

Reconstruction of Intra-Fractional Prostate Movement and Its Effect on Dose Distribution

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Introduction and objectives: Stereotactic body radiation therapy (SBRT) of prostate cancer (PCa) has recently been shown well tolerated in phase I and II trials indicating favorable normal tissue complication probability [1]. In addition, there is an ongoing discussion suggesting that the α/β ratio of PCa can be even lower than the α/β ratios of the surrounding organs [2,3], which supports use of hypofractionation for increased tumor control probability (TCP). Prostate has been reported to move randomly with a possibility to drift away from the isocenter [4,5]. As the number of treatment fractions is reduced, the risk of a TCP compromising geometric miss due to the unpredictable prostate motion increases. The focus of the present study was to retrospectively reconstruct dose distribution for patients for which prostate movement exceeded 3 mm, which was the threshold for repositioning the patient before continuing the treatment.

Methods: Five patients with local (T1c/T2) low and intermediate risk PCa that had received SBRT were selected. A fractionation scheme with a prescribed dose of 35 Gy was delivered twice a week in 5 fractions with two full opposite VMAT arcs using an Elekta Versa HD with Agility MLC (Elekta AB, Stockholm, Sweden). The CTV consisted of the prostate gland delineated to a CT image with the help of a registered MRI image. An isotropic margin of 3 mm was added to the CTV to create the PTV. D95 of PTV was normalized to cover 100 % of the prescribed dose. Real-time monitoring of prostate motion was manifested by using the RayPilot system (Micropos Medical AB, Gothenburg, Sweden), which consists of a treatment table top overlay, RayPilot Receiver, containing an integrated receiving antenna array shown in Fig. 1., and a wired electromagnetic transmitter, RayPilot Transmitter, transperineally implanted into prostate gland, which is shown in Fig. 2. The target was matched using a CBCT. Treatment was discontinued if radial prostate movement exceeded 3 mm from the CBCT match point (the origin). However, the radial displacement curve of prostate (i.e. transmitter) was saved, and is used in this study to retrospectively reconstruct the dose distribution that could have occurred without real-time tracking.



Fig. 1. RayPilot Receiver, a table top overlay containing the antenna array.

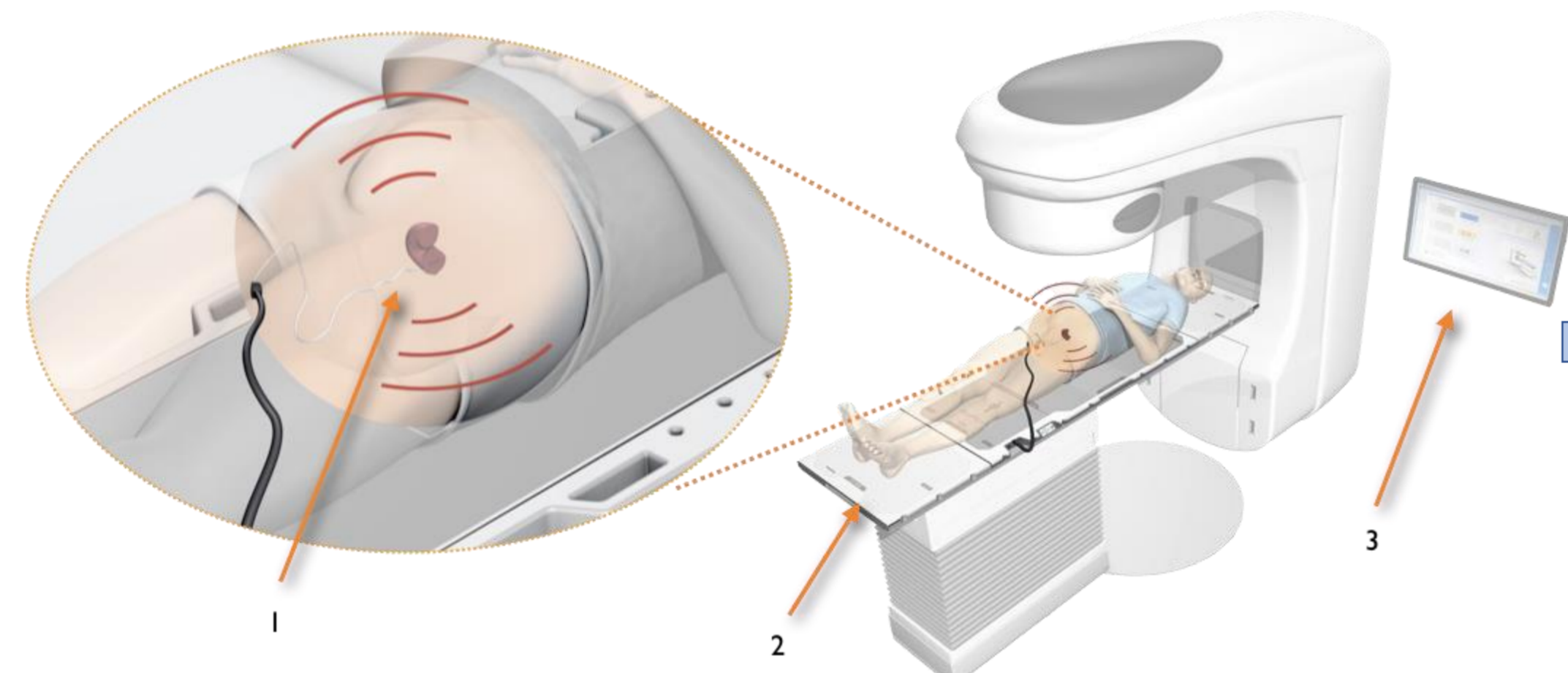


Fig. 2. RayPilot system in use including the electromagnetic RayPilot transmitter (1), RayPilot Receiver (2) and real-time tumour-tracking (3).

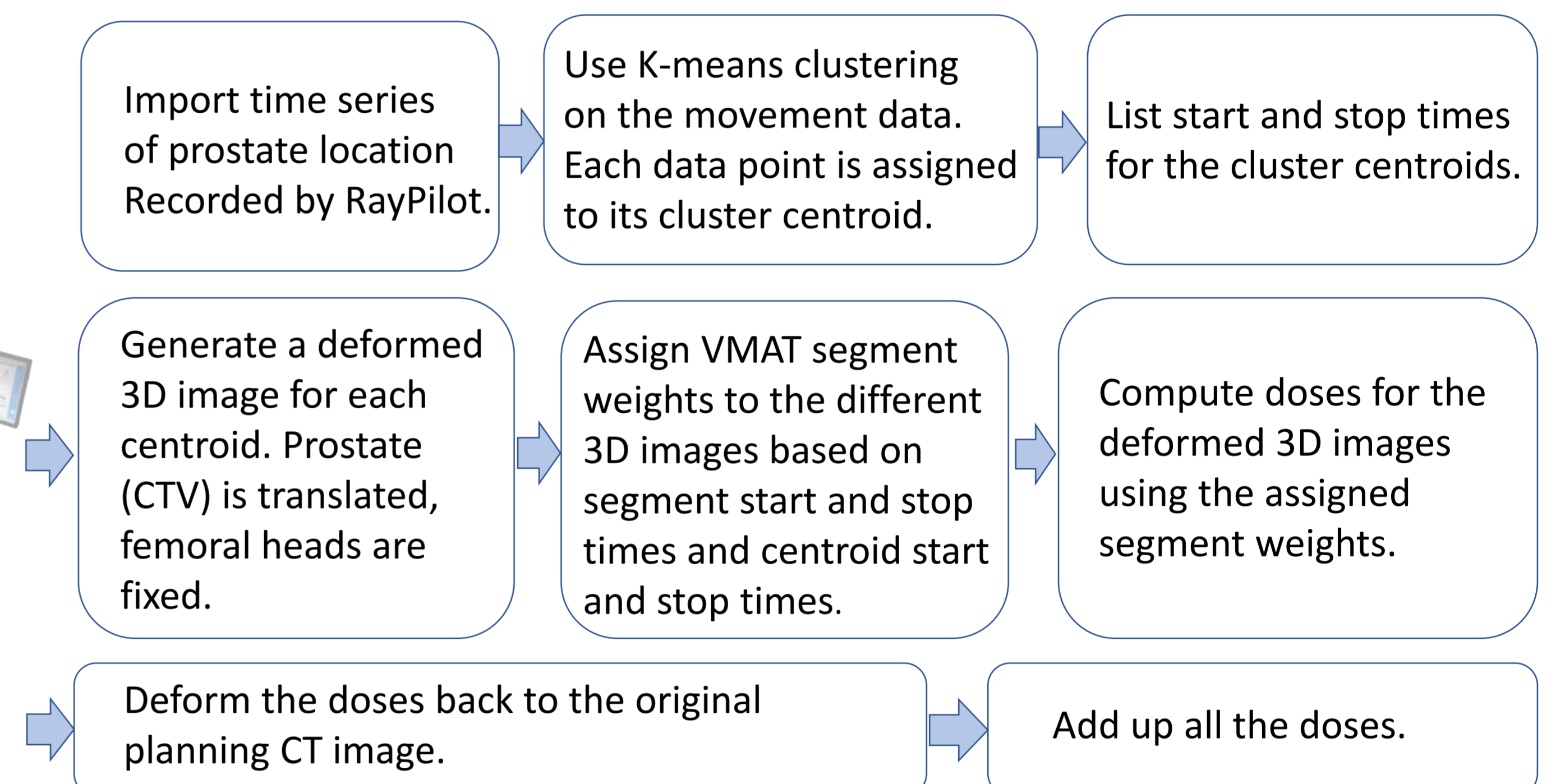


Fig. 3. Workflow of the dose reconstruction script.

The dose reconstruction was implemented using the scripting interface of a research version of RayStation 9A treatment planning system (RaySearch Laboratories AB, Stockholm, Sweden) reading 3D-coordinates of a RayPilot system time series representing prostate movement, and *k*-means clustering up to 30 clusters. In Fig. 3, a workflow of the script is represented. In this retrospective study, the prostate was allowed to move more than 3 mm. Dose distribution was reconstructed to the deformed CT images of each cluster and mapped back to the original CT image. CT images were created for each cluster by a transfer of a rigid prostate (CTV). Femoral heads were chosen to remain rigid and fixed. Soft tissues, and to some extent also pelvic bones, were deformed and transferred in relation to the prostate movement.

Results and conclusions: Since the treatment system did not record beam on times in relation to the movement data, worst case scenarios were chosen to study what could have happened without real-time monitoring during one fraction. Fig. 4. shows prostate time series recorded by RayPilot. The red and green stripes represent beam on times used by the dose reconstruction script. Fig. 5. shows original (upper) and reconstructed (lower) dose distributions for the same axial CT slice. Dose distributions in panel a) and b) correspond to the time series a) and b) in Fig. 4. In panel a), prostate movement in the cranio-caudal direction has left the cranial end without any dose, since the arcs were co-planar. In panel b), prostate movement has been mostly in the transversal plane (x and y displacements in Fig. 4 b), and the dose reduction can be seen in the right anterior corner of prostate (pink contour). The method allowed prostate movement induced D95 reductions to be analyzed per fraction series. Assuming a stationary prostate for the other four fractions, D95 reductions for the five patients were 7.6, 19.4, 0.3, 0.1 and 4.4 %. This represents a minimum error for the treatment. With prostate movement in more than one fraction the effect on the dose distribution would be even larger. Rectum average dose increased or decreased depending on the direction of prostate movement, the largest increase being 8.8 %. Bladder average doses always descended with a maximum of 80 %.

Fig. 4. Time series of prostate movement for two patients. Red and green stripes represent beam on times used by the dose reconstruction script.

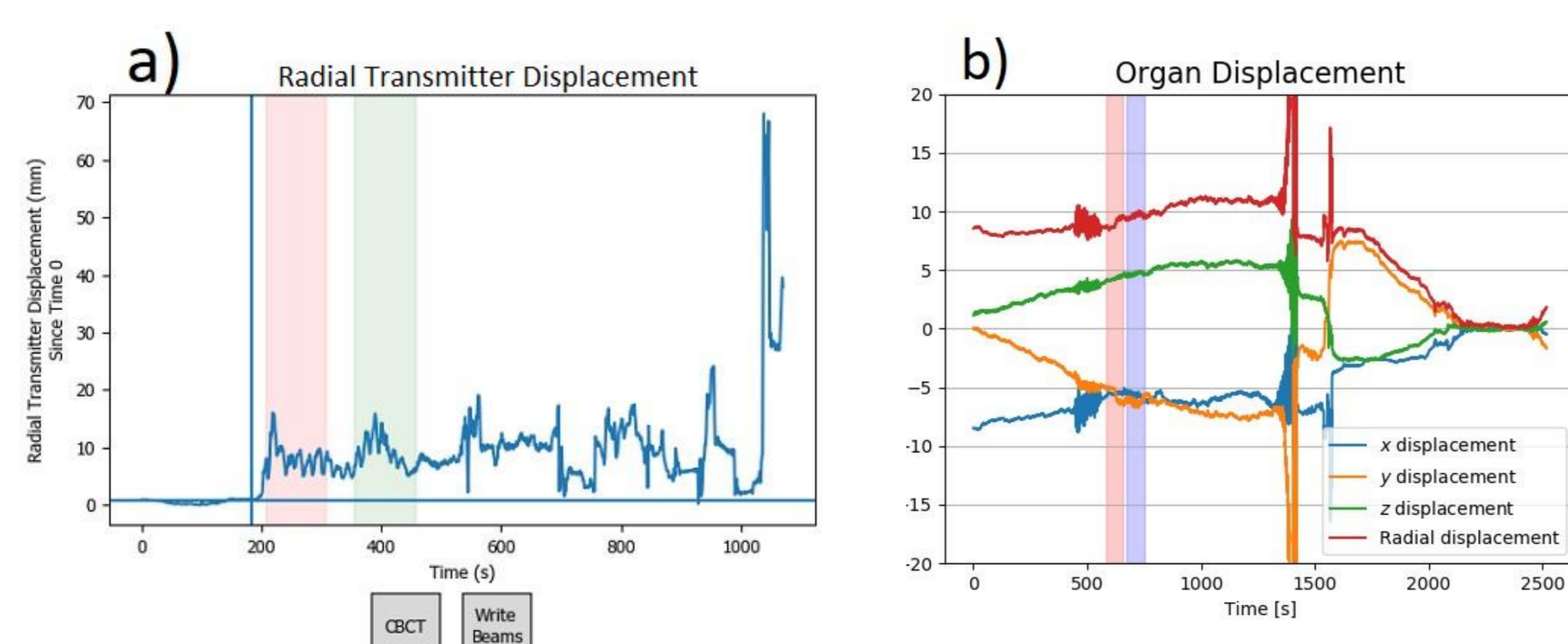
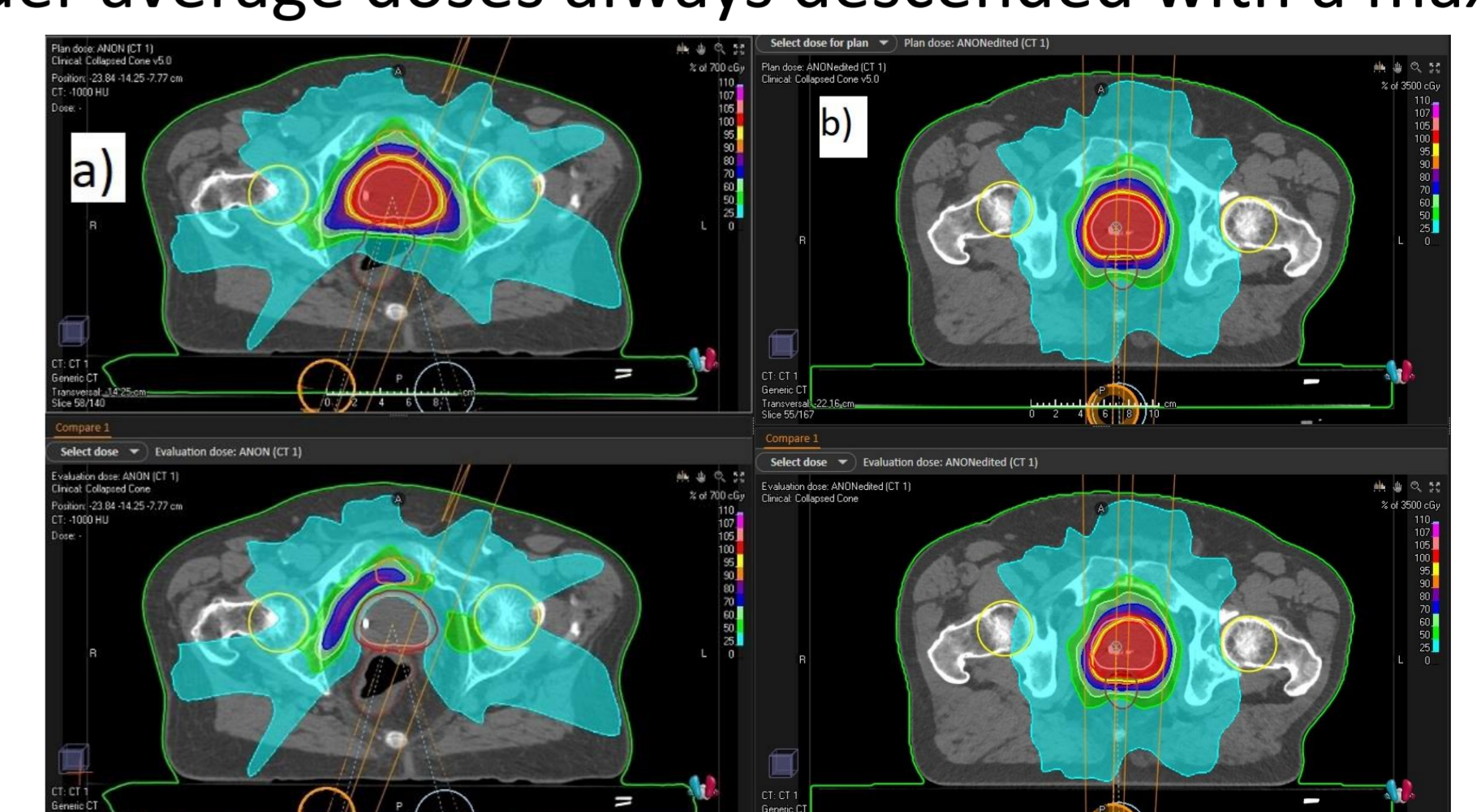


Fig. 5. Original (upper) and reconstructed (lower) dose distributions for two patients. Panels a) and b) correspond to the time series given in Fig. 4.



References

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