on time were analyzed as efficiency parameters.

Averaged RAD performance was compared with RA, followed by post hoc pairwise comparisons of individual RAD configurations. RA achieved significantly lower Rectum V70Gy ($p = 0.020$) and Bowel D0.1cc ($p = 0.018$) than averaged RAD. Among RAD configurations, 3arc1S demonstrated significantly improved PTV70 conformity ($p = 0.006$) and homogeneity ($p = 0.021$), with rectal and bladder sparing comparable to RA. RAD also significantly reduced beam-on time ($p < 0.001$), although total monitor units differed modestly ($p = 0.031$).

Overall, RAD provided dosimetric performance comparable to RA with improved delivery efficiency. The 3arc1S configuration offered the most favorable balance of target quality, organ-at-risk sparing, and treatment time, supporting its clinical feasibility for prostate cancer radiotherapy.

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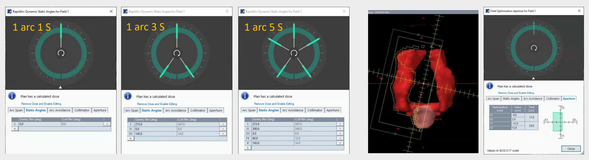
INTRODUCTION

RapidArc Dynamic (RAD) extends conventional RapidArc by integrating dynamic collimator rotation, static-angle modulated ports, and simultaneous optimization of arc and static components. These additional degrees of freedom may enhance organ-at-risk (OAR) sparing while preserving target coverage. Previous studies in breast, cervical, and multi-site radiotherapy have reported favorable dosimetric outcomes and potential efficiency gains.

However, prostate-specific evidence remains limited, and the optimal RAD configuration is unclear. This study compares multiple RAD arrangements with conventional RapidArc using rectal, bladder, and bowel dose–volume parameters, target conformity and homogeneity, monitor units, and beam-on time to determine whether RAD can improve OAR sparing while maintaining acceptable target quality and delivery efficiency.

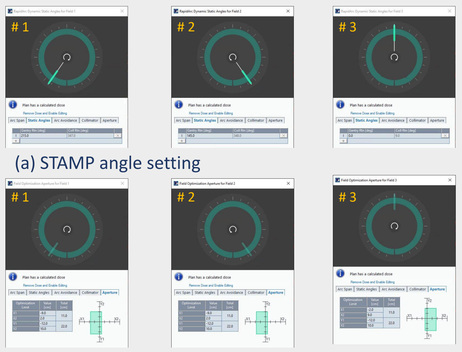
METHODS AND MATERIALS

Seven patients with prostate cancer underwent paired replanning using four RapidArc Dynamic (RAD) configurations—one arc with one, three, or five static angle-modulated ports (STAMPs; 1arc1S, 1arc3S, and 1arc5S) and three arcs with one STAMP (3arc1S)—and a conventional three-full-arc RapidArc (RA) plan. The beam arrangement for the one-arc RAD configurations is illustrated in Figure 1, while the three-arc RAD configuration is shown in Figure 2. All plans used identical anatomy, target volumes, organs at risk, prescription doses, and institutional planning objectives. Target quality was evaluated using the conformity index (CI) and homogeneity index (HI) for PTV70 and CI for PTV50.4. Rectal, bladder, and bowel dose–volume parameters, total monitor units, and beam-on time were also assessed. Averaged RAD outcomes were compared with RA using the Friedman test, followed by post hoc pairwise comparisons between each RAD configuration and RA to identify configuration-specific dosimetric and delivery-efficiency differences.



(a) STAMP angle setting (b) Aperture setting

Figure 1. Beam configuration of RAD with one arc.



(a) STAMP angle setting

(b) Aperture setting

Figure 2. Beam configuration of RAD with three arcs.

RESULTS

Compared with averaged RAD configurations, conventional RA significantly reduced Rectum V70Gy (3.60% vs. 3.70%, $p = 0.020$), Rectum V65Gy (10.07% vs. 10.42%, $p = 0.042$), and Bowel D0.1cc (52.70 vs. 53.23 Gy, $p = 0.018$), whereas Rectum V60Gy, Rectum V30Gy, Bowel V50Gy, and bladder parameters were comparable (Table 1). Averaged RAD achieved better PTV70 conformity than RA (CI: 0.88 vs. 0.86, $p = 0.004$), while RA showed slightly better PTV70 homogeneity and PTV50.4 conformity.

Configuration-specific results are summarized in Table 2. The 3arc1S configuration achieved the highest PTV70 CI (0.89, $p = 0.006$), lowest HI (0.064, $p = 0.021$), and lowest MU (805), while maintaining rectal and bladder sparing comparable to RA. Figure 3 displays median and interquartile distributions across all five techniques, illustrating consistent interpatient trends, limited overlap for beam-on time, and configuration-dependent variation in OAR doses and target indices. Lower boxplot values indicate improved OAR sparing and efficiency, whereas higher CI values indicate better conformity. RAD markedly shortened beam-on time (109.70 vs. 180.24 s, $p < 0.001$). Figure 4 demonstrates a representative case with isodose distribution of 3arc1S and RA.

	averaged RAD	RA	p value	Interpretation
Rectum V70Gy (%)	3.70 (3.62–4.16)	3.60 (2.85–4.33)	0.020	RA better at high-dose rectal sparing
Rectum V65Gy (%)	10.42 (10.18–10.85)	10.07 (9.65–10.32)	0.042	RA superior at intermediate dose
Rectum V60Gy (%)	15.57 (14.72–15.67)	14.96 (14.63–15.19)	0.084	No significant difference
Rectum V30Gy (%)	48.69 (47.13–51.42)	51.31 (48.85–51.60)	0.070	No significant difference
Bladder V70Gy (%)	4.42 (2.65–6.37)	4.93 (2.90–6.62)	0.090	No significant difference
Bladder V65Gy (%)	8.47 (5.32–11.54)	8.71 (5.43–11.43)	0.085	No significant difference
Bladder V60Gy (%)	11.53 (7.37–15.27)	11.69 (7.49–15.26)	0.111	No significant difference
Bladder V30Gy (%)	46.21 (41.35–50.19)	45.91 (41.79–47.77)	0.078	No significant difference
Bowel V50Gy (%)	3.42 (2.02–4.30)	3.29 (1.75–4.02)	0.064	No significant difference
Bowel D0.1cc (Gy)	53.23 (53.11–53.41)	52.70 (52.65–53.12)	0.018	RA better at high-dose bowel sparing
CI PTV70	0.88 (0.85–0.89)	0.86 (0.84–0.89)	0.004	RAD superior conformity
HI PTV70	0.07 (0.07–0.07)	0.06 (0.06–0.08)	0.027	RA better homogeneity
CI PTV50.4	0.73 (0.65–0.76)	0.75 (0.64–0.78)	0.002	RA superior elective conformity
Total MU	820.84 (805.92–829.48)	812.91 (802.50–823.50)	0.031	RA more efficient
Beam-on time (s)	109.70 (108.05–109.99)	180.24 (180.24–180.24)	<0.001	RAD markedly shorter

Table 1. Comparison between average RAD configurations and RapidArc for prostate cancer (n = 7)
p values derived from Friedman test for repeated measures.
Values are presented as median (25%–75%).

	1arc1S	1arc3S	1arc5S	3arc1S	RA	p value	Interpretation
Rectum V70Gy (%)	3.78 (3.60–4.22)	3.75 (3.58–4.19)	3.72 (3.52–3.92)	3.68 (3.50–3.90)	3.60 (2.85–4.33)	0.031	3arc1S and RA lowest
Rectum V65Gy (%)	10.62 (10.2–11.1)	10.54 (10.0–10.9)	10.47 (9.85–11.18)	10.33 (9.70–10.75)	10.07 (9.65–10.32)	0.042	RA best
Rectum V60Gy (%)	15.81 (15.2–16.4)	15.74 (15.0–16.0)	15.57 (14.7–15.7)	15.32 (14.8–15.6)	14.96 (14.63–15.19)	0.084	No significant difference
Rectum V30Gy (%)	49.8 (47.5–52.1)	49.2 (46.9–51.7)	48.7 (47.1–51.4)	47.9 (46.8–50.2)	51.3 (48.9–51.6)	0.070	No significant difference
Bladder V70Gy (%)	4.80 (3.0–6.8)	4.55 (2.9–6.5)	4.42 (2.65–6.37)	4.35 (2.6–6.1)	4.93 (2.9–6.62)	0.090	No significant difference
Bladder V65Gy (%)	8.95 (5.7–12.1)	8.71 (5.4–11.8)	8.47 (5.3–11.5)	8.20 (5.1–11.0)	8.71 (5.43–11.43)	0.085	No significant difference
Bladder V60Gy (%)	12.2 (8.1–15.8)	11.9 (7.7–15.4)	11.53 (7.37–15.27)	11.40 (7.3–14.8)	11.69 (7.49–15.26)	0.111	No significant difference
Bladder V30Gy (%)	47.5 (42.8–51.0)	46.8 (42.1–50.2)	46.21 (41.35–50.19)	45.8 (41.0–49.7)	45.91 (41.79–47.77)	0.078	No significant difference
Bowel V50Gy (%)	3.49 (2.0–4.3)	3.47 (2.03–4.34)	3.38 (2.05–4.34)	3.35 (2.01–4.21)	3.29 (1.75–4.02)	0.064	No significant difference
Bowel D0.1cc (Gy)	53.36 (53.24–53.48)	53.42 (53.14–53.58)	53.30 (53.20–53.50)	52.98 (52.79–53.05)	52.70 (52.65–53.12)	0.018	RA best high-dose bowel sparing
CI PTV70	0.86 (0.84–0.88)	0.87 (0.85–0.89)	0.88 (0.85–0.89)	0.89 (0.86–0.90)	0.86 (0.84–0.89)	0.006	3arc1S highest conformity
HI PTV70	0.070 (0.067–0.073)	0.068 (0.065–0.071)	0.067 (0.064–0.070)	0.064 (0.061–0.067)	0.066 (0.062–0.070)	0.021	3arc1S best homogeneity
CI PTV50.4	0.71 (0.65–0.75)	0.72 (0.66–0.76)	0.73 (0.65–0.76)	0.74 (0.67–0.78)	0.75 (0.64–0.78)	0.002	RA superior
Total MU	845 (830–860)	832 (818–845)	821 (806–835)	805 (790–818)	813 (802–824)	0.031	3arc1S lowest MU
Beam-on time (s)	145 (140–150)	132 (128–135)	121 (118–124)	110 (108–112)	180 (180–180)	<0.001	RAD markedly shorter

Table 2. Dosimetric comparison of RapidArc Dynamic configurations and RapidArc for prostate cancer (n = 7)
p values derived from post-hoc pairwise comparison for repeated measures.
Values are presented as median (25%–75%).

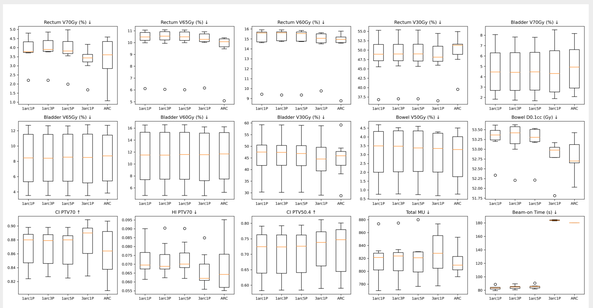


Figure 3. Boxplots showing median (IQR) organ-at-risk doses, target conformity, and planning efficiency across five prostate radiotherapy planning techniques (n = 7). Lower values indicate improved sparing and efficiency, whereas higher values indicate improved conformity. Friedman test was used for repeated-measures comparisons.

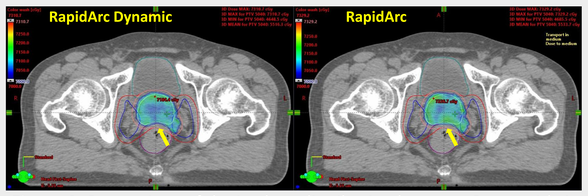


Figure 4. Comparison of the isodose distribution between 3 arcs with 1 STAMPs RapidArc Dynamic (RAD) and RapidArc (RA) plans for a prostate cancer. The cyan, orange, blue and red lines represent the prostate CTV, prostate PTC, pelvic lymphatic CTV and pelvic lymphatic PTV. Color wash represents the 70 Gy isodose.

DISCUSSION

RAD achieved dosimetric performance broadly comparable to conventional RA, but its advantages were configuration dependent. RA provided modest benefits for selected high-dose OAR endpoints, particularly Rectum V70Gy and Bowel D0.1cc. Conversely, the 3arc1S configuration improved PTV70 conformity and homogeneity while preserving rectal and bladder sparing comparable to RA. RAD also substantially shortened beam-on time, with only small differences in total monitor units. These findings support prior reports that RAD can maintain target coverage and improve selected dosimetric or efficiency outcomes, although performance varies with anatomy and beam arrangement. Overall, RAD should not be considered universally superior to RA. Among the tested configurations, 3arc1S offered the best balance of target quality, OAR sparing, and delivery efficiency, supporting its potential as a clinically feasible alternative for prostate radiotherapy. Larger studies are needed to confirm these findings.

CONCLUSIONS

RAD demonstrated dosimetric performance comparable to conventional RA, with configuration-dependent trade-offs. The 3arc1S configuration provided the most favorable balance, improving PTV70 conformity, dose homogeneity, and delivery efficiency while maintaining comparable rectal and bladder sparing. RA remained superior for selected high-dose rectal and bowel parameters. RAD, particularly 3arc1S, may therefore represent a clinically feasible alternative for prostate cancer radiotherapy, although validation in larger cohorts is required.

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