
# Adaptive Radiation Therapy

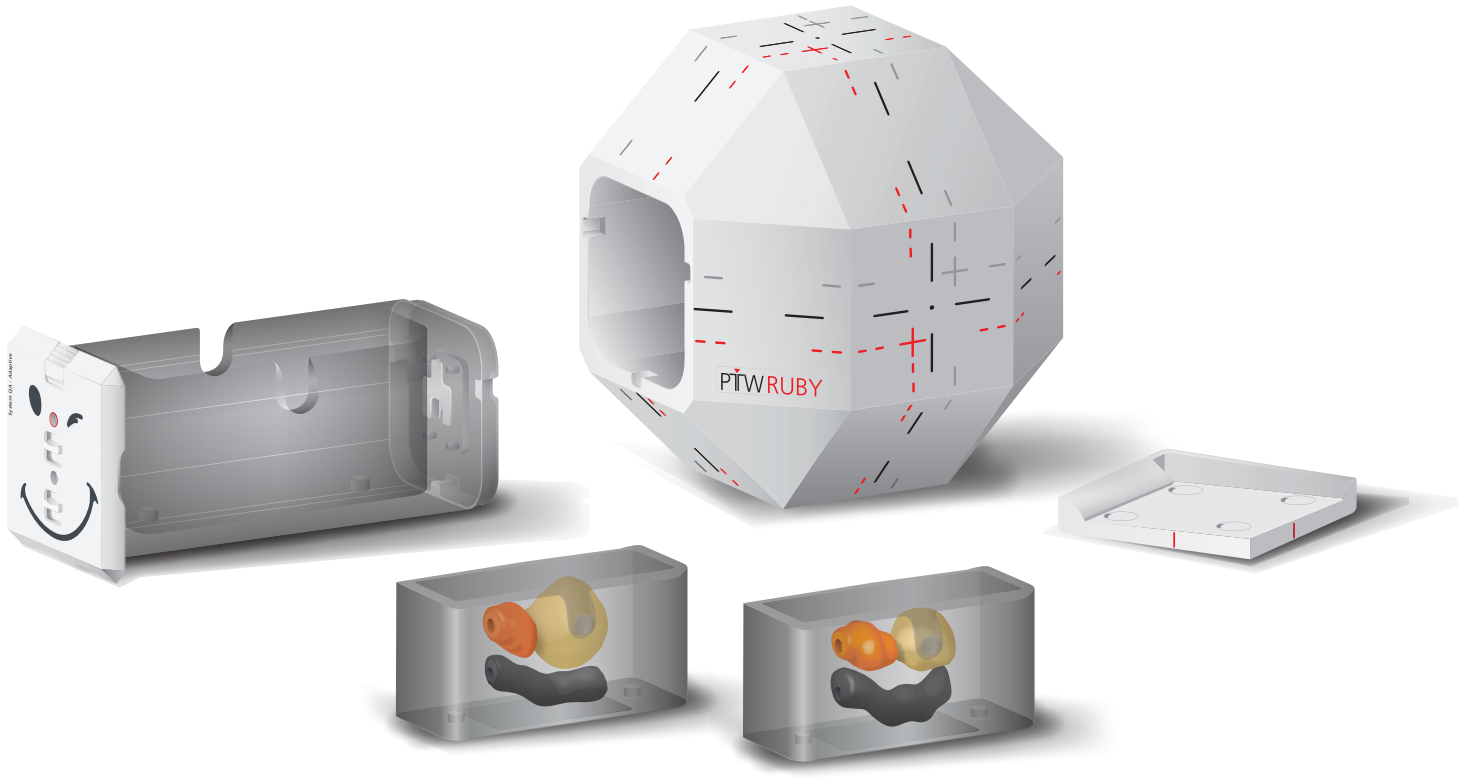
## Applications of the RUBY Phantom for Adaptive Radiation Therapy

PTW THE DOSIMETRY COMPANY

# Introduction

Online adaptive radiation therapy utilizing the Varian ETHOS™ system integrating CBCT, automatic contouring, and plan optimization gained attention recently. ETHOS™ enhances treatment accuracy and reduces radiation exposure to healthy tissues. This advanced technology necessitates quality assurance, including end-to-end tests. In online adaptive therapy, where daily planning is condensed compared to conventional treatments, identifying workflow issues is crucial, as they might not be detected by double-checking alone. With the new RUBY adaptive insert[1], the RUBY phantom is now amended to facilitate end-to-end testing for adaptive therapies.

It offers the possibility of inserting different organ sets and thus positioning anthropomorphic structures in the RUBY phantom. Two organ sets, each with structures of the bladder, prostate and rectum, are available - organ set prostate A and organ set prostate B. The organs are made of high-quality tissue equivalent material. The organ sets differ in terms of the volume of the bladder, rectum and prostate as well as the different shapes. The RUBY adaptive insert also allows a Semiflex 3D ionization chamber to be positioned in each organ. If no chamber is used, the holes can be closed with homogenous plugs so that the organs are complete.

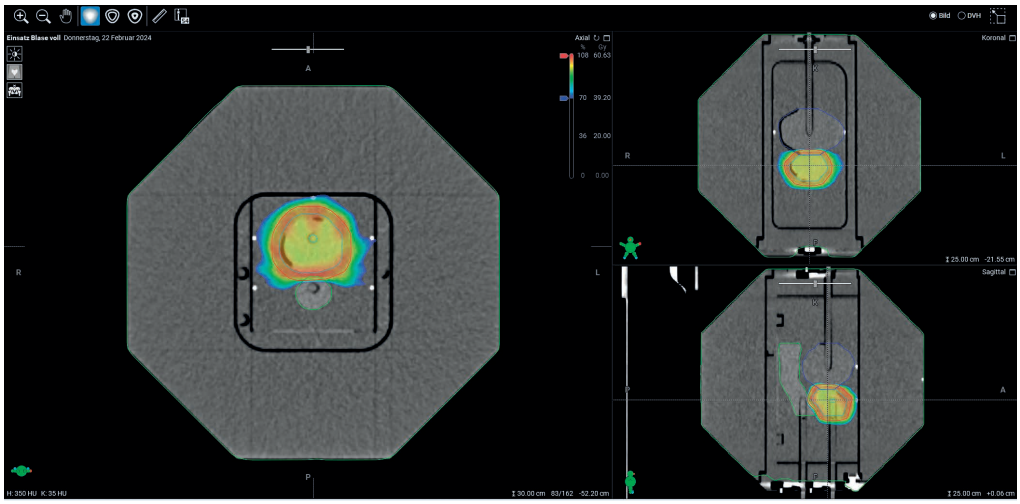



Two planning directives for a prostate intent are offered for a quick start, one for the adaptive and one for the IGRT workflow. The planning directives are for QA purposes only and must not be used for patient treatment. The time between two fractions has been reduced to 0 to allow multiple measurements within the same day. The fractionation concept was set to 50 x 2 Gy in order to have as many fractions available as possible and to have a standard fraction dose. If both planning directives are desired to be utilized, it is recommended that one RUBY patient be created for each workflow. It should be noted that the planning directives are a suggestion and should be adapted to institutional needs.

RUBY phantom with RUBY insert and organ set prostate A is used to generate a planning CT. Bladder, rectum and prostate, which is also the CTV, were contoured manually. The PTV was defined from the CTV structure with an isotropic margin of 5 mm. Additionally the measurement volume of the Semiflex 3D ionization chamber (radius 2.4 mm, length 4.8 mm) was contoured. To enable position adaptation and dose read-out during the adaptive workflow, the structure must be defined as CTV with the clinical goal of mean dose of priority „R“. Finally, a 9 field IMRT treatment plan was generated as a reference plan.

[1] RUBY insert System QA – adaptive

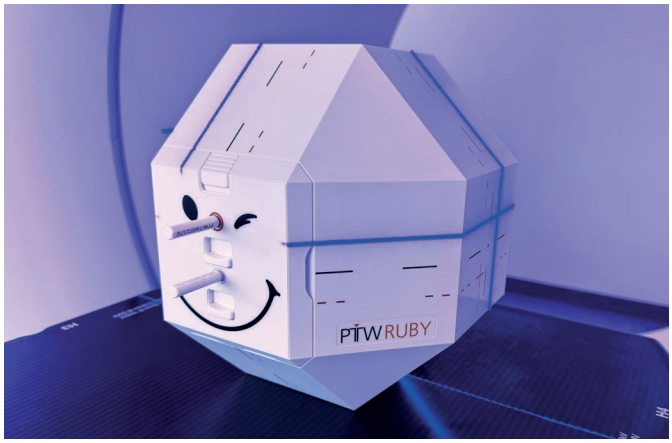
As a quick start download these customizable planning directives

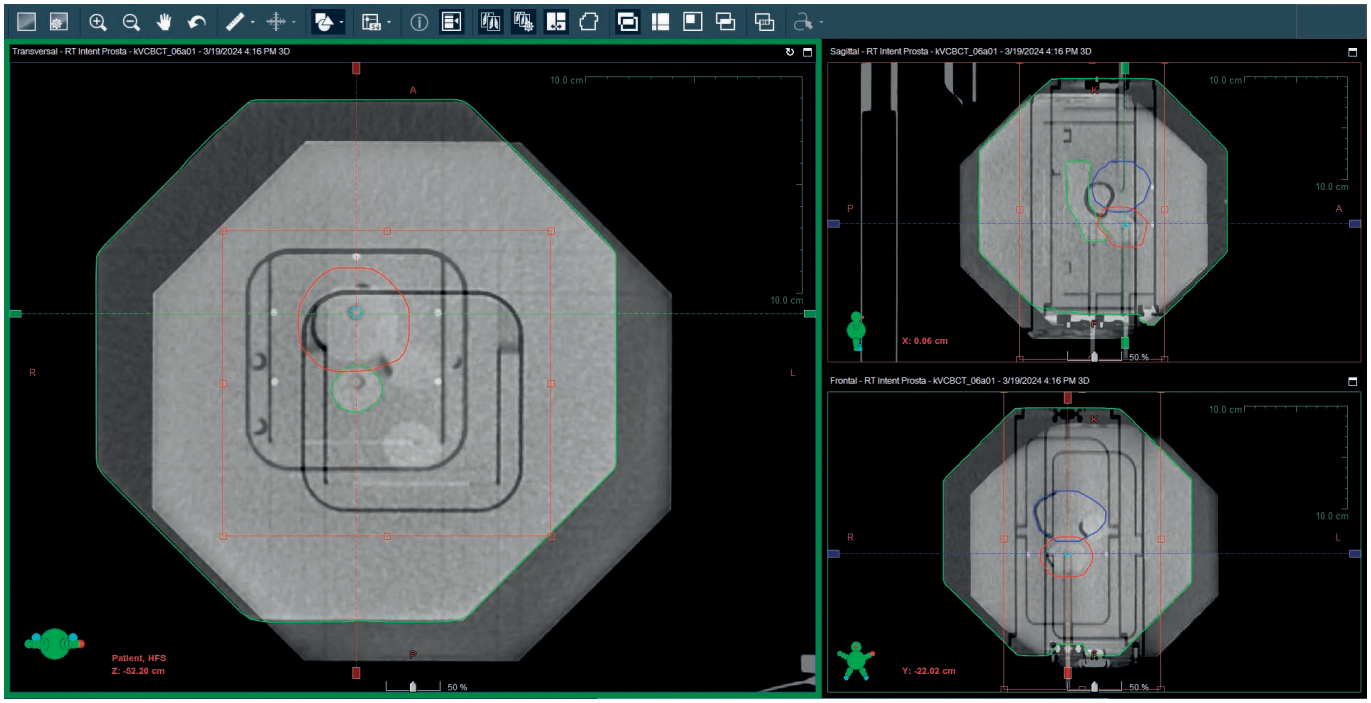


# IGRT Workflow

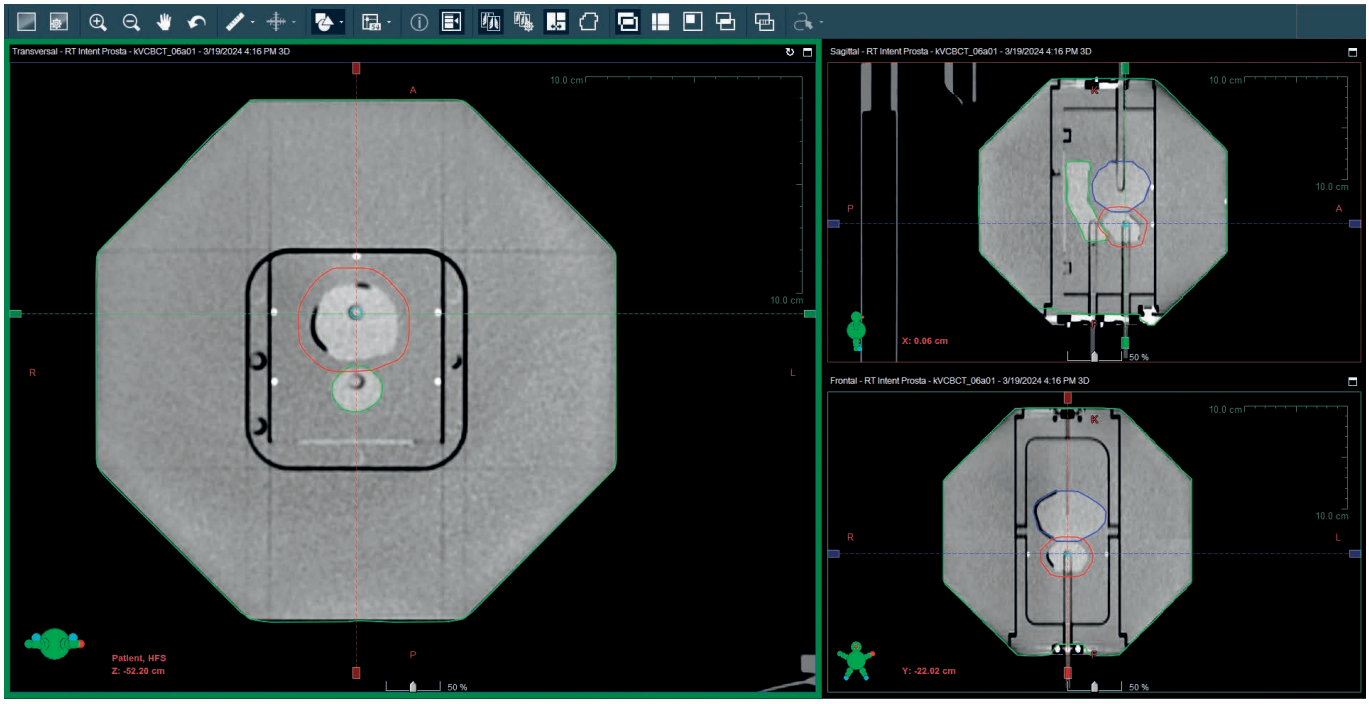
The RUBY insert was combined with the prostate A organ set, which is the same as used for the reference plan, and three homogeneous plugs were placed into the RUBY phantom. The RUBY phantom was then positioned at the ETHOS™ system with respect to the grey line. The grey line indicates a misalignment of the RUBY phantom of height = 1.8 cm, long = 1.4 cm and lat = -2.5 cm.

Image registration was performed automatically, limiting the registration area to the organs, as typically done during patient treatment. The calculated couch shift was within ± 1 mm of the specified shift values and the couch shift was performed.



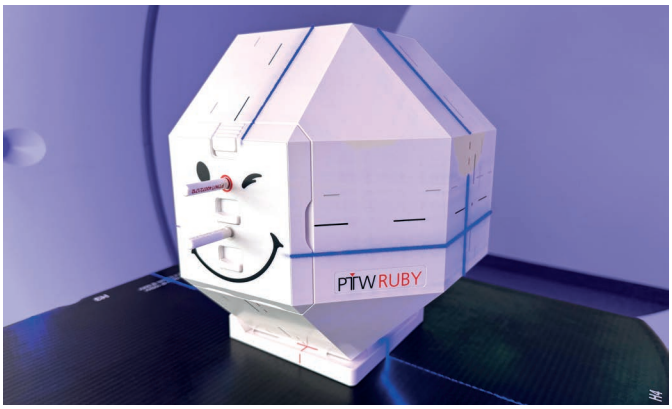
| | Height [cm] | Longitudinal [cm] | Lateral [cm] |
|---|---|---|---|
| Specification | 1.80 | 1.40 | -2.50 |
| Measurement | 1.91 | 1.35 | -2.59 |
| Difference | 0.11 | 0.05 | 0.09 |



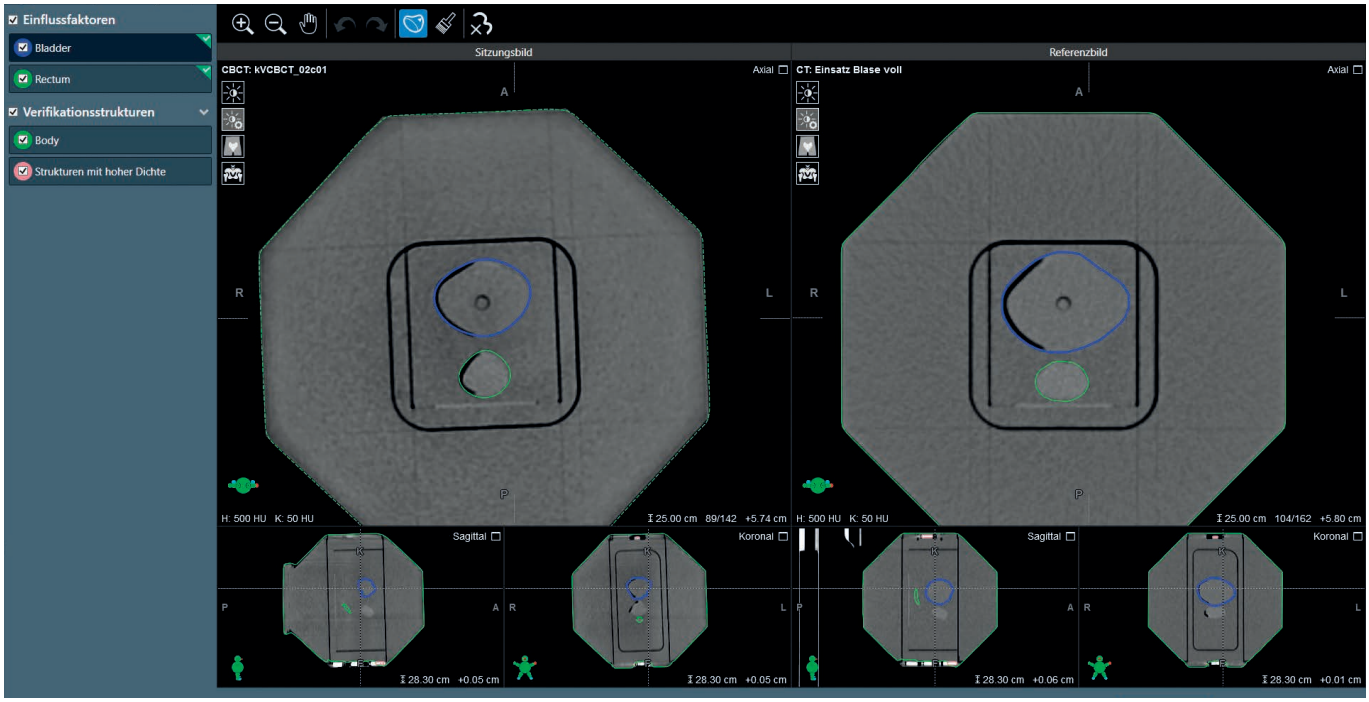

After a Semiflex 3D ionization chamber was positioned in the prostate, the reference plan was irradiated. The dose was measured using a UNIDOS Tango system considering the necessary correction factors. The expected dose value can be read from the ETHOS™ TPS as the mean value of the Semiflex 3D ionization chamber from the reference plan (1.97 Gy). The difference between the calculated and measured dose value was below 1 %.


# Adaptive Workflow

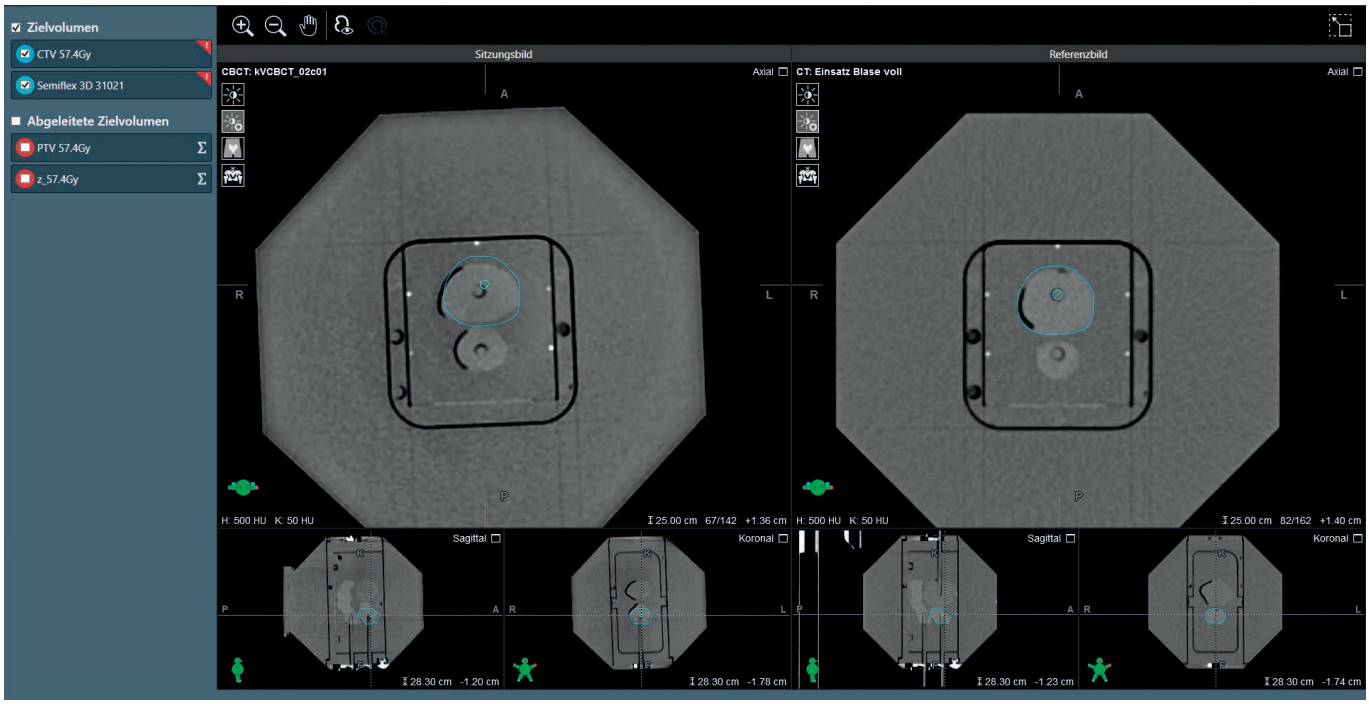
The RUBY insert was combined with the prostate B organ set, a different organ set as for the reference plan, and three homo-geneous plugs were placed into the RUBY phantom. The RUBY phantom was combined with the tilted base and then positioned at the ETHOS™ System using the red line on the phantom. This red line indicates a translational misalignment of the RUBY phantom of lat = 1.5 cm, long = 1.0 cm and height = 1.2 cm, as well as, a rotation, pitch and roll of 1°, 1.5° and 2.5°.



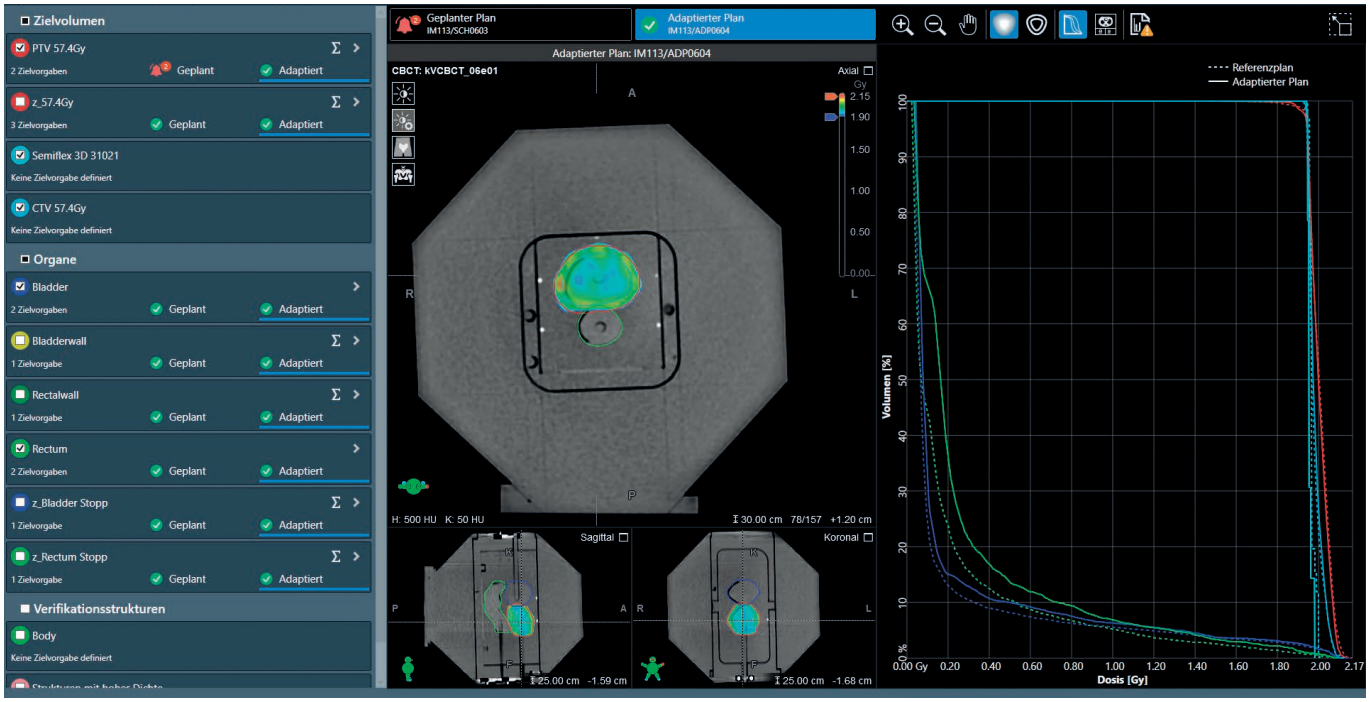
After the CBCT was acquired, influencer organs, bladder and rectum, were automatically contoured in the adaptive workflow. The algorithm identified the bladder and rectum as influencer, but the contours had to be processed manually.




In the next step, the CTV structures were automatically generated by a supervised deformable image registration. It is essential that the structure indicating the active volume of the Semiflex 3D ionization chamber is adapted to the measurement position in the prostate. The measurement position is still easily identifiable by the CT markers. To maintain the volume of the structure, it should be propagated rigidly from the planning CT and translated and rotated as needed, but not recontoured.

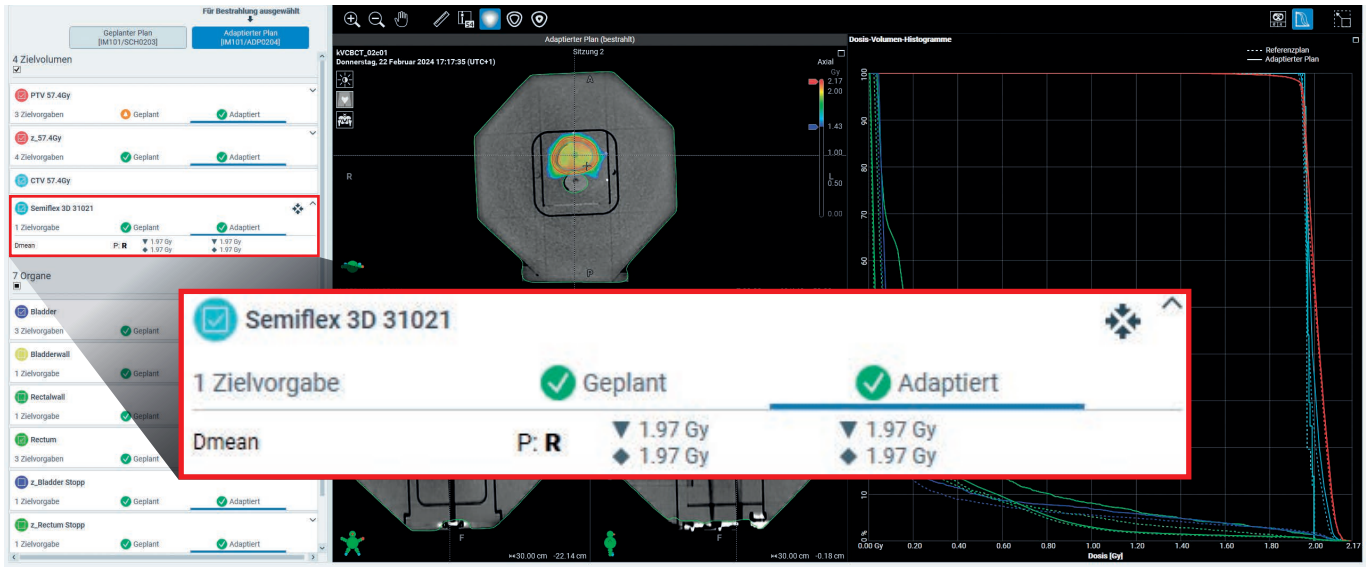



Once the Semiflex 3D ionization chamber has been propagated, the plan adaptation can be started. In this process, the plan adaptation compensates for the different organ shape as well as the changed organ position due to the tilting and misalignment of the RUBY phantom, representing a real patient treatment.




The red blind plug was removed and a Semiflex 3D ionization chamber was positioned in the RUBY phantom instead. The dose was measured using a UNIDOS Tango system considering the necessary correction factors.


As the clinical goal of the Semiflex 3D ionization chamber was set with priority "R", the mean value of the Semiflex 3D ionization chamber from the adapted plan (1.97 Gy) was reported to the monitoring in the ETHOS™ Treatment Management. The difference between calculated and measured dose value was below 1 %.

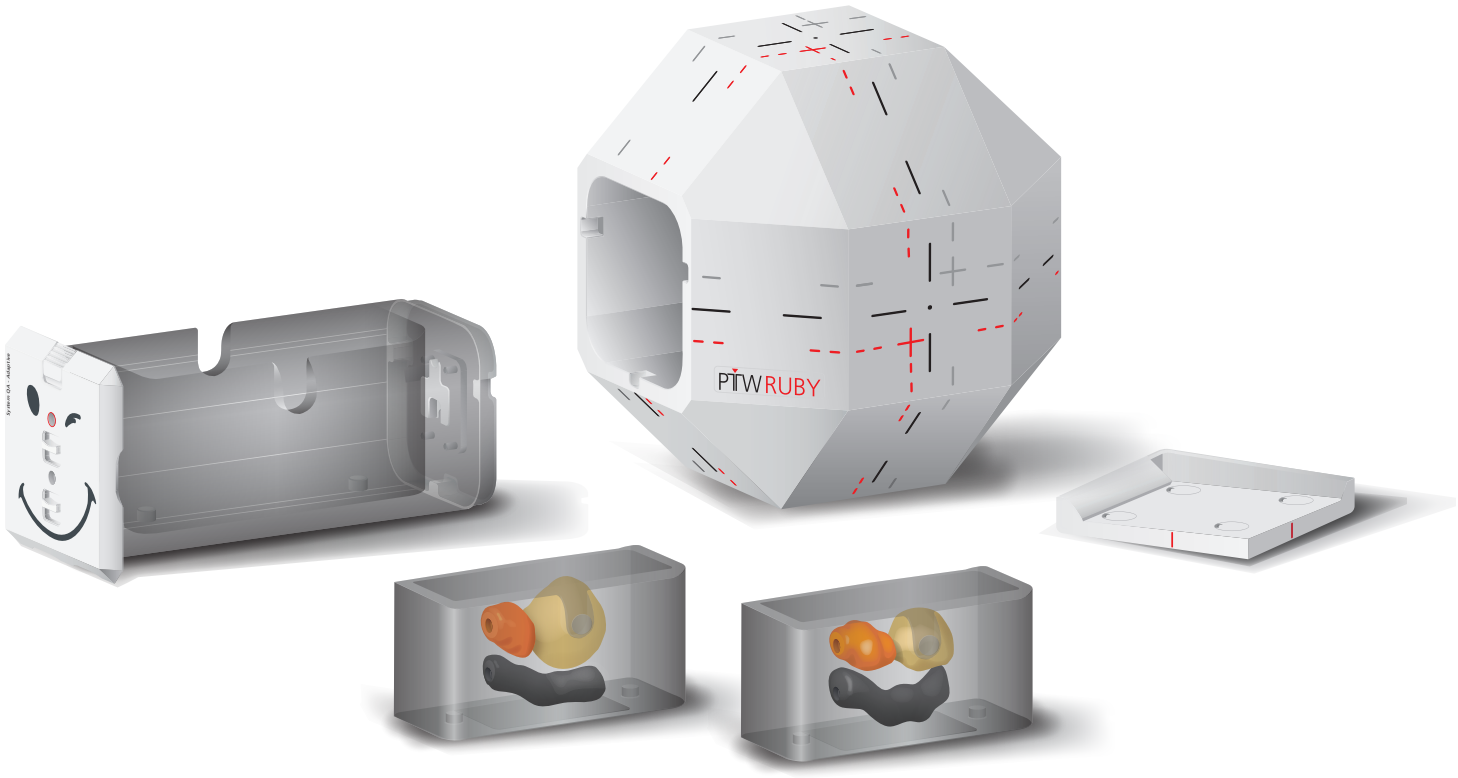



| | IGRT | Adaptive |
|---|---|---|
| TPS | 1.97 Gy | 1.97 Gy |
| Measurement | 1.97 Gy | 1.98 Gy |
| Difference | < 1% | < 1% |

# Conclusion

Quality assurance of the IGRT and of the adaptive workflow of a Varian ETHOS™ system is easily feasible with the RUBY adaptive insert. The CBCT image registration can be checked with a defined misalignment and the dose calculation in the prostate can be verified with an ionization chamber measurement. The use of different organ sets in the reference plan and during the radiation treatment itself, as well as defined misalignment, allows a very effective check of the plan adaptation.

The adaptation algorithm must compensate for a modified organ shape as well as a modified organ position. The RUBY phantom thereby mimics a realistic prostate treatment. The possibility of dose measurement in the prostate enables dosimetric verification of the plan. Additional dose measurements in the bladder and rectum, as well as simulations of treatments other than prostate are also possible.

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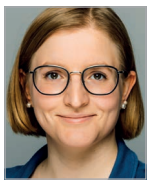

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