Replacement of EPID-based patient-specific QA by treatment analysis software

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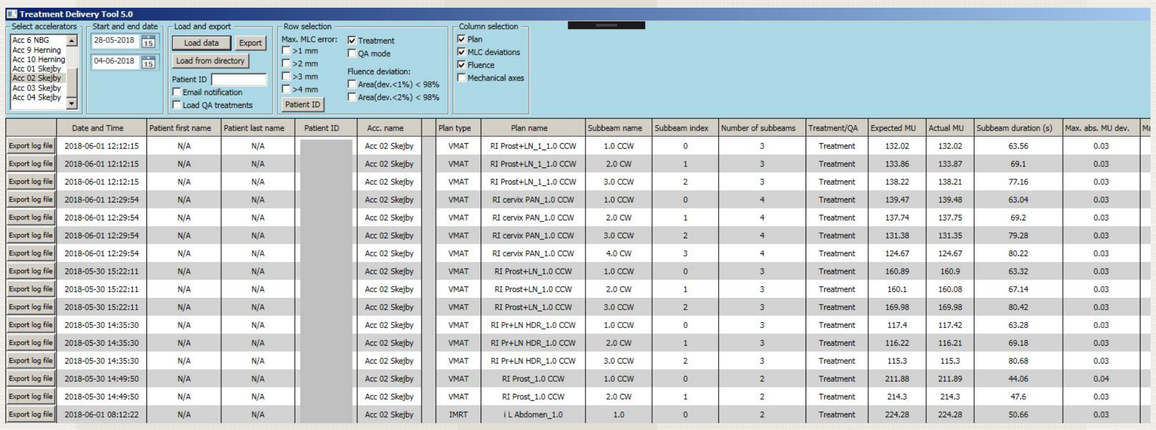
Introduction

Often radiotherapy centers perform QA of IMRT and VMAT plans by delivering the plans to the EPID (Electronic Portal Imaging Device) and comparing the measured dose to the calculated dose by an independent dose calculation engine prior to treatment. However, this procedure is both time consuming and reduces the patient throughput because the whole treatment must be delivered and measured using a clinical accelerator. In addition, noise and drift of the EPID response require considerable extra resources to investigate false dose deviations and to perform repetitive EPID measurements. Accordingly, there is a need for a more streamlined QA approach with the same level of patient safety.

Methods

The Treatment Delivery Tool is an in house-developed C# application (see figure 1) that can analyze both Varian Clinac and Varian TrueBeam treatment delivery log files. For each treatment the expected/actual fluence is calculated using the expected/actual MLC positions and the expected/actual MU for each time step in the log file, and the fluence deviation between the expected/actual fluence is quantified by the area fraction with <2 % dose deviation (metric 1) and the gamma 2 %/2 mm index (metric 2). In addition, the application calculates all key technical parameters of the treatment delivery (e.g. max. MLC deviation, max. MU deviation, max. MLC speed, and MLC modulation of the plan).

Each day the Treatment Delivery Tool automatically analyzes all treatments from the previous day for 8 Varian Clinac and 4 Varian TrueBeam accelerators and sends an e-mail alert if metric 1 is below 98 %.



	Date and Time	Patient first name	Patient last name	Patient ID	Acc. name	Plan type	Plan name	Subbeam name	Subbeam index	Number of subbeams	Treatment/QA	Expected MU	Actual MU	Subbeam duration (s)	Max. abs. MU dev.
Export log file	2018-06-01 12:12:15	N/A	N/A		Acc 02 Skejby	VMAT	RI Prost+LN_1_1.0 CCW	1.0 CCW	0	3	Treatment	132.02	132.02	63.56	0.03
Export log file	2018-06-01 12:12:15	N/A	N/A		Acc 02 Skejby	VMAT	RI Prost+LN_1_1.0 CCW	2.0 CW	1	3	Treatment	133.86	133.87	69.1	0.03
Export log file	2018-06-01 12:12:15	N/A	N/A		Acc 02 Skejby	VMAT	RI Prost+LN_1_1.0 CCW	3.0 CCW	2	3	Treatment	138.22	138.21	77.16	0.03
Export log file	2018-06-01 12:29:54	N/A	N/A		Acc 02 Skejby	VMAT	RI cervix PAN_1.0 CCW	1.0 CCW	0	4	Treatment	139.47	139.48	63.04	0.03
Export log file	2018-06-01 12:29:54	N/A	N/A		Acc 02 Skejby	VMAT	RI cervix PAN_1.0 CCW	2.0 CW	1	4	Treatment	137.74	137.75	69.2	0.03
Export log file	2018-06-01 12:29:54	N/A	N/A		Acc 02 Skejby	VMAT	RI cervix PAN_1.0 CCW	3.0 CCW	2	4	Treatment	131.38	131.35	79.28	0.03
Export log file	2018-06-01 12:29:54	N/A	N/A		Acc 02 Skejby	VMAT	RI cervix PAN_1.0 CCW	4.0 CW	3	4	Treatment	124.67	124.67	80.22	0.03
Export log file	2018-05-30 15:22:11	N/A	N/A		Acc 02 Skejby	VMAT	RI Prost+LN_1.0 CCW	1.0 CCW	0	3	Treatment	160.89	160.9	63.32	0.03
Export log file	2018-05-30 15:22:11	N/A	N/A		Acc 02 Skejby	VMAT	RI Prost+LN_1.0 CCW	2.0 CW	1	3	Treatment	160.1	160.08	67.14	0.03
Export log file	2018-05-30 15:22:11	N/A	N/A		Acc 02 Skejby	VMAT	RI Prost+LN_1.0 CCW	3.0 CCW	2	3	Treatment	169.98	169.98	80.42	0.03
Export log file	2018-05-30 14:35:30	N/A	N/A		Acc 02 Skejby	VMAT	RI Pr+LN HDR_1.0 CCW	1.0 CCW	0	3	Treatment	117.4	117.42	63.28	0.03
Export log file	2018-05-30 14:35:30	N/A	N/A		Acc 02 Skejby	VMAT	RI Pr+LN HDR_1.0 CCW	2.0 CW	1	3	Treatment	116.22	116.21	69.18	0.03
Export log file	2018-05-30 14:35:30	N/A	N/A		Acc 02 Skejby	VMAT	RI Pr+LN HDR_1.0 CCW	3.0 CCW	2	3	Treatment	115.3	115.3	80.68	0.03
Export log file	2018-05-30 14:49:50	N/A	N/A		Acc 02 Skejby	VMAT	RI Prost_1.0 CCW	1.0 CCW	0	2	Treatment	211.88	211.89	44.06	0.04
Export log file	2018-05-30 14:49:50	N/A	N/A		Acc 02 Skejby	VMAT	RI Prost_1.0 CCW	2.0 CW	1	2	Treatment	214.3	214.3	47.6	0.03
Export log file	2018-06-01 08:12:22	N/A	N/A		Acc 02 Skejby	IMRT	i L Abdomen_1.0	1.0	0	2	Treatment	224.28	224.28	50.66	0.03

Figure 1: List of delivered treatment fields in the Treatment Delivery Tool.

Results

Table 1 shows an overview of the significant fluence deviations detected over a period of 8 months, and figure 2 and 3 shows examples of fluence deviations during dynamic treatment. The fluence deviation in figure 2 is also measured with EPID-based QA as shown in figure 4. A good agreement between the fluence deviation measured by the EPID and the Treatment Delivery Tool is observed, however, the log file-based detection is much more accurate.

For static treatments a small MLC deviation of only 0.1 mm produces a significant fluence deviation at the field edge. This is the cause for the many small static fields in table 1 as the field edge occupy a large fraction of the field area for a small field. The many fluence deviations for small fields has revealed many inappropriate positions of closed MLC pairs, too large MLC-to-jaw margins, and very small treatment fields (<1 cm) that are not correctly modeled in the dose planning system.

Accelerator	Varian Clinac	Varian Clinac	Varian TrueBeam	Varian TrueBeam
Fluence deviation tolerance	Metric 1 < 98 %	Metric 2 < 98 %	Metric 1 < 98 %	Metric 2 < 98 %
Number of static fields	-	-	341 (1.46 cm)	23 (0.78 cm)
Number of dynamic fields	18	0	1	0

Table 1: Number of delivered fields with a significant fluence deviation over a 9 month period. For static treatments the average effective length of the field is also indicated.

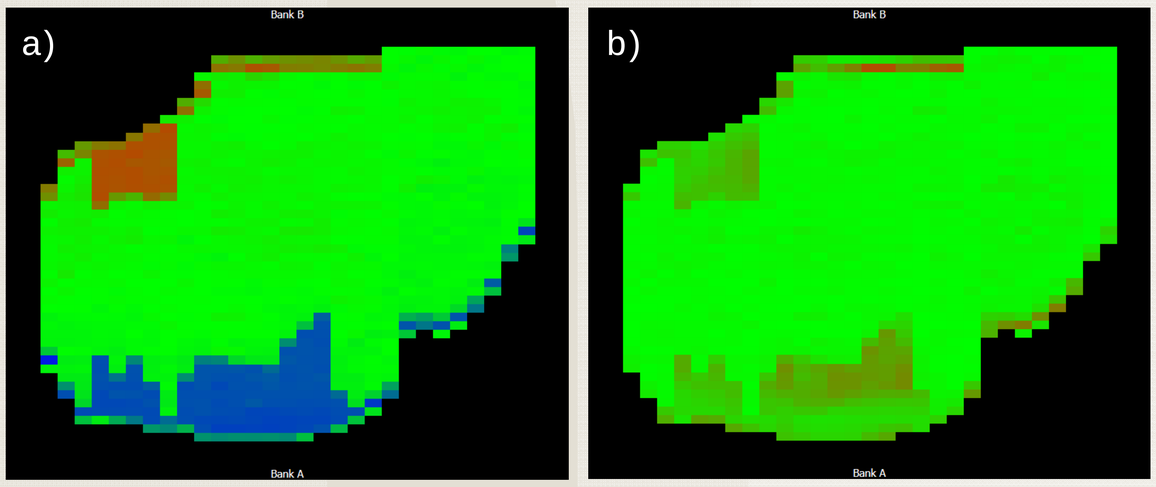


Figure 2: Fluence deviation of IMRT treatment due to position errors of MLC for a Varian Clinac. a) Color wash. b) Gamma evaluation.

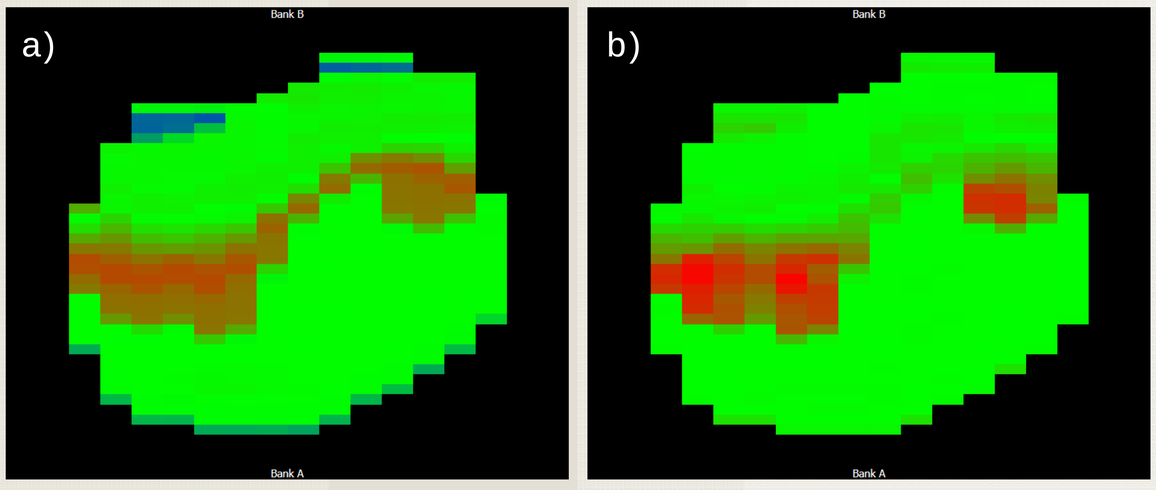


Figure 3: Fluence deviation of IMRT treatment due to a MU error for a Varian TrueBeam. a) Color wash. b) Gamma evaluation.

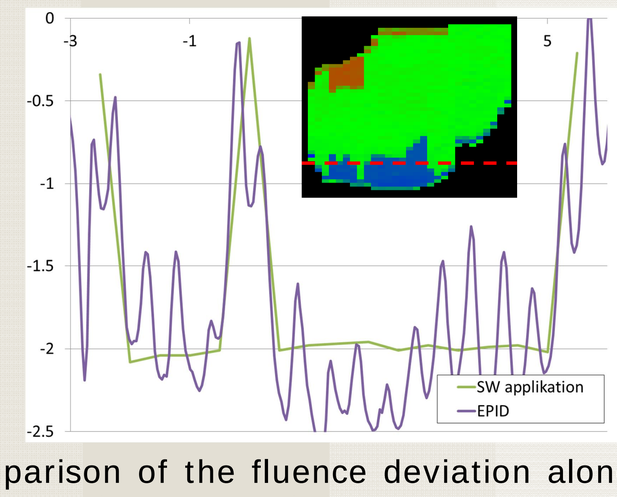


Figure 4: Comparison of the fluence deviation along the dotted red line measured with the EPID and the Treatment Delivery Tool.

The Treatment Delivery Tool is the final step in a complete patient-specific QA workflow. The other parts are an Eclipse (Varian, USA) API checking the plan quality, an independent dose calculation by MobiusCalc (Mobius, USA) in order to verify the dose calculation by Eclipse, and a comprehensive accelerator QA program in order to ensure a good agreement between treatment delivery and log file data.

Conclusion

The Treatment Delivery Tool is an effective and accurate tool for detecting dose delivery errors. The complete patient-specific QA workflow including the Treatment Delivery Tool is very efficient and provides the same level of patient safety as for EPID-based patient-specific QA.