On a New Approach to Reconstruct the Patient Dose from Phantom Measurements

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Background

The development of complex radiation treatment schemes emphasizes the need for advanced QA analysis methods to ensure patient safety. One such tool is the Delta4 DVH Anatomy software, where the patient dose is reconstructed from phantom measurements. Deviations in the measured dose are transferred to the patient anatomy and their clinical impact is evaluated *in situ*. Results from the original algorithm revealed weaknesses that may introduce artefacts in the reconstructed dose. These can lead to false negatives or obscure the effects of minor dose deviations from delivery failures, see for example [1].

As a means to address said weaknesses, a new patient dose reconstruction algorithm (DRA) has been developed.

Method

The main steps of the improved DRA are:

1. The dose delivered to a phantom is measured in a number of detector positions.
2. The measured dose is compared to an internally calculated dose distribution in said positions.
3. The so-obtained dose difference is used to calculate an energy fluence difference.
4. The fluence difference is used as input to a patient dose correction calculation routine.
5. Finally, the patient dose is reconstructed by adding said patient dose correction to the planned patient dose.

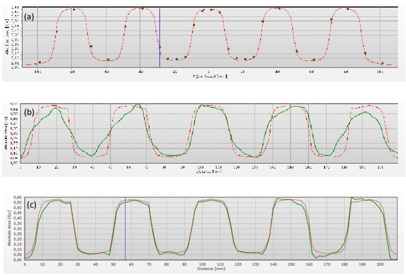
The internal dose calculation in step 2. and 4. is in the current version based on the Pencil Beam (PB) algorithm [2]. Since the PB algorithm is used to calculate corrections that are relatively small in magnitude the DRA is more or less independent of the TFS dose calculation algorithm.

Conclusions

The improvements in the dose reconstruction algorithm leads to a reduction in non-physical artefacts in the reconstructed patient dose. As a consequence, the possibility to detect deviations in the dose delivered to the patient is improved.

Results Bar Pattern

This case is reported in [1]. A Plastic Water slab is irradiated with a bar pattern shaped field. The delivered dose has strong gradients in the penumbra regions.



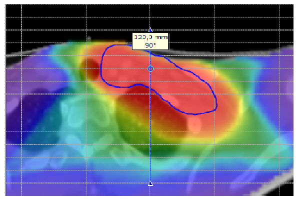
(a) Dose profile along the central axis of the Delta4 phantom. The red line show the planned phantom dose and the green markers show measured detector doses. (b) Dose profile of the old DRA dose, planned dose in red and reconstructed dose in green. (c) Dose profile of the new DRA dose, planned dose in red and reconstructed dose in green. For (b) and (c), the dose profiles are drawn in the inline direction of the field at 100 mm depth. The new DRA improves the quality of the reconstructed dose dramatically. Nevertheless, some detector resolution artefacts are still present in the low resolution regions (picture (c) far left and far right).

Results H&N patient

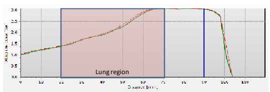
The H&N patient has a target in the upper thorax region. The target surroundings consists of inhomogeneous tissue such as bone and lung tissue.

PTV Gamma (3%/3mm)		
Phantom DRA	Old Patient DRA	New Patient DRA
99.7%	72.9%	96.6%

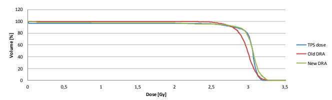
Gamma (3%/3mm) metric for the PTV of the H&N patient. The new dose reconstruction algorithm (DRA) improves the metric significantly.



Transversal view of the target with the dose profile defined along the dashed blue line. The blue circle indicates the position of the blue cursor in the dose profile below.



Dose profile through the patient. Reconstructed dose in green and TPS planned dose in red. As expected, a slight underdose can be seen in the lung region.



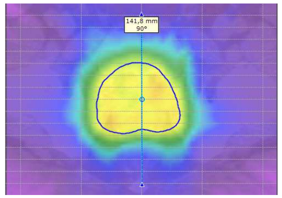
The blue line is the DVH for the TPS dose, the red line is the DVH for the old DRA dose and the green line the DVH for the new DRA dose. The new DRA dose shows better agreement with the planned dose and is less affected from reconstruction artefacts than the old DRA dose (the relatively shallow slope of the red line is a reconstruction artefact).

Results Prostate patient

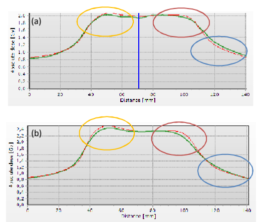
The prostate patient has a target situated in the pelvic region. The surroundings of the target consists of are fairly homogeneous tissue.

PTV Gamma (3%/3mm)		
Phantom DRA	Old Patient DRA	New Patient DRA
92.1%	92.2%	92.5%

Gamma (3%/3mm) metric for the target PTV prostves of the Prostate patient.



Transversal view of the target with the dose profile defined along the dashed blue line. The blue circle indicates the position of the blue cursor in the dose profile below.



Vertical dose profile through the target in the patient geometry (a) and phantom geometry (b). Reconstructed dose in green and TPS planned dose in red. The artefacts shown in the phantom geometry is qualitatively reconstructed in the patient geometry.

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Conflict of interest:

Erik Bängtsson is an employee of ScandiDos AB.

References:

[1] Stambaugh et al., *Evaluation of semiempirical VMAT dose reconstruction on a patient dataset based on biplanar diode array measurements*, Journal of Applied Clinical Medical Physics, 2014 15(2), pp. 169-180.
[2] Ahnesjö A., Saxner M., Trepp.A, *A pencil beam model for photon dose calculation*, Medical Physics, 1992 19(2), pp. 263-273.