

A decision support tool to optimize IMRT QA workflow in a multi-vendor equipment environment

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Abstract. Development of a software tool to ease the Intensity Modulated Radiation Therapy (IMRT) pre-treatment Quality Assurance process is presented in this study. The delivery of IMRT involves equipment from multiple vendors. The limitations of the equipment involved in this chain will impact on the best choice of equipment. This often results in the user needing to use multiple pieces of equipment before determining the most appropriate choices to optimise the QA work flow. This is a time consuming process and potentially delays the start of patient treatment. Software was developed in-house to assist the decision making process, validating deliverability of beam delivery parameters and selecting appropriate detector systems and configuration for QA of IMRT plans. The software has been demonstrated to be accurate and improves efficiency of IMRT pre-treatment QA.

1. Introduction

Intensity Modulated Radiation Therapy (IMRT) involves equipment from multiple vendors at various stages of the treatment course such as treatment planning, Quality Assurance (QA) and treatment delivery. Due to the complex nature of this treatment technique plan specific pre-treatment dosimetric verification is highly recommended to ensure the accurate and safe delivery of treatment[1]. Dose verification of IMRT plans is performed using a combination of 1D, 2D or 3D detector systems. In this process the patient plan is recalculated on the phantom image dataset and the phantom and detector position is optimised to cover the entire treatment field. The phantom position on treatment machine is derived during this process. Extensive dosimetric verification of IMRT plans is an essential component of IMRT to validate the accuracy of dose calculations performed by the planning system and treatment delivery by the Linear accelerator (linac). In the clinic routine pre-treatment verification is optimised to simple measurement geometry for efficient workflow. This optimisation process should be supported with sufficient experience and confidence, backed by detailed dose verification, on the Treatment planning System (TPS) and delivery system[2].

IMRT pre-treatment QA on a per beam basis using an Electronic Portal Imaging Device (EPID) has been shown to be more efficient in routine clinical practice[3]. Many approaches are in practice to convert an EPID image into dose matrix[4]. In simpler approaches EPID images are converted in to



dose images at the isocentre plane using appropriate calibration factors and the corresponding dose matrices are calculated in the TPS on a hypothetical phantom[5]. The EPID mount system on different vendor linacs offers different degrees of movement in-order to accommodate a range of field sizes and field asymmetries. If the field size exceeds the EPID measurement area the system triggers an interlock to avoid irradiation of the electronics section of the EPID. In practice the appropriate EPID position is identified at the treatment machine for each field. This consumes time for each patient dataset due to possible different EPID positional configurations available on different linacs. Further occasionally TPSs calculated IMRT field segments violate MLC motion limitations. Often this is not identified until the pre-treatment verification process causing delay in both QA and the initiation of patient treatment.

In this study we present an in-house software tool that identifies the presence of undeliverable segments in an IMRT beam. The developed software also predicts the appropriate EPID position configuration by considering the IMRT field size and vendor specific position limitations.

2. Materials and Methods

2.1. Multi-vendor equipment environment

South Western Sydney Local Health District (SWSLHD) provides a cancer treatment service to the south west region of Sydney, Australia through Liverpool Cancer Therapy Centre (LCTC) and Macarthur Cancer Therapy Centre (MCTC). The radiation oncology department in these centres includes radiation treatment equipment from a range of vendors. The distribution of TPSs and linacs used in these centres for our IMRT programme is shown in figure 1. Routine pre-treatment IMRT verification in our centres is performed using the Electronic Portal Imaging Device (EPID) associated with the linacs. If the field size of the IMRT beam exceeds the active area of the EPID verification is performed using the IMRT MatriXX ion chamber 2D array (IBA Dosimetry GmbH, Germany) to avoid irradiation of the electronics sections of the EPID device. Some of the important characteristics of the Siemens- Oncor (Siemens AG, Inc. Erlangen, Germany) and Elekta – Synergy (Elekta, Inc. Crawley, UK) EPIDs used for IMRT verification are shown in Table 1.

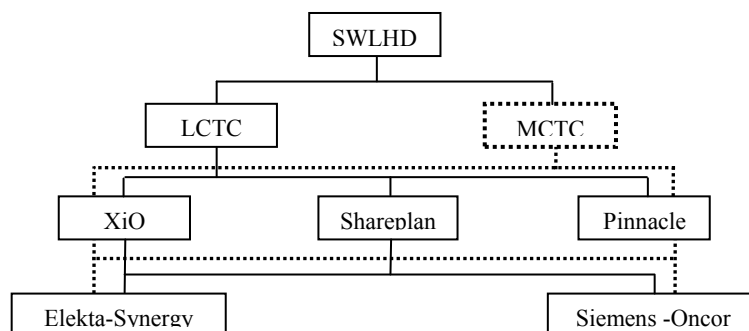


Figure1: Distribution of equipment used for IMRT in SWSLHD

Table 1: Key characteristics of Synergy and Oncor linac EPIDs

EPID physical characteristics	Siemens-Oncor	Elekta-Synergy
Source to detector distance	115cm and 145 cm	160 cm
Maximum field width that can be measured	31.6 cm @ 115cm 25.0cm @ 145 cm	26 cm
Lateral movement of EPID	Not Available	±11.8 cm
Longitudinal movement of EPID	Not Available	±11.8 cm

The beam segments calculated by XiO, version 4.6 (Elekta CMS software, Inc, MO, USA) TPS occasionally include an MLC segment that is not deliverable by the Elekta-Synergy linac. Figure 2 shows a segment of a prostate IMRT plan beam generated by XiO where two MLC leaves are interdigitized in the plan but the Elekta-Synergy MLC does not have this capability. Similarly the segments calculated by Pinnacle version 9.0 (Philips, WI, USA) for the Siemens-Oncon linac occasionally come with Y jaw over travel that is more than the actual Y jaw travel. These issues lead to IMRT beams containing invalid segments which are undeliverable. Usually the presence of invalid segments is identified at the time of pre-treatment QA and this causes a delay in the start of patient treatment.

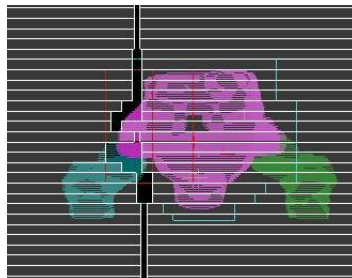


Figure2: Undeliverable IMRT segment generated by the XiO planning system for an Elekta-Synergy linac.

2.2. In-house computer program

In order to identify the presence of undeliverable segments in IMRT fields and to predict suitable QA devices and physical measurement configuration a software tool was developed in-house using the Python language, version 2.6.5. The software reads the treatment delivery file in Radiation Therapy Prescription (RTP) format from any TPS and searches for the presence of segments that violate the position limitations of MLC leaves and jaws in the Elekta-Synergy and Siemens-Oncon accelerators and records the segment number if they are present.

The direct relation of field size defined by $X1, X2, Y1$ and $Y2$ jaw positions in IEC coordinate systems to the detectors active area holds good only for collimator (coll) angle 0° . For coll angles other than 0° the maximum extent of the radiation field on the detector changes due to the rotation of the hypotenuse of the field. Figure 3 shows the change in field vertex co-ordinates due to coll rotation θ° . The co-ordinates of the field vertex due to coll rotation θ° from co-ordinates derived from the IEC system is calculated using equations 1 and 2. From the calculated field vertices the effective extent of the radiation field on the detector is calculated.

$$X^1 = X \cos \theta - Y \sin \theta \quad (1)$$

$$Y^1 = X \sin \theta + Y \cos \theta \quad (2)$$

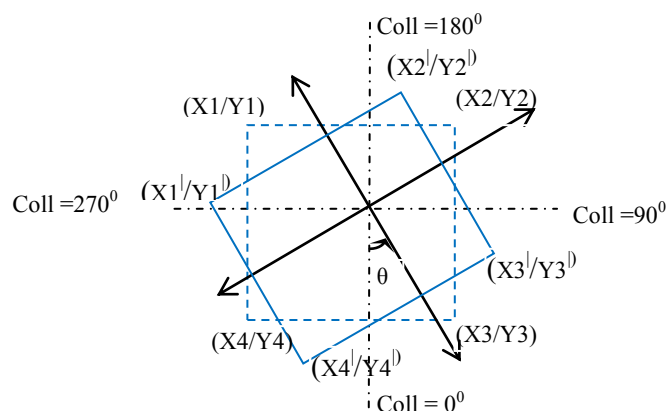


Figure3: Change in co-ordinates of field vertices due to collimator rotation.

The decision tree implemented in the in-house software for the selection of appropriate detectors and the position configuration of the EPID is shown in figure 4. In the decision making process the possible EPID position configurations in Elekta and Siemens linacs (Table 1) and the field vertices calculated using equation 1 and 2 are considered. If the field extent exceeds the active area of the EPID the ion chamber 2D array will be recommended for the measurement. In Elekta linacs the following four EPID configurations are possible based on IMRT field size and collimator angle:

1. A centred position of the EPID and planned collimator and gantry angle for the measurement will be recommended if,

$$|X^i|_i \text{ and } |Y^i|_i \leq 13.0 \text{ cm} \quad (3)$$

Where, $X^i|_i$ and $Y^i|_i$ are the co-ordinates of the field vertices and $i \in \{1,2,3,4\}$.

2. A centred position of the EPID and planned gantry angle with the collimator angle set to 0° will be recommended for measurement if,

$$(|X^i|_i \text{ or } |Y^i|_i > 13.0 \text{ cm}) \text{ and } (|X|_i \text{ and } |Y|_i \leq 13.0 \text{ cm}) \quad (4)$$

3. An off centred position of the EPID and planned collimator and gantry angle will be recommended if

$$(|X^i|_i \text{ or } |Y^i|_i > 13.0 \text{ cm}) \text{ and } (|X|_i \text{ or } |Y|_i > 13.0 \text{ cm}) \text{ and } (FEx \text{ or } FEy \leq 26.0 \text{ cm}) \quad (5)$$

Where, FEx and FEy are the field extents on the detector in X and Y directions. The required EPID offset in lateral and longitudinal directions is calculated as follows

$$\text{Lateral offset} = (X_1^i + X_3^i)/2 \quad (6)$$

$$\text{Longitudinal offset} = (Y_2^i + Y_4^i)/2 \quad (7)$$

4. An off centred position of the EPID and planned gantry angle but collimator set to 0° will be recommended for measurement if

$$(|X^i|_i \text{ or } |Y^i|_i > 13.0 \text{ cm}) \text{ and } (|X|_i \text{ or } |Y|_i > 13.0 \text{ cm}) \text{ and } (Fx \text{ or } Fy \leq 26.0 \text{ cm}) \quad (8)$$

Where, Fx and Fy are the field width and height in X and Y directions. The required EPID offset in lateral and longitudinal directions is calculated using equations 6 and 7 by using field vertices at collimator angle 0° .

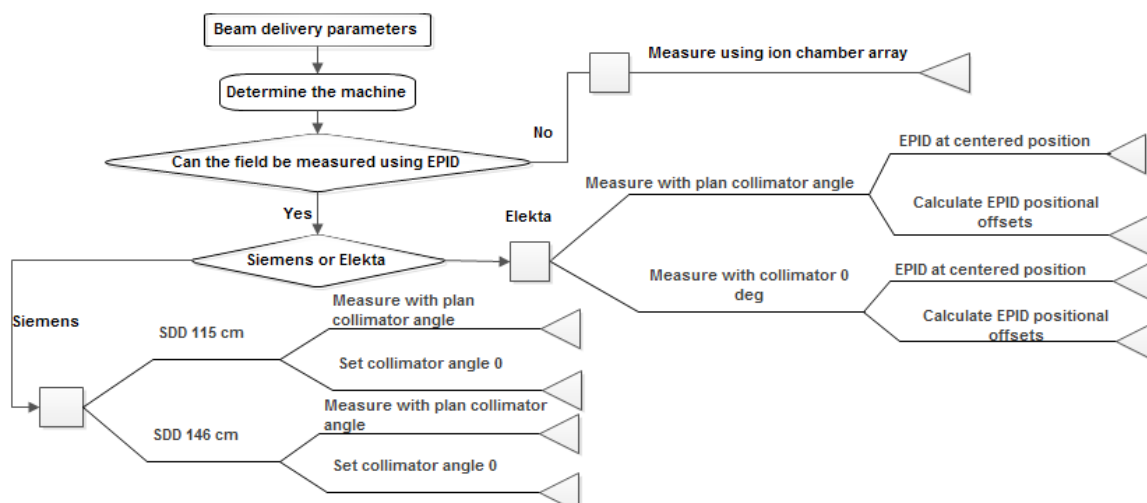


Figure4: Decision tree implemented in the in-house software to select the appropriate detector system and measurement setup considering limitations of equipment and IMRT field size.

In Siemens linacs the following four EPID configurations are possible based on IMRT field size and collimator angle:

1. EPID at 146 cm distance and planned collimator and gantry angle for the measurement will be recommended if,

$$|X^1|_i \text{ and } |Y^1|_i \leq 12.5 \text{ cm} \quad (9)$$

2. EPID at 146 cm distance and planned gantry angle but collimator angle set to 0^0 will be recommended for measurement if,

$$(|X^1|_i \text{ or } |Y^1|_i > 12.5 \text{ cm}) \text{ and } (|X|_i \text{ and } |Y|_i \leq 12.5 \text{ cm}) \quad (10)$$

3. EPID at 115 cm distance and planned gantry and collimator angle will be recommended for measurement if,

$$12.5 \text{ cm} \geq (|X^1|_i \text{ and } |Y^1|_i) \leq 15.8 \text{ cm} \quad (11)$$

4. EPID at 115 cm distance and planned gantry angle but collimator angle set to 0^0 will be recommended for measurement if,

$$[12.5 \text{ cm} \geq (|X^1|_i \text{ or } |Y^1|_i > 15.8 \text{ cm})] \text{ and } [12.5 \text{ cm} \geq (|X|_i \text{ and } |Y|_i \leq 15.8 \text{ cm})] \quad (12)$$

Based on the individual field specific detectors choice and EPID setup the overall action will be presented by the software for efficient measurement of IMRT fields.

3. Results and Discussion

The user interface of the software and its sections provide various options such as treatment delivery file selection, clinic selection, date, planner and physicist name, output report file (in PDF) name and destination selection, display of analysis results and the option to enter additional comments (Figure 5).

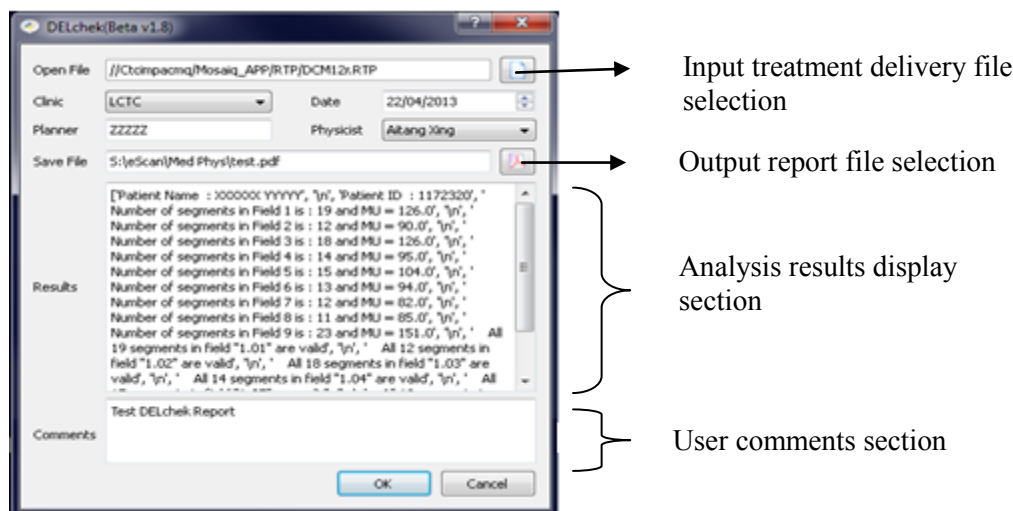


Figure 5: Annotated figure showing various sections of the user interface of in-house software

The software successfully generates the intended report from the treatment delivery file. Figure 6 shows a sample report generated by the software from the treatment delivery file derived from the Pinnacle TPS for a Siemens linac. The patient details, plan details, presence of total number of IMRT and setup fields and presence of total number of prescription and identification of correct treatment delivery machine within the selected clinic have been accurately identified by the software (Plan details section of Figure 6). Similarly the treatment parameter details such as field ID, jaw positions, gantry and collimator angles, beam Monitor Units (MU) and minimum and maximum MU of segments in an IMRT beam also accurately identified by the software from treatment delivery file (Beam parameters section of Figure 6). The total number of segments per beam and deliverability is correctly predicted by the software. In the sample case the presence of an invalid segment (segment no 11) in field ID 1.16 due to violation of the over travel limit of the Y jaw has been accurately detected by the software. The selection of the appropriate detector system (ion chamber array or EPID)

and setup of EPID, is accurately determined by the software considering possible positional options available for EPID of Elekta and Siemens linacs (Segment validity and detector selection section of figure 6). Based on these results the overall recommended action is also presented by the software to escalate the identified issues for corrective action.

DELcheck v1.8

Liverpool and Macarthur Cancer Therapy Centres
Sydney, NSW, Australia.

IMRT Segments Validation and QA-MS Report

WARNING : This analysis confirms only the deliverability of IMRT segments generated for SIEMENS Linear accelerator with 41 pairs of leaves and ELEKTA-SYNERGY Linear accelerator with 40 pairs of leaves. It does not verify the dosimetric accuracy of IMRT fields under any circumstance.

Patient ID : 1172320

Patient Name : XXXX YYYYYY

Plan ID : WEEK3.2

Planning System : Pinnacle3 v 9.0

Number of Prescriptions in this plan : 1

Number of Fields in this plan : 9

Date: 2013-04-22

Clinic: LCTC

Treatment Machine : M3

Model : Oncor

Number of IMRT Fields : 9

Plan details section

Beam summary :

Field ID	Gantry	Coll	X1 / X2	Y1 / Y2	MUs	Min / Max Seg MU
1.12	165.0	10.0	-11.5 / 9.9	-8.0 / 14.0	120.0	4.0 / 19.2
1.13	125.0	14.0	-8.0 / 7.4	-8.0 / 15.0	118.0	5.2 / 13.7
1.14	70.0	13.0	-8.5 / 7.0	-8.5 / 16.0	93.0	4.3 / 15.4
1.15	40.0	10.0	-9.0 / 9.1	-8.5 / 14.5	85.0	4.0 / 10.5
1.16	0.0	0.0	-11.0 / 10.5	-8.0 / 15.5	141.0	6.4 / 14.0
1.17	320.0	350.0	-8.9 / 8.5	-8.5 / 15.5	93.0	5.6 / 13.7
1.18	285.0	345.0	-6.5 / 8.5	-8.0 / 16.0	93.0	4.0 / 11.7
1.19	235.0	350.0	-7.5 / 8.5	-8.0 / 14.5	73.0	4.0 / 13.5
1.20	205.0	355.0	-9.9 / 11.0	-8.0 / 14.0	153.0	4.0 / 17.2

Beam parameters section

Segments Deliverability and measurement suggestion :

Field ID	No. of Segs	Segs validity	Measurement suggestion
1.12	16	All are valid	EPID @ 115 cm with treatment Gantry and Coll
1.13	15	All are valid	EPID @ 115 cm with Gantry and Coll set to "0"
1.14	12	All are valid	Contact Physics for MatrixXX measurement
1.15	16	All are valid	EPID @ 115 cm with Gantry and Coll set to "0"
1.16	16	[11]is Invalid	Contact Physics
1.17	11	All are valid	EPID @ 115 cm with Gantry and Coll set to "0"
1.18	13	All are valid	Contact Physics for MatrixXX measurement
1.19	10	All are valid	EPID @ 115 cm with treatment Gantry and Coll
1.20	19	All are valid	EPID @ 115 cm with treatment Gantry and Coll

Segment validity and detector selection section

Total No. of segms : 128

Recommended Action :

Contact Physics to fix invalid segments

Exclude fields ['1.14', '1.18'] and contact Physics

Recommended action section

Comments :

Test Delcheck report

Comments section

Planner: ZZZZZ

Physicist : Aitang Xing

Figure 6: Annotated figure showing various sections of the report generated by in-house software

4. Conclusion

The software successfully generates a comprehensive report that includes a summary of prescription and beam parameters and identification of undeliverable beam segments if present. It provides a seamless workflow to validate the deliverability of segments and chose appropriate detector system and measurement setup. The introduction of this software tool has increased the efficiency of our pre-treatment IMRT QA process in a multi-vendor environment.

References

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