RETROSPECTIVE DVH-BASED COMPARISON OF SCHEDULED AND ADAPTED VARIAN ETHOS PLANS IN PELVIC ONLINE ADAPTIVE RADIOTHERAPY

A. Vlaykov[1], I. Iliev[1]

[1]St. Ivan Rilski Hospital, Plovdiv, Bulgaria

Abstract- **This retrospective DVH based study compared daily scheduled vs adapted Varian Ethos plans in pelvic online adaptive radiotherapy. Thirty patients contributed 359 paired fractions; the primary target analysis included 29 patients and 351 fractions with complete initial plan, scheduled plan, and adapted plan values. For them the treatment planning system reported a dose covering 90% of the planning target volume (PTV D90). Scheduled and adapted PTV D90 values were normalized to the corresponding initial plan PTV D90. Operational target benefit was defined as either recovery from less than 95% to more than or equal to 95% of the initial plan value or an improvement of more than or equal to 2.0 percentage points if the scheduled value was already more than or equal to 95%; these thresholds were relative to the initial plan PTV D90, not prescribed dose. Fraction level results were summarized only. Patient level inference results used each patient's median from the adapted plans minus the scheduled plan and a two sided Wilcoxon signed rank test by treatment site. Overall, 56.41% of the fractions meet the target benefit definition. 8.83% showed deterioration of more than 1 percentage point. Patient level median differences were +2.95 percentage points for prostate (12 patients; p=0.00049), +1.53 for bladder (5 patients; p=0.3125), and +2.00 for rectal cases (12 patients; p=0.00195). Benefit occurred in 65.88%, 47.46%, and 47.62% of fractions, respectively; deterioration occurred in 2.35%, 19.49%, and 6.35%. Secondary organ at risk analyzes were descriptive. Patient level differences were statistically significant for the prostate and rectal cohorts but not for the smaller, more heterogeneous bladder cohort. A DVH framework can be used for a retrospective audit when full DICOM image and CBCT data is unavailable.**

Keywords- **Online adaptive radiotherapy, Varian Ethos, DVH, scheduled plan, adapted plan, pelvic radiotherapy, PTV D90.**

I. INTRODUCTION

Uncertainty due to interfractional variation of a patients' internal anatomy is a persistent challenge for pelvic radiotherapy. The degree of bladder/rectal filling; position of the target; and overall patient geometry will affect both target coverage and dose to OARs when the treatment plan developed for the original planning CT scan is applied through out treatment. Image guided radiotherapy provides a means to reduce errors associated with the placement of a patient on a radiotherapy couch. Couch corrections cannot however account for the internal deformation of the OAR's and PTV from one day to another.

Cone Beam Computed Tomography (CBCT) is used in conjunction with online adaptive radiotherapy (oART) to address these issues. The CBCT is performed prior to each treatment session to assess the anatomical position of the OAR's and PTV. An optimized treatment plan is then generated based upon the CBCT obtained immediately prior to the delivery of radiation. This method of oART has been referred to as "Varian Ethos" workflow. The scheduled plan refers to the unadapted version of the reference plan delivered to the current anatomical position. The adapted plan is an optimized version of the reference plan which accounts for changes in anatomy as determined by the CBCT. Comparisons of planned parameters between scheduled and adapted plans represent decisions made by physicians, physicists, and/or radiation therapists during each treatment session [3-5].

There have been many studies demonstrating clinical benefits of oART for prostate cancer and other sites within the pelvis. Although oART may provide a substantial advantage over standard radiotherapy in terms of dose distribution, there are several challenges associated with implementing this technology into routine practice. One major concern is the time it takes to adapt a treatment plan after completion of the CBCT. Another issue is that it may not be possible or necessary to adapt all treatment plans. Additionally, even if oART appears to produce superior results during each individual treatment session, a patient-level assessment of whether such results persist across multiple fractions is needed.

Finally, obtaining complete DICOM images for reconstruction and dose accumulation is difficult. As a result, some studies rely solely on DVH data. While a DVH-based-only study can still be useful for determining the ultimate dosimetric effects of adaptations, there should be clear definitions regarding its scope and limitations.

This study compares the dosimetry of adapted versus scheduled plans for patients undergoing radiotherapy for prostate, bladder, and rectum cancers using only DVH data from the Varian Ethos system. The study incorporates patient level statistical testing along with descriptive statistics at the fraction level, and defines an objective measure of target benefit.

II. MATERIALS AND METHODS

Study Design & Data Source

A retrospective clinical dosimetrical evaluation was conducted using individualized Excel files for each patient based on plan checks completed by Mobius3D v4.0.2 for the

first planned, initially scheduled and adapted Varian Ethos plans created at MBAL Medical Complex "St. Ivan Rilski" in Plovdiv, Bulgaria. There were thirty-one individualized files that were assessed for eligibility after which the paired fraction rules were applied to evaluate the pelvic dataset consisting of 30 patients and 359 paired fractions (i.e., thirteen prostate patients [178 fractions], five bladder patients [118 fractions] and twelve rectal patients [63 fractions]).

All evaluations regarding targets and OARs utilized the values as provided by the treatment planning system and captured within the Mobius3D plan check report. No analysis was performed utilizing the values provided by Mobius3D to recalculate dose or gamma results. The available dataset also did not contain CT, CBCT or synthetic CT image series; RTPLAN, RTDOSE or RTSTRUCT objects; automatically created or edited contours; deformation registration fields or cumulative dose. Therefore, the study only analyzed the exported final DVH values without attempting independent image registration, contour verification, dose calculation or dose accumulation.

Plan States and Paired Fraction Structure

Each analytic row included information for one patient and one treatment fraction along with values for the scheduled and adapted plans compared side-by-side as a paired comparison. The initial plan remained in the same row as the patient-specific reference values. However, comparisons made against the initial plan were utilized solely for normalizing and providing context for the interpretations of the comparisons made between the scheduled plan and adapted plan.

Primary Target Analysis Subset

The primary target analysis subset required complete initial, scheduled and adapted plan values be present for PTV D90 which is defined as the treatment planning system reported dose covering ninety percent (90%) of the PTV. For this reason, one prostate patient who contributed eight paired fractions lacked sufficient PTV D90 data to compare normalized and thus was excluded from only the normalized primary target analysis. Therefore, this subset consisted of 29 patients and 351 paired fractions: 12 prostate patients / 170 fractions, 5 bladder patients / 118 fractions, and 12 rectal patients / 63 fractions (See Fig. 1).

Primary target metric and benefit definitions

The continuous results of interest for each pair of fractions, scheduled and adapted PTV D90 values were normalized to the patient-specific original plan PTV D90. The main continuous outcome was the difference in the normalized PTV D90 adapted versus scheduled, given as a percentage difference. A positive delta indicated an increased PTV D90 through adaptation.

$$Scheduled\ normalized\ PTV\ D90 = 100 \times \frac{PTV\ D90\ (scheduled)}{PTV\ D90\ (original)}$$

$$Adapted\ normalized\ PTV\ D90 = 100 \times \frac{PTV\ D90\ (adapted)}{PTV\ D90\ (original)}$$

$$Delta\ PTV\ D90 = adapted\ normalized\ PTV\ D90 - scheduled\ normalized\ PTV\ D90$$

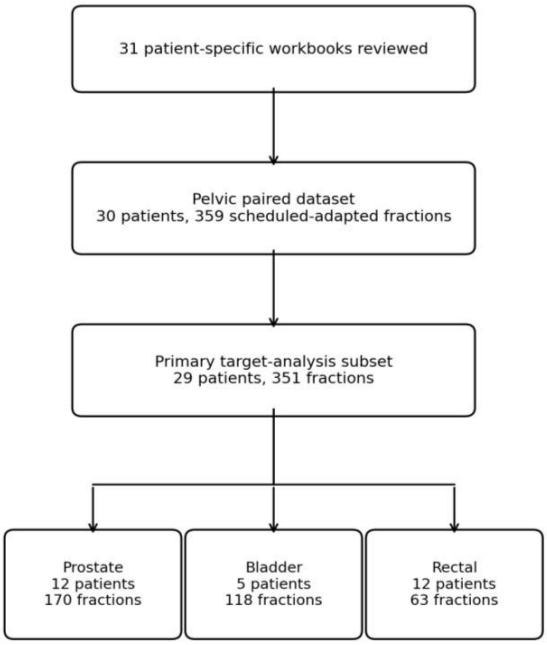

Fig. 1 Cohort derivation and primary target analysis subset.

Clinical interpretation rules

A treatment fraction was considered to have achieved its operational target benefits when one of two conditions were satisfied. The reference recovery rule consisted of the condition that both the scheduled normalized PTV D90 was less than 95% and the adapted normalized PTV D90 was greater than or equal to 95%. The additional benefit rule would apply if the scheduled normalized PTV D90 was already greater than or equal to 95%, and then the adapted plan resulted in a gain in this parameter of at least 2.0 percentage points. Target deterioration was identified when the adapted plan had a loss of more than 1.0 percentage point compared with the scheduled normalized PTV D90. This reference recovery threshold of 95% is based upon the patient-specific initial plan's PTV D90 reference; it should not be taken as being equivalent to a typical coverage metric for prescription doses, e.g., PTV D95 > or = 95% of the prescribed dose.

Secondary and treatment site specific were OAR outcomes. The maximum dose values reported by the exporting treatment planning system (TPS) were analyzed. Descriptive summaries were prepared for adapted minus scheduled differences, and dose changes of at least 0.5 Gy were noted whenever possible for the relevant metric. These findings were viewed as descriptive signals due to the fact

that the metrics utilized were maximum dose rather than small volume dose metrics. The determination of whether or not a particular treatment fraction received its operational target benefits was based solely on the primary target benefit criteria and not upon the findings related to OAR.

Statistical analysis

Daily frequencies and magnitudes of adaptive effects were analyzed at a fraction-by-fraction basis so that repeated measurements could be avoided when analyzing patients' responses. Inference regarding individual patients' responses were made using a single representative summary statistic for each patient. For each patient, the median of the adapted minus scheduled differences across all available pairs of fractions was computed, and tested separately for each of three patient groups -prostate, bladder and rectum, using a two-sided Wilcoxon signed rank test. Continuous variable results are provided as medians with inter-quartile range (IQR), while categorical outcome results are presented as counts/percentages. There were no missing values imputed into the statistical analyses, and each metric was analyzed using complete cases only. No pooled inferential test was conducted across treatment sites. Therefore, statistical significance was established at p-value < .05, and there was no need to make adjustments for multiple testing since site-specific p-values will be assessed in conjunction with their respective effect sizes, consistencies and sample sizes.

Ethics and data protection

Approval and permission to perform this independent retrospective study was granted from MBAL Medical complex "st. Ivan rilski", Plovdiv, Bulgaria. Data utilized in this study were derived directly from routine clinical practice and thus did not alter patient selection, planning nor treatment delivery. Patient identifiers were deleted prior to creating the analytical database, and only those variables required for conducting the paired-dose volume histogram (DVH) analysis were included in the analytical database.

III. RESULTS

Cohort and overall target benefit

Overall, there were 351 paired fractions for 29 patients. A total of 198 of these fractions (56.41%), across the three sites, satisfied the definition of an operational target benefit. There were a total of 88 additional benefit fractions (25.07%) and 110 reference recovery fractions (31.34%). Target potential for loss was detected on 31 fractions (8.83%) as well. In addition to being different by site, both the size and rate of the target benefit varied substantially at each of the three sites (Tables 1 and 2; Figure 2).

Table 1. Primary normalized PTV D90 results by treatment site. Fraction level values summarize paired fractions; patient level values summarize within patient median differences. Values are adapted minus scheduled; pp, percentage points.

Treatment site (patients/fractions)	Fraction level difference, pp median (IQR)	Patient level difference, pp median (IQR); p
Prostate (12/170)	3.10 (1.28 to 7.94)	2.95 (2.07 to 6.61) p=0.00049
Bladder (5/118)	1.87 (-0.51 to 3.06)	1.53 (-0.51 to 2.21) p=0.3125
Rectal (12/63)	1.48 (0.00 to 8.49)	2.00 (0.35 to 5.81) p=0.00195

Table 2. Fraction level operational target benefit and potential deterioration. Total benefit comprises reference recovery and additional benefit.

Treatment site	Recovery n (%)	Total benefit n (%)	Potential deterioration n (%)
Prostate	64 (37.65)	112 (65.88)	4 (2.35)
Bladder	27 (22.88)	56 (47.46)	23 (19.49)
Rectal	19 (30.16)	30 (47.62)	4 (6.35)
All	110 (31.34)	198 (56.41)	31 (8.83)

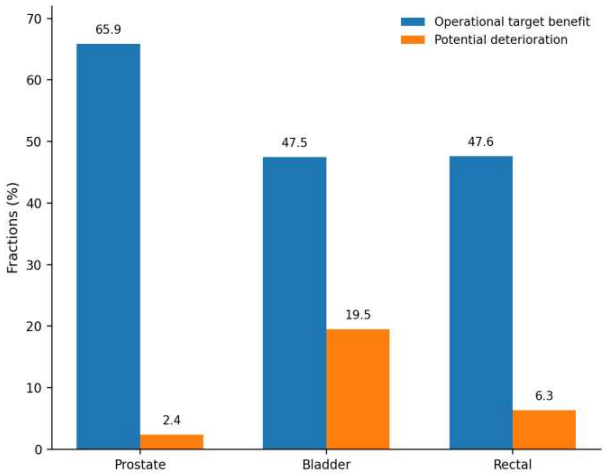

Fig. 2 Fractions meeting the target benefit definition and fractions with potential target deterioration by treatment site.

Prostate

The prostate target analysis used data from 12 patients and 170 fractions. The median normalized PTV D90 at the fraction level for the scheduled and adapted plans was 96.94% and 100.00%, respectively. The median adapted minus scheduled value is +3.10 percentage point (IQR 1.28-7.94) at the fraction level, and at the patient level it is +2.95 percentage points (IQR 2.07-6.61). All 12 patients have a positive median adapted minus scheduled value. The Wilcoxon signed-rank test shows that there is a significant advantage of the adaptive plan over the scheduled plan (p = .00049).

At the operational target levels, the prostate had benefits in 112/170 fractions (65.88%) with 64 being reference recovery fractions (37.65%) and 48 being additional benefit fractions (28.24%). There were potential target deteriorations in 4/170 fractions (2.35%).

Bladder

The bladder target analysis used data from 5 patients and 118 fractions. The median normalized PTV D90 at the fraction level for the scheduled and adapted plans was 98.21% and 99.83%, respectively. At the fraction level, the difference between the scheduled and adapted plans was +1.87 percentage points (IQR -0.51 to 3.06). At the patient level, the difference between the scheduled and adapted plans was +1.53 percentage points (IQR -0.51 to 2.21). Three patients had a positive patient-level median difference, and two had a negative median difference. The test was not statistically different at the $p < .05$ level (.3125).

At the operational target levels, the bladder had benefits in 56/118 fractions (47.46%) with 27 being reference recovery fractions (22.88%) and 29 being additional benefit fractions (24.58%). There were potential target deteriorations in 23/118 fractions (19.49%) which is the greatest number of potential target deteriorations of the three treatment sites.

Secondary analysis using exported treatment planning system maximum dose values demonstrated a median adapted - scheduled difference of -1.05 Gy (IQR -3.40 to .88) for the left femoral head/neck and -2.20 Gy (IQR -4.60 to -.73) for the right. Reductions of at least 0.5 Gy occurred in 66/118 left femoral head observations (55.93%) and 94/118 right femoral head observations (79.66%). Increases of at least 0.5 Gy occurred in 38/118 left femoral head observations (32.20%) and 11/118 right femoral head observations (9.32%), respectively. Thus, the OAR dose reduction signal was greater and more consistent on the right side.

Rectum

The rectum target analysis used data from 12 patients and 63 fractions. The median normalized PTV D90 at the fraction level for the scheduled and adapted plans was 98.52% and 100.00%. The fraction level differences between scheduled and adapted plans were +1.48 percentage points (IQR 0.00 to 8.49) and +2.00 percentage points (IQR .35 to 5.81) at the patient level. All but two of the patients had a positive median difference; those two had no median difference. The Wilcoxon signed-rank test demonstrates a significant advantage of the adaptive plan compared to the scheduled plan ($p = .00195$).

At the operational target levels, the rectum had benefits in 30/63 fractions (47.62%) with 19 being reference recovery fractions (30.16%) and 11 being additional benefit fractions (17.46%). There were potential target deteriorations in four of 63 fractions (6.35%).

Secondary analysis using exported treatment planning system maximum dose values for secondary OAR endpoints were available for eleven patients / fifty-five fractions for rectal dose demonstrating a median difference of -0.10 Gy (IQR -0.245 to .020). Six out of 55 fractions (10.91%) experienced reductions of at least 0.5 Gy, whereas zero experienced increases of at least 0.5 Gy. For ten patients / fifty fractions of bowel maximum dose values, there was a median difference of -0.285 Gy (IQR -0.960 to .065). Forty percent of these fractions had a reduction of at least 0.5 Gy, while ten percent had an increase of at least 0.5 Gy.

IV. DISCUSSION

This research shows that a large portion of the normalised PTV D90s calculated using adapted Varian Ethos plans for all patients are better than the corresponding scheduled normalised PTV D90 values, however this is very treatment site dependent. More than 50% of all treated fractions met the defined operational target benefit. The greatest benefits with the largest amount of consistency occurred with prostate cancer, with all patients experiencing a positive median difference and nearly two-thirds of fractions meeting the target benefit criteria. There was also a significant positive result for patients who received radiation treatments for rectal cancer. Patients who received radiation treatments for bladder cancer experienced a positive average trend, with nearly 50% of fractions resulting in a target benefit; however, there was substantially greater variance per-patient and a larger percentage of fractions resulted in target detriment.

These results support previous studies that have shown that the use of daily adaptations to address interfractional changes in anatomy will restore target coverage and improve plan quality for prostate patients whose original plan has been compromised by changes in anatomy [5, 7, 8] . In addition to demonstrating improved target coverage through the use of adaptations, this study provides a new perspective on how these improvements occur -- specifically that the benefits seen in this study were due to the fact that the median within-patient differences were positive in all 12 prostate patients. The bladder data require a more conservative interpretation. Bladder volumes and shapes can change greatly from fraction-to-fraction and throughout a treatment course [9, 10]; thus, the relationship between target dose and organ-at-risk (OAR) dose sparing may also vary from one fraction-to-another. Although there was not a significant difference for the entire bladder patient population, the group consisted of only five patients and exhibited considerable heterogeneity. The fraction-level data indicate that adaptations resulted in improved normalised target doses for many treatment days; however, they also clearly show that an improvement cannot always be assumed. Therefore, this supports the necessity for reviewing both target and OAR dose metrics on a fraction-by-fraction basis.

There was a significant positive patient level target advantage for patients receiving radiation treatments for rectal cancer. All patients experienced a median within-patient difference that was positive; thus, there was no patient with a negative median difference. The effects were moderate

in terms of magnitude but frequent enough that almost 50% of fractions met the target benefit definition. The secondary OAR analyses indicated a noticeable reduction in maximum bowel-loop dose; however, the reductions in maximum rectum dose were less evident. Unfortunately, these findings are only descriptive due to the limited availability of OAR dose metrics.

One strong aspect of the study methodology is its ability to separate fraction-level questions from patient-level questions. A decision regarding whether to adapt a plan is typically made at the fraction level; therefore, frequency measures are clinically interpretable. If hundreds of fractions were formally tested as if they were independent, then this would create pseudo-replication and result in overly optimistic estimates of precision.

The two-rule definition of target benefit was designed to provide practical interpretability. The reference recovery rule identifies those fractions in which adaptation restored a degraded scheduled plan value back up to the chosen initial plan reference value. The additional benefit rule prevents categorizing of small changes as "meaningful" when the scheduled normalized PTV D90 is near the reference value. Nevertheless, they could potentially serve as useful tools for quality reviews, audits and future prospective studies evaluating potential adaptation triggers [6].

Because the classification is normalized to each patient's original plan (PTV D90), it does not evaluate whether a prescribed treatment protocol meets prescription-based limits, or provides sufficient levels of target coverage for the specific protocol. In addition, because the classification applies binary rules, favorable trends are not always captured — i.e., an appreciable improvement which still falls below the 95% reference value will not be considered "recovery," nor will values near either threshold likely exhibit category shifts due to small numerical fluctuations. Therefore, quantitative comparisons between continuously adapted and scheduled should be analyzed in conjunction with the frequency data reported for the categorizations. No sensitivity analyses were performed using different thresholds than those used above.

The primary limitations of this study stem from its retrospective DVH only design. As such, this study could not examine imaging quality, contour accuracy, deformation registration, synthetic CT accuracy or accumulated delivered dose -- all known sources of uncertainty associated with CBCT guided adaptive radiotherapy (oART) requiring formal quality assurance programs [11-15]. Furthermore, while the number of patients examined was relatively large compared to other similar studies, particularly those examining bladder cancer patients, the number of bladder patients studied was modest; furthermore, treatment prescriptions and target definitions varied among sites; PTV D90 and maximum dose OAR endpoints used in this study were taken directly from structured treatment planning systems exported via Mobius3D without independent DICOM-based verification; point max dose can be sensitive to both contouring and calculation variability; and OAR endpoints were variable and site-specific. Finally, the study did not include clinical outcome data.

While these limitations exist, the dataset presented here includes 351 direct scheduled-adapted target comparisons and permitted every formal statistical conclusion to be related to individual patients instead of artificially inflated counts of fractions.

V. CONCLUSION

This retrospective DVH-based study revealed that the Ethos-plans (which had been adapted) met the operational target/criterion more frequently than the deterioration criterion. The strength and consistency of the differences in the individual case analyses were greatest and most pronounced for prostate cancer. For rectum the differences were statistically significant; however, they varied to a greater degree than those seen for prostate. Differences for bladder cases were much less consistent, and there was no statistical significance. Thus, at the level of dose fractions, an assessment could be made as to when adapted plans would have been advantageous. Conversely, at the level of the individual patient, the consistency of the advantages of using adapted plans could be assessed. While a DVH-only approach has its limitations in terms of replacing actual image data from DICOM images, CBCT, etc., and plan studies; it provides a reasonable means of evaluating/auditing the impact on the final dosimetry of using either scheduled or adapted plans.

VI. DECLARATIONS

Funding: The study received no external project or grant funding.

Conflicts of interest: The authors declare no conflict of interest.

Ethics and data protection: Institutional approval and permission to conduct the independent retrospective analysis were obtained from MBAL Medical Complex "St. Ivan Rilski", Plovdiv, Bulgaria. The study used data generated during routine clinical care and did not alter treatment. Direct patient identifiers were removed before creation of the analytical dataset and were not retained in the analysis.

Acknowledgements: The authors thank MBAL Medical Complex "St. Ivan Rilski", Plovdiv, for granting access to the dosimetric data and permission to conduct the analysis independently.

VII. REFERENCES

1. Stroom JC, Heijmen BJM. Geometrical uncertainties, radiotherapy planning margins, and the ICRU-62 report. Radiotherapy and Oncology. 2002;64(1):75-83.
2. Bujold A, Craig T, Jaffray D, Dawson LA. Image-guided radiotherapy: has it influenced patient outcomes? Seminars in Radiation Oncology. 2012;22(1):50-61.

3. Dona Lemus OM, Cao M, Cai B, Cummings M, Zheng D. Adaptive radiotherapy: next-generation radiotherapy. Cancers. 2024;16(6):1206.
4. Liu H, Schaal DW, Curry H, Clark R, Magliari A, Kupelian PA, et al. Review of cone beam computed tomography based online adaptive radiotherapy: current trend and future direction. Radiation Oncology. 2023;18(1). PMCID: PMC10475190.
5. Byrne M, Archibald-Heeren B, Hu Y, Teh A, Beserminji R, Cai E, et al. Varian Ethos online adaptive radiotherapy for prostate cancer: early results of contouring accuracy, treatment plan quality, and treatment time. Journal of Applied Clinical Medical Physics. 2022;23(1). PMCID: PMC8803282.
6. Yock AD, Ahmed M, Masick S, Morales-Paliza M, Kluwe C, Shinde A, et al. Triggering daily online adaptive radiotherapy in the pelvis: dosimetric effects and procedural implications of trigger parameter-value selection. Journal of Applied Clinical Medical Physics. 2023;24(10). PMCID: PMC10562041.
7. Eckl M, Sarria GR, Springer S, Willam M, Ruder AM, Steil V, et al. Dosimetric benefits of daily treatment plan adaptation for prostate cancer stereotactic body radiotherapy. Radiation Oncology. 2021;16(1). PMCID: PMC8335467.
8. Calvo-Ortega JF, Laosa-Bello C, Moragues-Femenia S, Torices-Caballero J, Pozo-Masso M, Jones A, et al. Online adaptive five-fraction ablative radiotherapy for prostate cancer using a conventional linear accelerator. Practical Radiation Oncology. 2025;15(4):e371-e381.
9. Azzarouali S, Goudschaal K, Visser J, Hulshof M, Admiraal M, van Wieringen N, et al. Online adaptive radiotherapy for bladder cancer using a simultaneous integrated boost and fiducial markers. Radiation Oncology. 2023;18(1). PMCID: PMC10557331.
10. Fischer J, Fischer LA, Bensberg J, Bojko N, Bouabdallaoui M, Frohn J, et al. CBCT-based online adaptive radiotherapy of the bladder: geometrical and dosimetrical considerations compared with conventional IGRT. Radiation Oncology. 2025;20(1). doi:10.1186/s13014-025-02710-y.
11. Zhao X, Stanley DN, Cardenas CE, Harms J, Popple RA. Do we need patient-specific QA for adaptively generated plans? Retrospective evaluation of delivered online adaptive treatment plans on Varian Ethos. Journal of Applied Clinical Medical Physics. 2023;24(2):e13876.
12. Zheng D, Cummings M, Zhang H, Podgorsak A, Li F, Dona Lemus OM, et al. Clinical practice-based failure modes and root cause analysis of cone beam CT-guided online adaptive radiotherapy of the pelvis. Cancers. 2025;17(9):1462.
13. Yoganathan SA, Khemissi A, Paloor S, Hammoud R, Al-Hammadi N. An end-to-end quality assurance procedure for Ethos online adaptive radiotherapy. Journal of Medical Physics. 2025;50(1):140-147.
14. Lavrova E, Garrett MD, Wang Y, Chin C, Elliston CD, Savacool M, et al. Adaptive radiation therapy: a review of CT-based techniques. Radiology: Imaging Cancer. 2023;5(4). PMCID: PMC10413297.
15. Byrne M, Ray X, Kisling K, Archibald-Heeren B, Finnegan R, Luo S, et al. Pelvic dose accumulation accuracy in a CBCT-based online adaptive radiotherapy system. Journal of Applied Clinical Medical Physics. 2025;26(7):e70160.

Contacts of the corresponding author:

Authors: Anton Vlaykov
Institute: St. Ivan Rilski Hospital
City: Plovdiv
Country: Bulgaria
Email: antonvlaykov@gmail.com