THERAPANACEA

Experience AI-powered offline adaptive radiotherapy planning with ART-Plan™

AdaptBox

White paper

Introduction

Nowadays, standard radiotherapy treatments are based on a static plan that is determined before the start of treatment. However, during the course of treatment, the patient's tumor or normal tissue may change due to factors such as tumor shrinkage, weight loss, or organ motion. These changes may impact the initial treatment plan that may no longer accurately reflect the actual dose delivered to the target and organs at risk (OARs).

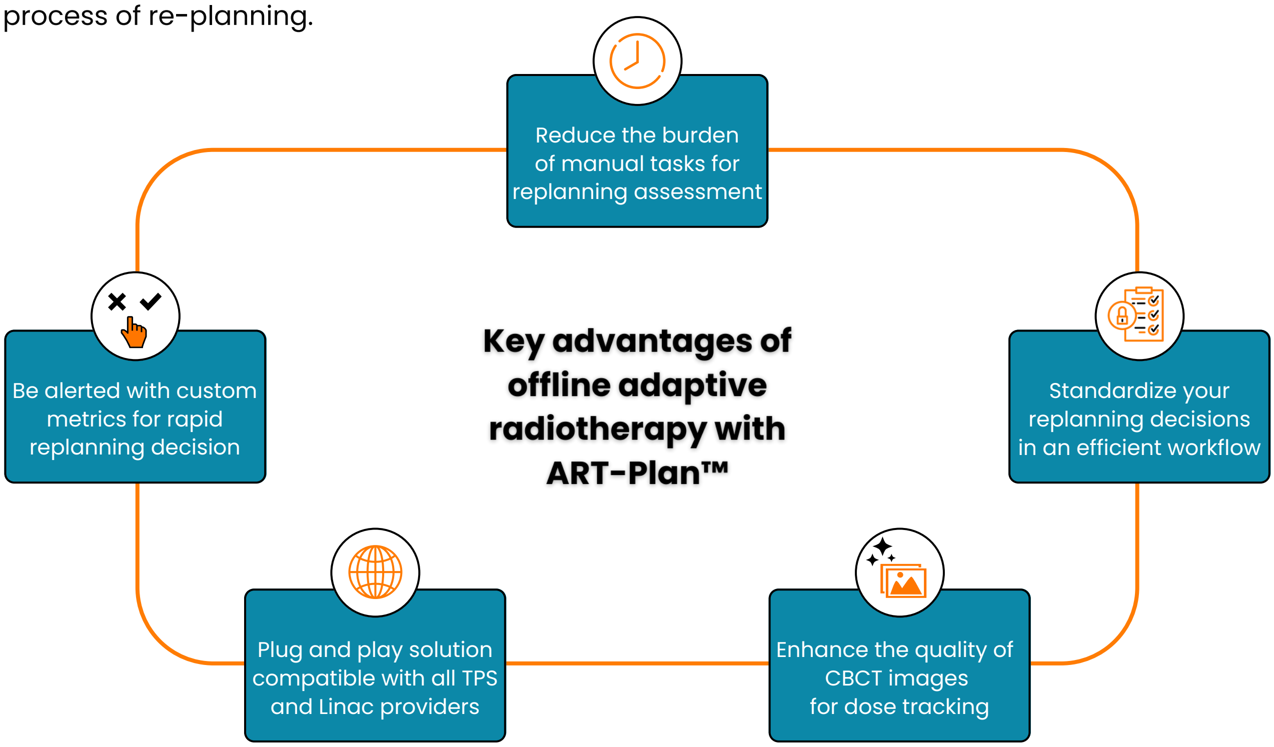
Adaptive radiotherapy (ART), a new treatment strategy developed in recent years aiming to correct for anatomical variations between the treatment fractions, is becoming more and more established. This approach allows for a more precise and personalized delivery of radiation, and has the potential to improve outcomes for patients.

The ultimate goal of ART is to improve accuracy of doses delivered to the patients and to reduce the risk of side effects on healthy tissues. ART could be used for a variety of cancer types, including prostate, lung, and head and neck cancer.

A big enabler of ART is the introduction of image-guided radiotherapy treatment, for which patients undergo repeated imaging, such as cone-beam computed tomography (CBCT), commonly used for patient positioning purposes and plan adaptation decisions.

However, CBCT images suffer from several image quality deficiencies such as poor image quality, inconsistency of HU values, poor soft-tissue differentiation and limited field of view, which limit their use for dose calculations and objective clinical decision-making on adaptation needs. To overcome these barriers, TheraPanacea is proposing a new solution for offline ART.

As part of this new solution, ART-Plan™* now includes AdaptBox, a new tool that gathers AI-powered synthetic CT (SynCT) generation from CBCT images, accelerated dose calculation and alert generation in case of need of re-planning. With AdaptBox, radiation oncology practitioners will be able to track the daily doses and standardize their decision making process of re-planning.



*Not available in all markets

Experience offline adaptive radiotherapy workflow in your Clinic with ART-Plan™

At TheraPanacea, we developed a new solution that enables offline ART for male pelvis localization. Our CE-marked and FDA-cleared software ART-Plan™ is now completed with our new module AdaptBox*. Through the new AdaptBox module, you will be able to generate AI-based high resolution synthetic CT from CBCT images with an augmented field of view, use SmartFuse to propagate target contours from planning CT, automatically delineate organs at risk thanks to Annotate, and compute daily doses on new anatomy to quantitatively evaluate the actual dose delivered to the patient.

Discover our offline adaptive workflow:

Enhanced and augmented CBCT
Generate synthetic CT images from daily CBCT images

Target contours
Propagate target contours from your planning CT with SmartFuse

Auto-delineation of OARs
Automatically delineate organs at risk on your daily synthetic CT with Annotate

Accelerated dose calculation
Calculate the daily dose with our new collapsed-cone dose engine

Alert generation
Generate alerts based on personalized triggers to assess the need of replanning

All steps of the AdaptBox workflow have been clinically validated following strictly derived protocols from thorough literature review, international guidelines and recommendations, as well as discussion with renowned clinical centers.

*pending regulatory clearance in the US

Step 1: AI-based synthetic CT generation from CBCTs

Creation of deep learning synthetic CT image with improved image quality and extended field of view

To overcome limitations of CBCT images such as limited quality, inconsistency of HU values, poor soft-tissue differentiation, and small field of view, TheraPanacea developed an AI-based solution to generate synthetic CTs from CBCT images. Thanks to this cutting edge technology, CBCT images are improved to the point that automatic OAR annotation, full scale dose simulation and replanning decisions can be reliably performed.

Two clinical studies [1,2] have demonstrated the feasibility of using artificial intelligence to transform CBCT images into high resolution synthetic CTs based on improved similarity metric and the non-inferiority dosimetric endpoints when compared to doses on planning CT.

The first study [1] assessed the similarity between the planning CT and sCT by measuring the Mean Absolute Error (MAE), the Structural Similarity Index Measure (SSIM) and the Peak Signal to Noise Ratio (PSNR) on a cohort of 50 prostate cancer patients.

The second one [2] aimed at evaluating the dose calculation accuracy of the synthetic CT images generated from 20 prostate cancer patients. To do so, planning CTs and synthetic CTs were compared based on DVH parameters (D2%, D50%, D95%, D98%, and Dmean) and dose distribution with global gamma criteria (2%/2mm and 3%/3mm).

	MAE CBCT (HU)	***MAE sCT (HU)***	***SSIM CBCT***	***SSIM sCT***	***PSNR CBCT (dB)***	***PSNR sCT (dB)***
Mean	50.97	38.12	0.79	0.94	31.14	32.92
Std	13.12	8.3	0.07	0.07	2.28	3.41

Table 1: Overall results of imaging metric between planning CTs/CBCTs and planning CTs/synthetic CTs.

Structure	**DVH parameter**	**Mean relative difference (%)**	**Median relative difference (%)**
PTV	Dmean	0.262	0.154
	Dmax	0.438	0.311
	D98	0.702	0.552
	D95	0.353	0.377
	D50	0.338	0.158
	D5	0.376	0.153
	D2	0.383	0.158

Table 2: Overall dosimetric results comparing doses calculated on planning CTs and on synthetic CTs. PTV=Planning Target Volume

Step 2: Propagation of target contours and automatic OAR delineation

Perform automatic and reliable propagation of target contours using robust multi-metric elastic and rigid fusion with SmartFuse

After generating the synthetic CT from your daily CBCT, target contour propagation from the planning CT is a necessary step in our adaptive workflow. In order to accomplish this step, our previously clinically validated software, SmartFuse, is the perfect tool.

A study [3] demonstrated the clinical benefit of using SmartFuse for the propagation of target contours from the planning CT to the daily synthetic CT.

A cohort of 20 pelvis patients was used for this evaluation. A qualitative assessment of the propagation of target contours from the planning CT was done through a scoring mechanism: A/acceptable, B/ acceptable after minor corrections, and C/ not acceptable for clinical use. Two independent annotations were used: one for the original CBCT and one for the generated synthetic CT. To account for inter-expert variability, three experts were involved in the evaluation.

Structure	Percentage of A&B for rigid pCT-CBCT	Percentage of A&B for rigid pCT-sCT	Percentage of A&B for deformable pCT-CBCT	Percentage of A&B for deformable pCT-sCT
Target	92.2%	89.6%	72.9%	87.5%

Table 3: Qualitative fusion results for OAR contour propagation for both rigid and deformable registration between planning CT and CBCT and planning CT and synthetic CT.

This study demonstrates how using a synthetic CT in your adaptive workflow led to a better contour propagation as compared to using standard CBCT images, thus justifying the benefits of using the synthetic CT.

Perform automatic delineation of organs at risk on the synthetic CT with Annotate

After generating your daily synCT and propagating target contours from the planning CT, the next step of the workflow is the contouring of OARs on the new anatomy. To replace the tedious task of manual contouring, TheraPanacea proposes the use of Annotate for automatic delineation of OARs on your daily synthetic CT.

OARs included

Anal Canal	Penile bulb
Bladder	Prostate
Left femoral head	Rectum
Right femoral head	Seminal vesicle

The ability of Annotate to generate automatic contours of OARs on CBCT-based synthetic CTs was validated in another clinical study [4]

For a total of 40 patients, automatic annotations of 8 OARs were performed and compared against 9 expert contours based on calculation of Dice Similarity Coefficients (DSCs). To evaluate the quality of AI contours, the mean DSC scores obtained were compared to the mean DSC between experts.

Results show that Annotate provides clinically acceptable contours as good as the level of experts. Structures like anal canal and penile bulb, which present lower DICE scores, could be quickly adjusted by the users with our smart editing tools provided in AdaptBox.

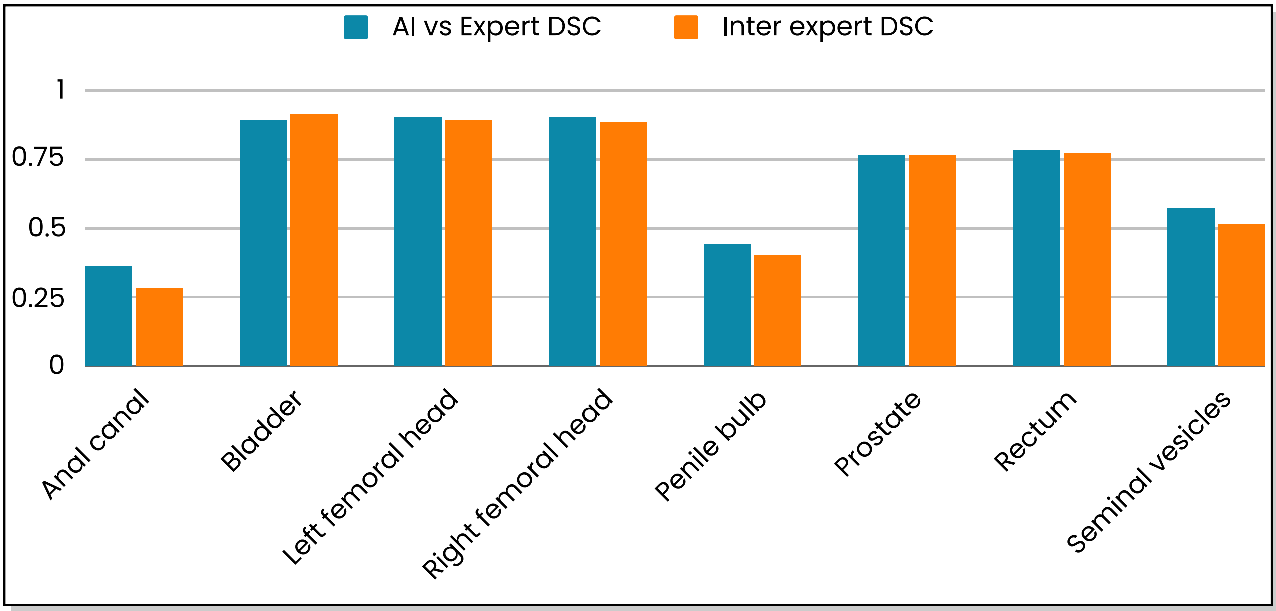
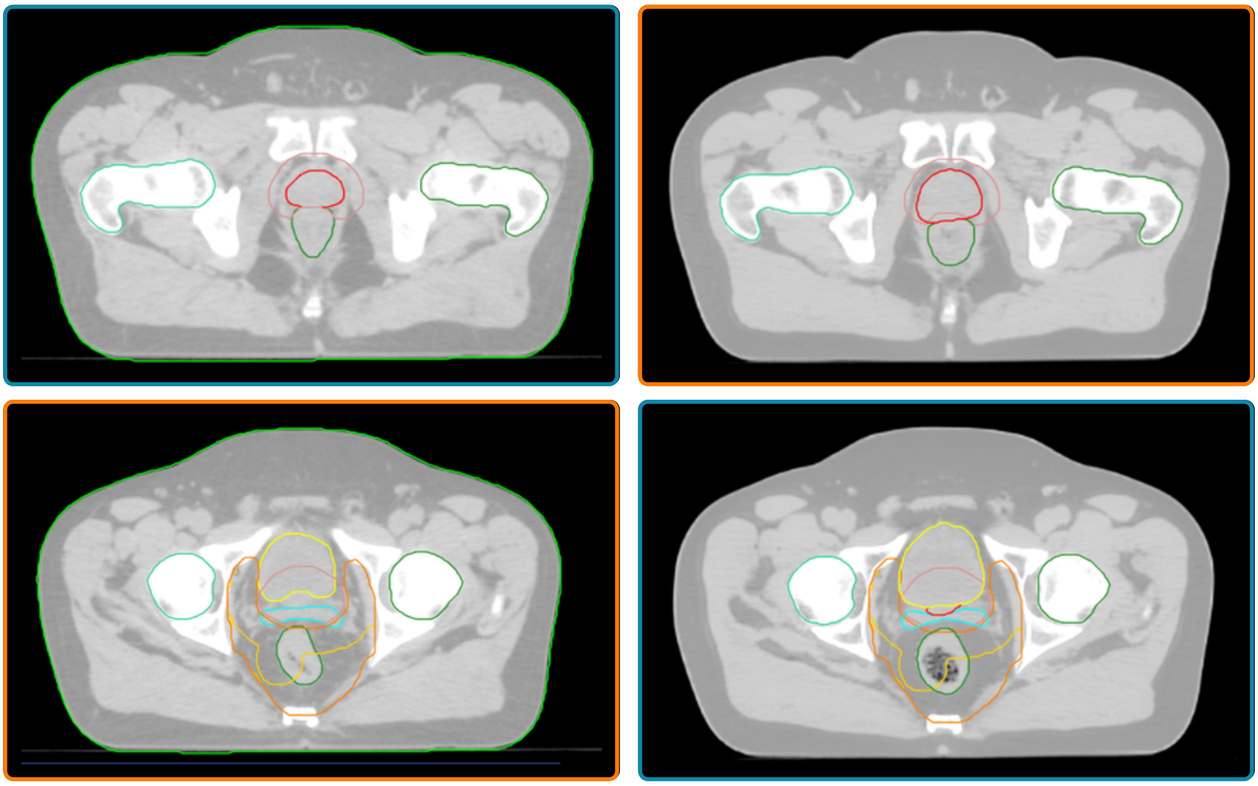


Table 4: Overall results of Annotate DSC vs inter-expert DSC per organ



Planning CT (left) and respective synthetic CT from CBCT (right) side by side.

Step 3: Accelerated dose calculation

Perform accelerated full scale dose calculation on daily synthetic CTs

In order to evaluate the daily dose on your synthetic CT of the day, dose calculation is necessary. To quantitatively quantify the need of replanning, TheraPanacea developed its own dose engine for accelerated dose calculation.

Our new dose engine is based on the collapsed cone convolution algorithm* in order to reduce the computational time without any loss of accuracy for the dose predictions.

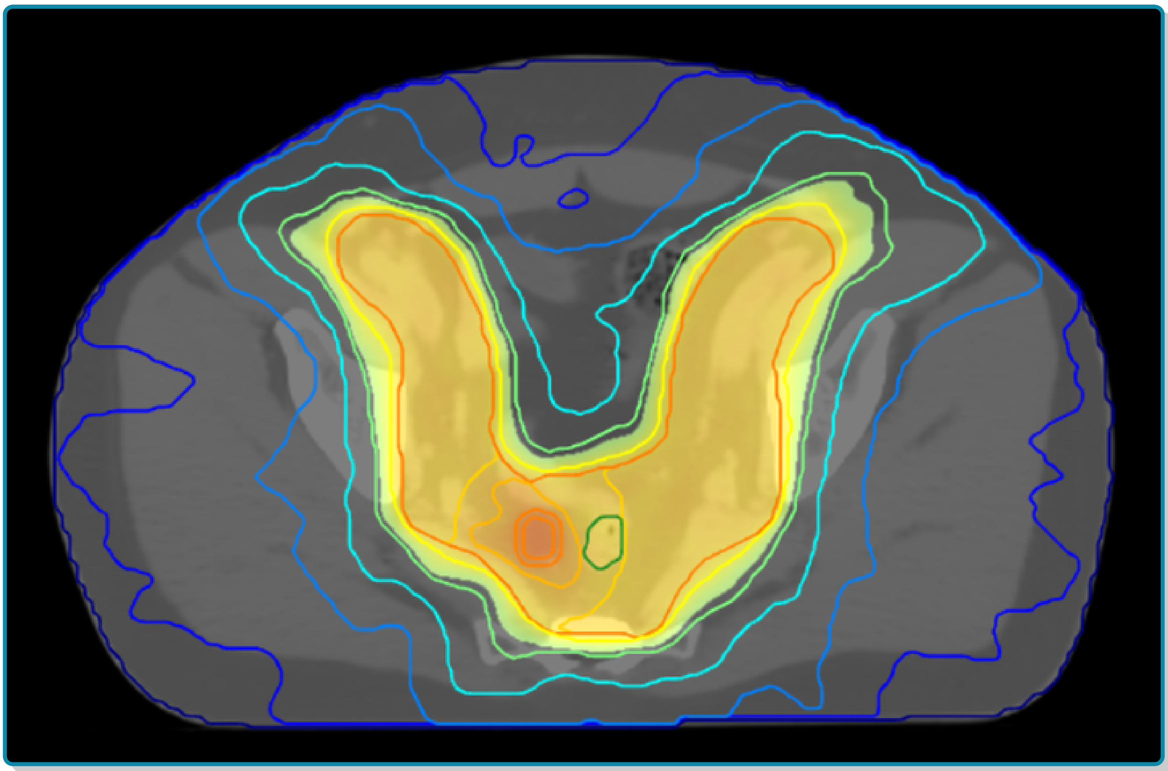
A clinical study showed non-inferiority of our new dose engine compared to other dose engines included in commercially available TPS.

This study was conducted on 90 pelvis cancer patients to assess the relative difference between doses calculated on our dose engine and those calculated by commercial TPS. The evaluation was based on global gamma index analysis and evaluation of clinically relevant dosimetric end-points from dose volume histograms (DVH). For both the PTV and OARs, different DVH parameters were evaluated and compared.

Threshold	1%	10%
Median 2%/2mm	99.33	99.97
Median 3%/3mm	99.92	99.88

Table 5: Median global gamma index

Overall, relative doses differences for the PTV and all OARs to commercially available dose engine were found to be below 2% for all DVH parameters.



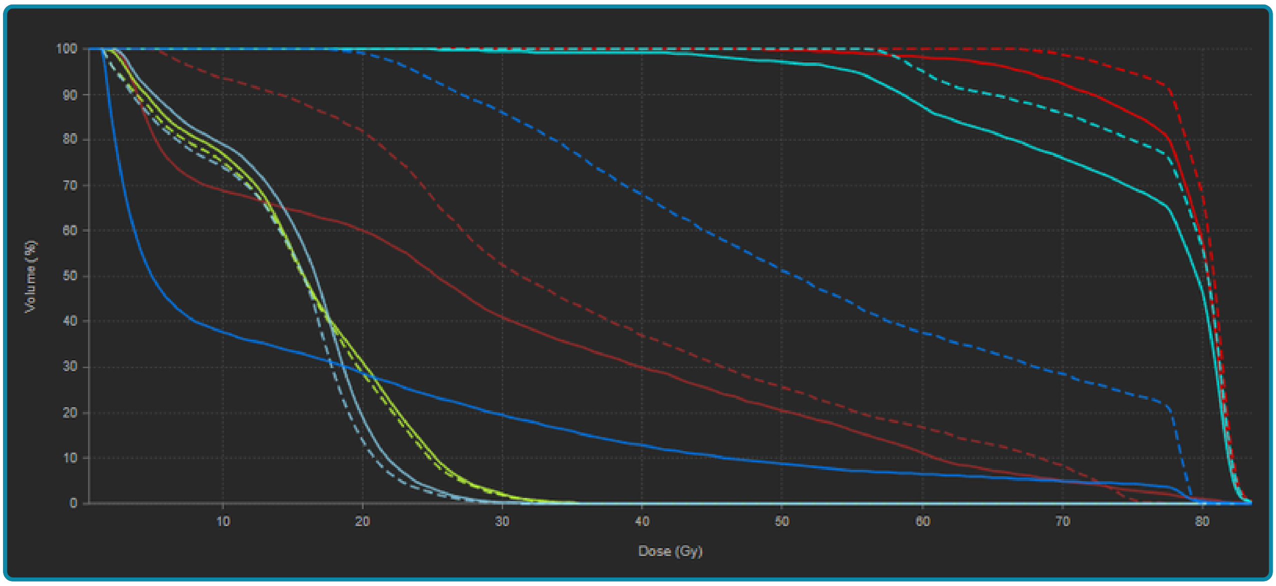
Synthetic CT from CBCT with isodose and dose map

*Ahnesjö A. Collapsed cone convolution of radiant energy for photon dose calculation in heterogeneous media. Med Phys. 1989 Jul-Aug

Step 4: Alert generation when need of replanning

Dose and volume tracking and generation of alerts when there is a need of replanning

in order to take the decision to replan or not, it is important to evaluate changes in anatomy and evaluate the dose of the day. AdaptBox allows you to visualize the two images of the patient and to display planned and delivered dose side-by-side. You will be able to set personalized triggers based on DVH parameters to generate alerts when there is need of replanning.



Display DVH of planning CT and synthetic CT of the day

dotted line: fraction
solid line: planning

Check dose differences between fractions based on personalized DVH parameters	Check exact DVH values for both the planning CT and the daily synCT	Check your dose constraints on your daily synCT

Conclusion

With AdaptBox users will now be able to track daily delivered dose and to evaluate the actual delivered dose to the patient, thus helping in the decision making process for replanning. It will also avoid unnecessary replanifications thus avoiding extra CT dose, extra step in the workflow, loss of time, and treatment disruption. The use of AdaptBox will lead to benefits across different healthcare stakeholders.

AdaptBox provides several benefits for the users,

Gain of time comparing to manual replanning	More standardization to eliminate the inter- and intra-variability	Automatic contouring, deformable registration and daily dose tracking

And also for the patients!

More standardized care for radiotherapy patients	Potential reduction in toxicity and better tumor control	Adaptive radiotherapy personalized to each patient

Moreover, AdaptBox paves the way to research in order to better define clinical triggers and generate more robust evidence about the right thresholds and quantified clinical outcomes.

AdaptBox is the right tool for your clinic to automate your entire offline ART process

Book a demo today to discover AdaptBox

Always looking ahead

At TheraPanacea, we are devoted to bringing the best products on the market for patients, experts and clinics. On top of that, we are continuously working to improve our existing modules.

We are already working closely with renowned centers to better define triggers, add new anatomies to AdaptBox and add the possibility to perform dose accumulation in the upcoming versions. Stay tuned to discover all our updates and do not hesitate to book a demo to discover our products!

Our Partners

At TheraPanacea, we work with a range of partners across the medical field without whom all of this would not have been possible.

References

[1] Roque et al., ESTRO 2023, Can artificial intelligence bring cone beam CT acquisitions to planning CT quality?

[2] Roque et al., ESTRO 2023, Self-learning GAN based synthetic CT generation: unlocking CBCT-based adaptive radiotherapy

[3] Roque et al., ESTRO 2023, Clinical evaluation of fusion for offline adaptive radiotherapy: AI-based synthetic CT vs CBCT

[4] Roque et al., ESTRO 2023, AI-based delineation for CBCT offline adaptive radiotherapy: an interexpert variability evaluation

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Intended Use Summary
ART-PlanTM is a class IIb medical device. It is a software intended to be used by trained clinicians who are familiar with radiation therapy. The software consists of different modules, each used for specific purposes at a different phase of radiation treatment planning. It allows the display, visualization, volume rendering, annotation (manual and semi-automatic), registration and fusion of different types of medical images. It also allows the generation of pseudo-CT from MR and CBCT images. Finally, it allows dose computation on CT images for external beam irradiation with photon beams.