THERAPANACEA

ART-PLAN ™
SmartPlan

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Volumetric modulated arc therapy (VMAT) is widely used today for radiotherapy (RT) treatment planning.

However, manual treatment planning (MP) is labor-intensive and highly dependent on each planner's judgement and experience. With the emergence of knowledge-based treatment planning approaches, deep learning dose prediction and dose mimicking solutions are highly sought for speeding up planning while maintaining high plan quality.

Therapanacea has developed the module SmartPlan , an AI-based automatic planning solution aimed at reducing reliance on manual RT planning and minimizing variability among planners, ultimately benefiting patients by offering more consistent treatment outcomes and potentially **reducing overall treatment times.**

01

How Does SmartPlan Integrate with Clinical Environments?

The **SmartPlan** module within the ART-Plan+ standalone medical device is configured to integrate with the user's clinical environment (TPS, treatment machines, beam energy and fluence mode).

It takes as inputs: the patient's CT images, contoured structures (DICOM RT Struct), and a user-selected dose prescription, then **generates a treatment plan (RT-Plan) within a few minutes.**

The RT-Plan output from SmartPlan is subsequently **imported into the user's TPS for final dose calculation.**

After review and approval by the radiation oncologist, **the treatment plan can be used to deliver treatments**, ensuring **high standards of precision and efficiency** (Figure1).

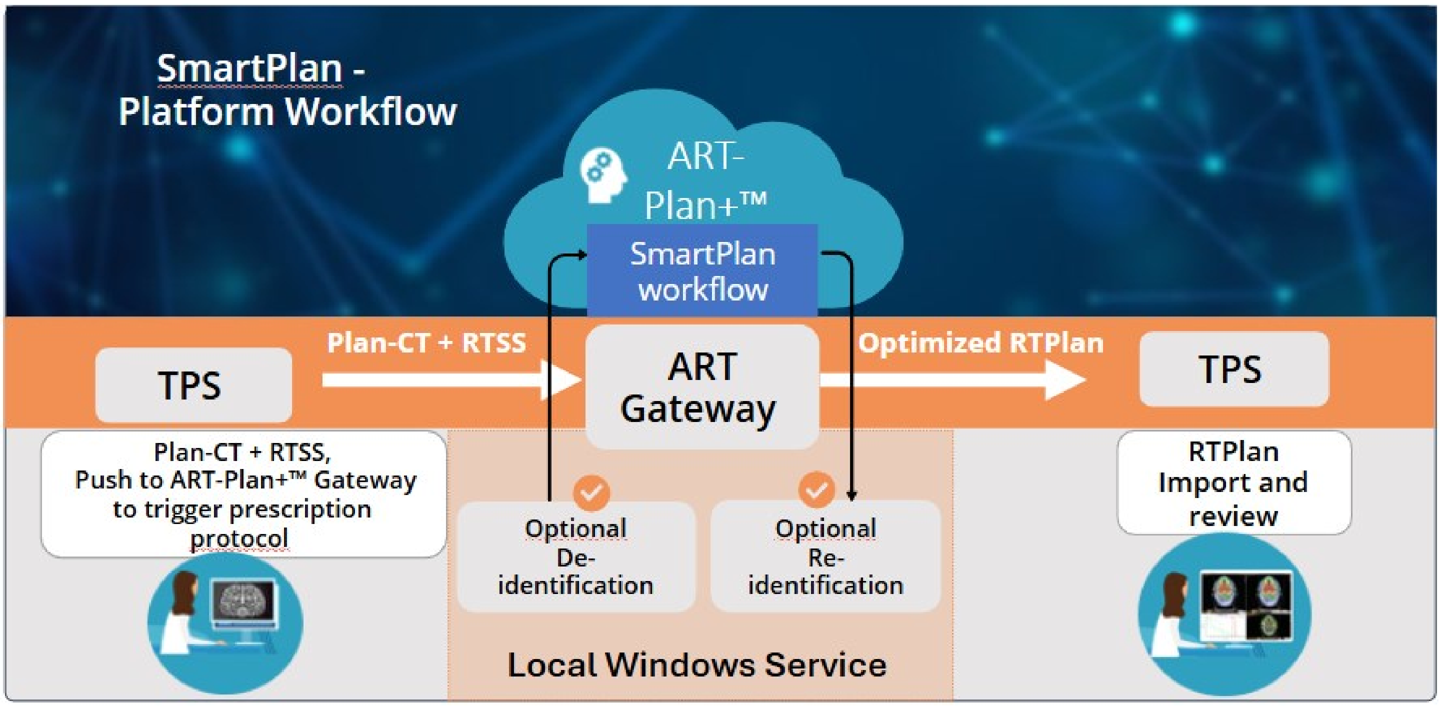


Figure1. SmartPlan integration into clinical workflow

02

How Does SmartPlan Use AI for Dose Prediction and Direct Aperture Optimization in VMAT Planning?

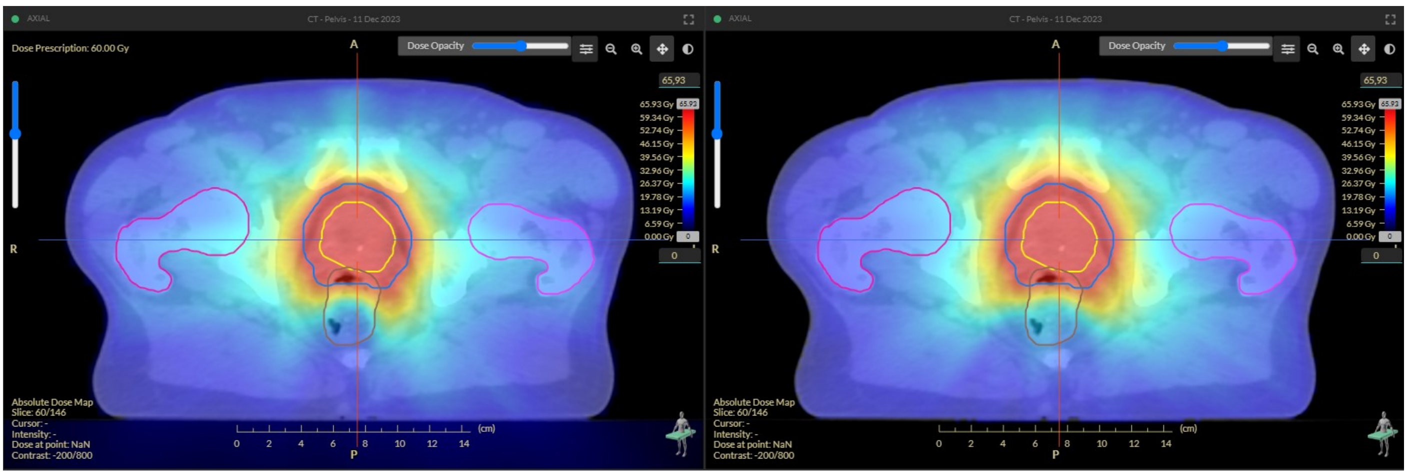
The SmartPlan pipeline takes as input a planning CT with associated organs-at-risk (OAR) and planning target volume (PTV) contours, alongside the tabular information related to the targeted Linac machine and a prescription dose.

It involves two main stages: (i) dose prediction by a deep learning model and (ii) direct aperture plan optimization that aims at reproducing the predicted dose.

For the dose prediction step, a pixel-to-pixel model (Ronneberger et al. 2015) is trained to predict 3D dose volume outputs from CT and ROI contour 3D volume inputs. The training was performed using generative adversarial model training (Isola et al. 2017) to help ensure the physical realism of the hypothetical dose volumes generated at inference time.

For the second step, direct aperture VMAT plan optimization uses custom gradient-based algorithms to minimize deviations from the predicted dose within each anatomical or planning structure. Objective weights were carefully tuned through hyperparameter optimization, ensuring an optimal balance between target coverage and normal tissue protection.

Figure 2. Example of a a Smartplan dose distribution (right side) versus a clinical plan (left side) for a prostate cancer case.



03

What are the main strengths?

Time Savings and Workflow Efficiency

Time is a critical factor in busy clinical environments. SmartPlan significantly reduces the time spent on treatment planning by generating accurate plans in a fraction of the time it takes with manual planning. This allows healthcare providers to treat more patients and enhances overall clinical workflow. By automating repetitive, time-consuming tasks, SmartPlan frees up clinicians to focus on higher-priority aspects of patient care, ultimately improving productivity and patient outcome.

High-Quality, Consistent Treatment Plans

SmartPlan excels at managing the inherent complexity of radiotherapy treatment planning. Using advanced algorithms, it generates optimal treatment plans that ensure precise radiation delivery to the tumor while minimizing exposure to surrounding healthy tissues. The system consistently produces high-quality plans that meet rigorous clinical standards, reducing variability and ensuring consistency, regardless of the planner's experience. In environments with limited staff or expertise, SmartPlan ensures every patient receives a top-tier treatment plan, making it easier to deliver high-quality care to a broader patient population. It also fosters a standardized approach across multiple planners and treatment centers, enhancing consistency—particularly valuable in multi-center clinical trials or resource-limited settings.

Seamless Integration with Adaptive Radiotherapy Workflows

As tumors can change in size or position during treatment, adaptive radiotherapy is essential for maintaining precision. SmartPlan will play a key role in adaptive workflows by integrating daily imaging and quickly adjusting treatment plans to reflect the patient's anatomy on any given day. This adaptability ensures that each patient receives a highly accurate and individualized treatment plan for every treatment fraction, improving treatment effectiveness and outcomes throughout the course of therapy.

04

How Has SmartPlan Been Validated for Prostate Cancer Treatment?

SmartPlan solution has been extensively tested for several prescriptions for the treatment of prostate cancer. The validation protocol consists of two steps:

1. **Quantitative evaluation** by comparing the plan results against specific dose constraints defined by international guidelines for each prescription.

2. **Qualitative evaluation** by conducting slice-by-slice review of the dose distribution by medical experts (Radiation Oncologists or Medical Physicist with a Radiation oncologist supervision) to assess plan quality and safety.

Below is the list of the available prescriptions for the radiotherapy treatment of localized prostate.

Prescriptions	Guidelines used for dose criteria
60 Gy in 20 Fx	ICRU, CHHiP trial
76Gy in 38 Fx and 74 Gy in 37 Fx	ICRU, CHHip Trial, Quantec
80 Gy + 56 Gy to LN in 40 Fx	ICRU, GETUG
80 Gy + 56 Gy to SV in 40 Fx	ICRU, GETUG

Table 1. Available prescriptions for SmartPlan module

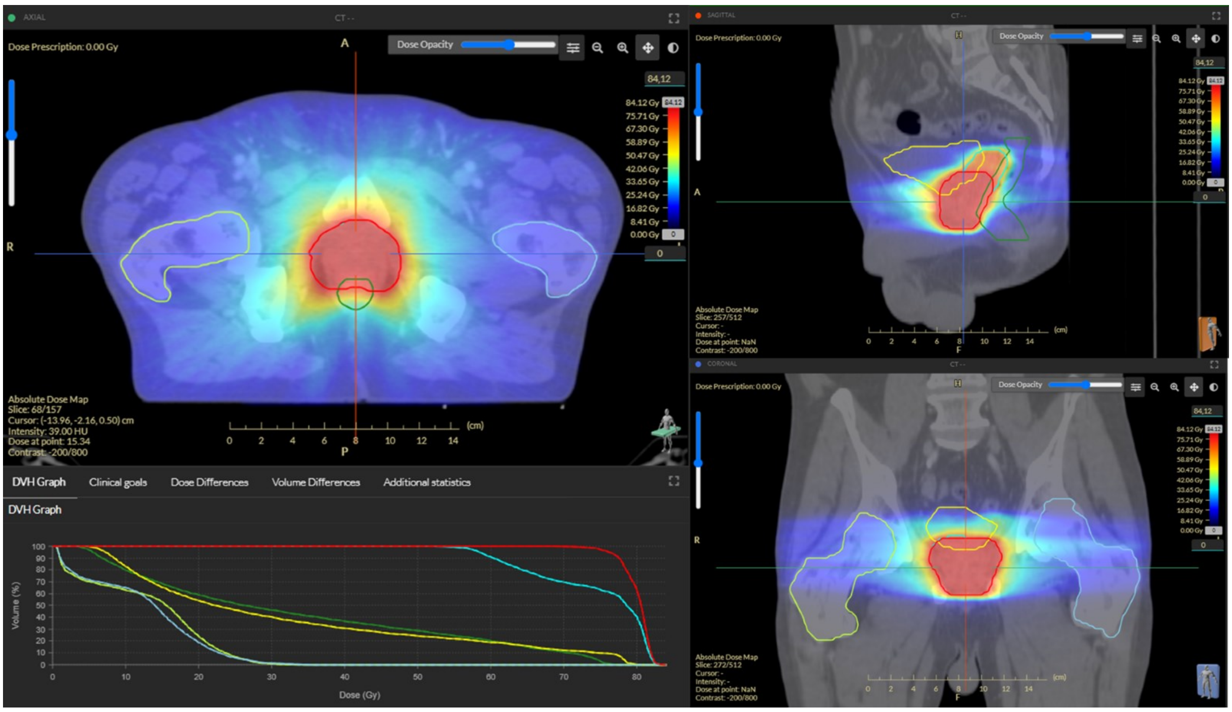


Figure 3. SmartPlan dose distribution of a normo-fractionated prostate treatment case (dose prescribed: 80Gy to prostate and 56Gy to the seminal vesicles)

05

1/2

What Have Clinical Studies Revealed About SmartPlan's Performance?

SmartPlan, an advanced CE-marked software solution, underwent a rigorous clinical and technical evaluation process to ensure safety, quality, and clinical efficacy for automated treatment planning.

Several clinical studies evaluating the performance of SmartPlan solution have been published (Prunaretty et al. 2024; Prunaretty et al. 2025; Delasalles et al. 2024; Vauclin et al. 2024; Costea et al. 2024; Green et al. 2024; Kathib et al. 2025). These investigations demonstrate the feasibility of a fully automated treatment planning pipeline across multiple prescriptions, producing high quality plans comparable to or better than manual plans in terms of dosimetry and machine deliverability.

An end-to-end clinical study for normo-fractionated prostate treatments was performed by Prunaretty et al. on 20 prostate-only and 20 whole-pelvic cases. The average generation time for the plans was 4.4 minutes and 13.4 minutes on a server equipped with 4 NVidia 3070 GPUs. The quality of the automated plans was comparable to manual plans for both indications. For prostate localization, the automated pipeline showed statistically significant reduction in the dose delivered to the rectum while improving the coverage and homogeneity on the low dose target volume. Although the generated plans had a higher median total number of MUs, all the plans had successfully passed the portal dose verification QA process with no statistically significant correlations between the gamma passing rates and the number of MUs or the modulation complexity scores. Green et al. reported results of a blinded evaluation between manual and automatic plans conducted by three experts from different countries.

Both manual and Automatic plans were considered clinically acceptable by experts in similar proportions (87% and 85% for manual and automatic plans, respectively). Additionally, experts noted their preference between the two plans, and it was demonstrated that plans generated by SmartPlan solution were **equal or better than manual plans** in 18/25, 13/25 and 22/25 of the cases for expert 1, expert 2 and expert 3, respectively.

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The feedback of the experts revealed differences in the clinical practices between different centers and countries, with respect to clinical priorities. The SmartPlan solution was further evaluated for mild-hypofractionated prostate treatment in another study by Khatib et al. Clinical evaluation was conducted on 20 prostate cases with a prescription dose of 60 Gy in 20 fractions. Dosimetric comparison showed comparable target coverage to the manual plans and improved sparing of the rectum while successfully passing plan quality assurance criteria and being less complex in terms of machine deliverability metric. Furthermore, all the plans were deemed clinically acceptable after medical physicist and radiation oncologist review.

Figure 4. Comparison of a Smartplan dose distribution (right side) versus a clinical plan (left side) for a prostate cancer case.

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Bibliographic References

Convolutional Networks for Biomedical Image Segmentation, Ronneberger O, Fischer P and Brox T, U-Net:. MICCAI 2015

Image-to-Image Translation with Conditional Adversarial Networks, Isola P, Zhu J, Zhou T and Efros A, 2017 IEEE Conference on Computer Vision and Pattern Recognition (CVPR), Honolulu, HI, USA, 2017, pp. 5967-5976, doi: 10.1109/CVPR.2017.632

Published work (1/2)

Quantitative Evaluation of a Fully Automated Planning Solution for Prostate-Only and Whole-Pelvic Radiotherapy, J. Prunaretty, B. Ungun, R. Vauclin, M. Costea, N. Norbert, N. Paragios, P. Fenoglietto, *Cancers* vol. 16,22 3735. 5 Nov. 2024, doi:10.3390/cancers16223735

Dose Prediction for Prostate Radiotherapy Planning, E. Delasalles, R. Vauclin, E. Mengin, B. Ungun, M. Costea, N. Bus, N. Komodakis, P. Fenoglietto, G. Güngör, N. Paragios, European Society for Radiotherapy and Oncology Conference, 2024

End-to-end automatic treatment planning for prostate radiotherapy, R. Vauclin, B. Ungun, E. Delasalles, E. Mengin, N. Bus, M. Costea, G. Güngör, F. Gassa, V. Gregoire, P. Maury, C. Robert, P. Fenoglietto, N. Paragios, European Society for Radiotherapy and Oncology Conference, 2024

Published work (2/2)

Quantitative and qualitative evaluation of an automated planning solution for prostate radiotherapy, M. Costea, B. Ungun, R. Vauclin, E. Delasalles, E. Mengin, N. Bus, G. Güngör, M. Moll, S. Cozzi, V. Gregoire, P. Fenoglietto, N. Paragios, European Society for Radiotherapy and Oncology Conference, 2024

Quantitative and qualitative evaluation of an automated planning solution for prostate radiotherapy, W. Green, R. Mcbeth, G. Güngör, M. Moll, S. Cozzi, V. Gregoire, M. Costea, P. Zidane, N. Bus, B. Ungun, N. Paragios, K. Teo, P. Fenoglietto,, American Society for Radiation Oncology Conference, 2024

Quantitative evaluation of a fully-automated planning solution for prostate-only and whole-pelvic radiotherapy, J. Prunaretty, B. Ungun, R. Vauclin, M. Costea, N. Norbert, N. Paragios, P. Fenoglietto, European Society for Radiotherapy and Oncology Conference, 2025

Evaluation of an Artificial Intelligence-Based Industrial Solution for Automated Prostate Planning, Y. Khatib, B. Roman-Vilboux, M. Costea, B. Ungun, R. Vauclin, N. Paragios, V. Plagnol, European Society for Radiotherapy and Oncology Conference, 2025