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Analysis of Trajectory Log Files of TrueBeam Medical Electron Linear Accelerator for Patient Specific IMRT QA

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Abstract

Aim: To demonstrate trajectory log files of TrueBeam medical electron linear accelerator as patient specific IMRT QA tools.

Materials and Methods: Twenty six IMRT fields treated using Truebeam medical electron linear accelerator (LINAC) comprising different clinical cases were selected and analysed using software tools were developed to: (i) extract useful information from the trajectory log binary file of Truebeam accelerator, (ii) compare leaf positions derived from trajectory log data,(iii) calculate fluence from the expected and actual leaves positions, and (iv) plot the error histogram from the expected and actual fluence, for patient specific QA.

Results: The percentage error in fluence calculated from expected and actual leaves positions are almost negligible. In all the cases studied, median and mode of percentage errors are zero while mean ranges from -0.01 to 0.003. Minimum and maximum values of percentage error are in range of -1.1 to 1.04.

Conclusions: Software tools were developed to analyse the MLC Log files of True beam LINAC as patient specific QA in IMRT. The based fluence map estimated through log files analysis shows that the dose delivered to the patient by the Truebeam LINAC is highly accurate. This tool can be used as patient specific IMRT QA for other medical LINAC as well.

Keywords: IMRT; Trajectory log file; Patient Specific IMRT QA.

Introduction

Intensity modulated radiotherapy (IMRT) is a complex radiotherapy process and demand stringent quality assurance (QA) process for whole chain of radiotherapy process [1-6]. Especially pre-treatment dose verification commonly known as patient specific dosimetry QA is carried out by almost all the IMRT practicing radiotherapy centre [7]. QA process for IMRT implementation in clinical practice can be divided in three groups: (1) Commissioning of the IMRT system which includes planning system (TPS) parameter adjustment, dosimetric tests with different phantoms, adjustment of the delivery system and tests of the data transfer; (2) Regular machine related quality assurance procedures which comprise mechanical precision of static test fields or mechanical and dosimetric precision of dynamic test fields; and (3) Regular patient related quality assurance procedures which involve dosimetric plan verification, dosimetric field by field verification and independent monitor unit (MU) checks.

First two QA programs are standard in nature and must be followed for beam delivery devices even without IMRT/ volumetrically modulated radiotherapy (VMAT) capabilities. The most common IMRT error includes error in calibration or commissioning of treatment planning and delivery system, wrong field data transfer etc. In an ideal situation, TPS used for IMRT are designed and commissioned to accurately simulate the beam delivery system; Machine QA programme for MLC calibration and known mechanical problems for each MLC and delivery type and Patient-specific QA focuses on potential clinical errors. To avoid patient specific potential clinical error, measurement based patient specific IMRT QA is performed [8-13]. It is performed only for limited number of times and requires considerable time of delivery system as well as of medical physicist. However, patient specific clinical errors can occur at any time during the course of treatment. If the treatment planning system has been commissioned suitably for IMRT and adequate periodic machine QA for IMRT are in place, measurement based patient specific IMRT QA can be replaced with software based IMRT QA for some radiotherapy equipments. Trajectory log file which is `free information' and can be harvested for purposes of documenting individual patient treatments. Data in log files does not require any additional time or dose for the patient. Data in log file can be analysed off-line for IMRT QA purposes. Log file data have been explored for QA by a number of researchers [14-17]. However limited information is available on the TrueBeam trajectory log file generated fluence map based IMRT QA. This paper describes the method of IMRT QA by comparing the fluence calculated from expected leaves positions and actual leaves positions derived from trajectory log file.

Materials and Methods

The QA studies were performed using Trajectory Log file generated by Truebeam medical electron linear accelerator (Varian Medical Systems, Palo Alto, California). Truebeam control system generates a trajectory log file which records the actual axis position and delivers MUs at periodic intervals of 20 ms along with their expected values. The system is configured to record 60,000 data sets for a period of 20 minutes at an interval of 20 ms. The trajectory log file stores data in a binary format which needs to be converted into a readable format for intended application. A single binary file generated includes information about expected and actual values of gantry angle, collimator angle, jaws positions, couch position, delivered dose in MU, beam status, control points, carriage position and MLC leaf positions. The file records the linear dimensions in cm, rotational scale in degree and dose in MU. The leaf positions stored in the trajectory log file are the position of leaves at isocentre. After each dynamic MLC (DMLC) field delivery the trajectory log file for that particular field is written to a file on the control system computer. There is no trajectory log file recorded when the beam is paused either due to minor fault or user interruption by pressing beam off button. A complete file description may be found elsewhere [18]. In this study, software tools were developed to:

(i) Extract useful information from the trajectory log binary file of Truebeam accelerator,

(ii) Compare leaf positions derived from trajectory log data,

(iii) Calculate fluence from the expected and actual leaves positions, and

(iv) Plot the error histogram from the expected and actual fluence.

Twenty six IMRT fields treated using Truebeam medical electron linear accelerator (LINAC) comprising different clinical cases were selected and analysed using above mentioned tools for patient specific QA.

Results and Discussion

Figure 1 shows the fluence map derived from the expected leaves positions while Figure 2 presents the fluence map derived from actual leaves position recorded in trajectory log file of an IMRT treatment field.

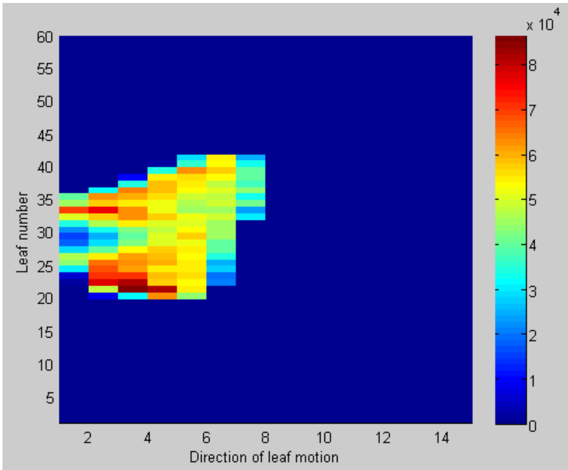


Figure 1: Fluence map derived from the expected leaves positions.

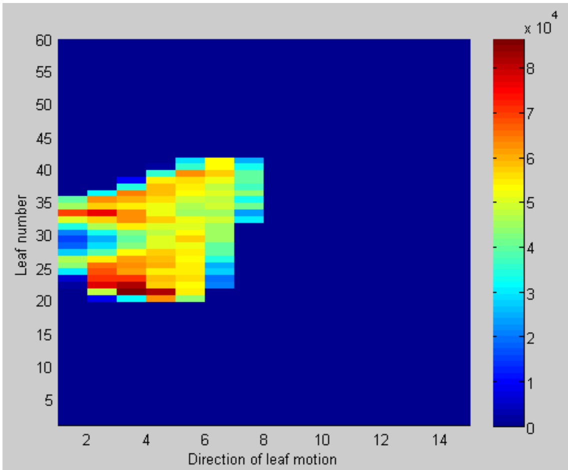


Figure 2: Fluence map derived from the actual leaves positions.

Figure 3 presents the percentage error between fluence derived from expected leaves positions and actual leaves positions.

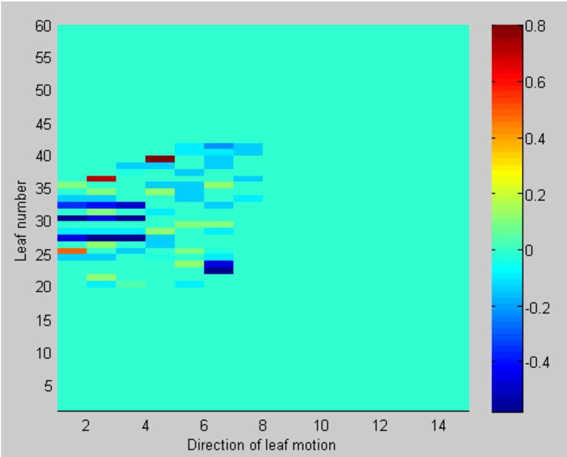


Figure 3: Percentage error in fluence map derived from the actual and expected leaves positions.

Figure 4 shows error between fluence derived from expected leaves position and actual leaves positions.

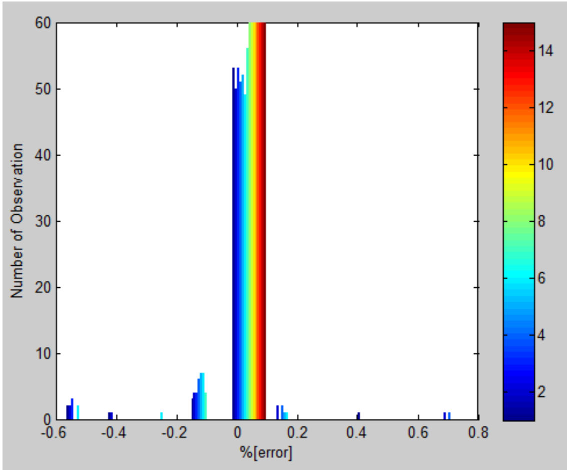
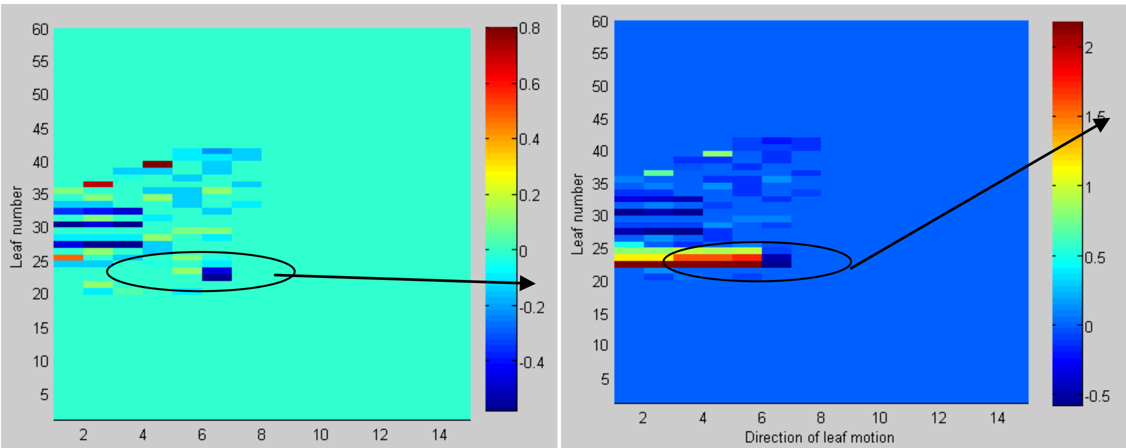


Figure 4: Histogram showing difference in fluence derived from the actual and expected leaves positions.

To validate the developed software tool, intentional errors in leaves positions were introduced and fluence was calculated. Figure 5 shows the percentage error in fluence derived from the actual and expected leaves positions with and without intentional errors.

Figure 5: Difference in fluence map derived from the actual and expected leaves positions (a) without intentional error (b) with intentional error.



(a) (b)

.The circled zone indicates the region where error was introduced and it is being clearly visible in the fluence map. This validation gives confidence that developed tools are working for the intended purpose. Minimum, maximum, mean, median and mode of percentage errors between expected and actual fluence for twenty six IMRT field treated by Truebeam accelerator are shown in Table 1. It can be observed from the data in this table that the percentage error in fluence calculated from expected and actual leaves positions are almost negligible. In all the cases studied, median and mode of percentage errors are zero while mean ranges from -0.01 to 0.003. Minimum and maximum values of percentage error are in range of -1.1 to 1.04. The error between expected and actual leaves positions are found to be as expected. These results indicate that the leaves positions are well monitored in the Truebeam LINAC using reliable control system. It is also important to add here that these IMRT fields were found acceptable for patient treatment through conventional patient specific QA methods (such as gamma analysis using 2D detector system).

However, the log files based analysis can be performed with every treatment field without giving extra dose to the patient as well as without taking extra machine time.

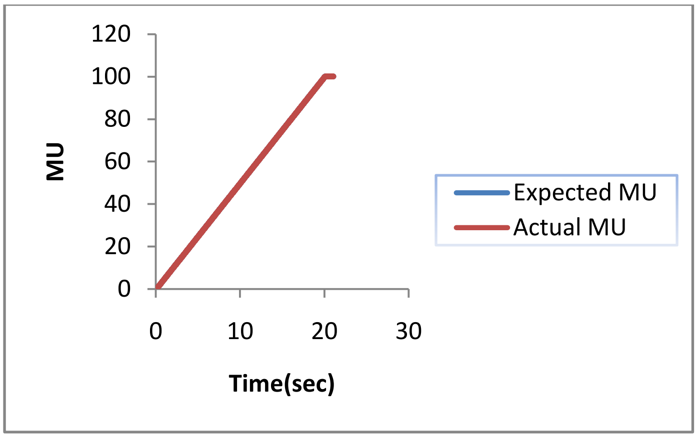


Figure 6: Variation of expected and actual Monitor Unit (MU) with time.

Figure 6 shows the plot of the expected and actual MU with respect to the time. It is observed from this plot that the expected and actual MU with respect to the time is matching very well. There are no noticeable variations in the expected and actual MU. Similar results were observed for other field also. In this way, each treatment field can be verified without extra machine time and error due to MLC leaves positions can be eliminated.

Table 1: Relative percentage error between expected and calculated fluence for Truebeam medical electron linear accelerator.

Treatment Field	Relative percentage error between expected and delivered fluence				
	Minimum	Maximum	Mean	Median	Mode
1	-0.8	0.15	0.0030	0	0
2	-1.3	0.71	-0.0100	0	0
3	-0.65	1.00	0.0010	0	0
4	-0.61	0.84	-0.0020	0	0
5	-0.22	1.04	-0.0004	0	0
6	-0.57	0.81	-0.0004	0	0
7	-0.16	0.16	-0.0030	0	0
8	-0.14	0.14	-0.0030	0	0
9	-1.1	0.55	-0.0044	0	0
10	-0.72	0.46	-0.0013	0	0
11	-0.68	0.53	-0.0023	0	0
12	-0.73	0.91	-0.0011	0	0
13	-0.62	0.28	-0.0017	0	0
14	-0.79	0.97	0.0002	0	0
15	-1.02	0.74	-0.0084	0	0
16	-0.15	0.26	-0.0008	0	0
17	-0.67	0.15	-0.0040	0	0
18	-0.97	0.13	-0.0050	0	0
19	-0.64	0.34	-0.0031	0	0
20	-0.87	0.87	-0.0030	0	0
21	-0.67	0.49	-0.0030	0	0
22	-1.18	0.67	-0.0028	0	0
23	-1.28	0.46	-0.0070	0	0
24	-0.47	3.18	0.0013	0	0
25	-0.17	1.35	0.00052	0	0
26	-0.58	0.8	0.0070	0	0

Conclusions

Software tools were developed to analyse the MLC Log files of Truebeam LINAC as patient specific QA in IMRT. The based fluence map estimated through log files analysis shows that the dose delivered to the patient by the Truebeam LINAC is highly accurate. This tool can be used as patient specific IMRT QA for other medical LINAC as well.

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