Optimization of Electronic Portal Imaging Devices (EPIDs) for Small VMAT Fields

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INTRODUCTION

- Due to the complexity and uniqueness of volumetric modulated arc therapy (VMAT) treatment plans, patient-specific pre-treatment quality assurance (QA) is necessary to ensure that the linear accelerator is capable of delivering the planned dose distribution calculated in the treatment planning system (TPS)[1,2]
- A small-field treatment plan is less than 3 x 3 cm^2 and satisfies at least one of three conditions: loss of lateral charged particle equilibrium (LCPE), partial occlusion of the beam source by the collimating system, and the detector size is much larger than the beam dimensions[3,4].
- Ionization chambers are not ideal for small fields due to perturbation effects. The use of EPID for patient specific QA is gradually becoming common in cancer centres due to its simplicity and setup[5]. The gamma analysis developed by Low et al[6] is used to assess and verify a treatment plan before delivery to a patient.

AIM

The purpose of this study is to evaluate and optimize the effectiveness of EPIDs for small field VMAT plans. This is accomplished through optimizing the Portal Dose Image Prediction (PDIP) algorithm for an extended SID.

METHODS

- Standard QA procedures at our institution uses a source-to-imager distance (SID) of 100 cm for all pre-treatment verification plans using a general-purpose Portal Dose Image Prediction (PDIP) algorithm configured at this distance (PDIP Version 13.6, Varian Medical Systems).
- A new PDIP algorithm was configured by generating a new kernel based on measured AIDA fields portal images and output factors measured at an SID=150cm.
- A small field PDIP algorithm was configured at SID = 150cm and output factors for fields < 6x6cm.
- Four SRS brain cancer patient plans were randomly selected for evaluation with 5 scenarios: original general algorithm (SID = 100cm, 150cm), new general algorithm (SID = 100cm, 150cm) and new small-field algorithm (SID = 150cm).
- The patient plans were delivered on Varian TrueBeam linear accelerators (Varian Medical Systems, Palo Alto, CA, USA) equipped with a 120 MLC and an integrated amorphous silicon (aSi) EPID (Varian aS1200: a 43 × 43 cm^2 flat-panel, with a matrix of 1,190 × 1,190 pixels and 0.336 mm pixel resolution).
- Gamma analysis was used to assess the level of agreement between the measured dose and the predicted dose. In short, the γ-index is a quality index used as a numerical measure of agreement or disagreement. For a selected passing criteria of dose-difference and distance-to-agreement (e.g. 3%, 3 mm) a γ-index is generated with a pass-fail criteria (if $\gamma \leq 1$ the calculation passes but if $\gamma > 1$ calculation failed)[6].
- The percentage of the field that satisfies the defined gamma criterion (DD, DTA) is defined as the gamma passing rate (%GP).

RESULTS

- Slightly increased gamma passing rates were observed when portal images were normalized to the central axis (n = 40, mean = 97.0, SD = 5.70) compared to absolute dose (n = 40, mean = 96.0, SD = 9.07), however we fail to reject the hypothesis that the data is significantly different (Paired samples t-test, t = -1.586, p = 0.121, df = 39).
- There is no significant difference between the mean %GP of the algorithms for both fields normalized to the absolute dose (1-way ANOVA, F=0.004, p > 0.05, df =4, 35) and central axis (1-way ANOVA, F=0.217, p > 0.05, df =4, 35)
- The new small field PDIP at SID=150cm provided the most improvement in gamma passing rates for either clockwise or counterclockwise arcs.
- Portal images acquired at SID=150cm inherently have an increased sensitivity due to the increased spatial resolution relative to the field portal at the extended SID.

Table 1. Summary of results. Mean gamma passing rates (%GP) for a gamma criteria of 3% dose difference and 3 mm distance-to-agreement. Values are presented for counter-clockwise (CCW) (n = 4) and clockwise (CW) (n = 4) Arc SRS Brain Treatment Plans, taken at SID = 100cm or SID = 150cm, and normalized to the absolute volume dose or dose at the spatial centre (central axis) of the irradiated area.

Algorithm	SID (cm)	Normalization	%GP CCW	%GP CW	%GP Avg
Original	100	Absolute Dose	99.5 ± 0.3	93.0 ± 11.7	96.3 ± 8.4
		Central Axis	97.9 ± 1.9	95.6 ± 7.9	96.8 ± 5.4
	150	Absolute Dose	99.3 ± 0.5	92.7 ± 13.1	99.0 ± 9.3
		Central Axis	99.8 ± 0.2	96.2 ± 7.4	98.0 ± 5.2
New General	100	Absolute Dose	99.4 ± 0.6	92.2 ± 13.2	95.8 ± 9.5
		Central Axis	96.8 ± 3.1	94.3 ± 9.8	95.5 ± 6.9
	150	Absolute Dose	99.6 ± 0.3	92.0 ± 14.5	95.8 ± 10.3
		Central Axis	98.8 ± 1.1	95.0 ± 9.2	96.9 ± 6.4
New Small Field	150	Absolute Dose	99.8 ± 0.2	92.4 ± 14.5	96.1 ± 10.3
		Central Axis	99.8 ± 0.3	95.8 ± 8.0	97.8 ± 5.7

ALGORITHM COMPARISON

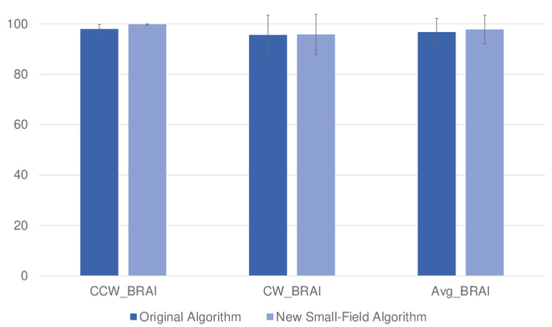

Fig 1. Bar chart comparing gamma passing rates (%GP) of the current algorithm (original at SID=100cm) and proposed new small-field algorithm (SID=150 cm). Doses are normalized to the central axis

PORTAL DOSIMETRY IMAGES

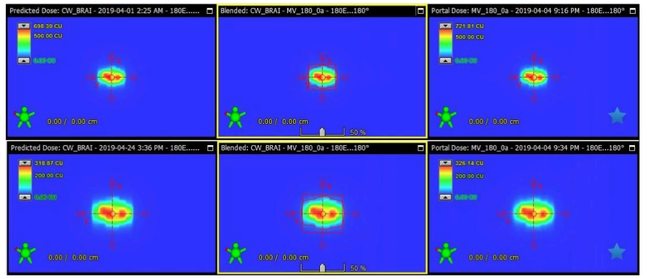

Fig 2. Portal Dosimetry images of a clockwise arc SRS brain treatment plan. From left to right: the predicted dose generated from the PDIP algorithm, predicted dose superimposed on the portal dose delivered by the linear accelerator (linac), and portal dose delivered by the linac. The algorithms presented are (a) the original general algorithm at SID = 100cm and (b) new small-field algorithm at SID = 150cm.

CONCLUSIONS

- Results from this study indicate that an optimal configuration geometry is possible to optimize the pre-treatment QA of small field VMAT plans.
- Although the increase in %GP in the new algorithm is small (1.9% for CCW, 0.2% for CW), this is still clinically significant. For small field brain SRS plans with a prescribed dose of 20 Gy in 1 fraction, a dose difference (i.e. error) of 1% results in a dose of 200 cGy for patients. An increase in the sensitivity of the portal dosimetry system via a more optimal PDIP algorithm will ensure that the correct dose is delivered to the patient, minimizing dose to healthy tissue and organs at risk.
- An extended SID (such as SID = 150cm) provides potential increase in sensitivity and may be more effective for evaluating pre-treatment quality assurance for small field VMAT plans.
- The implementation of a new optimized PDIP algorithm and extended SID for small fields can be achieved without additional resources.
- Limitations to the study include a small sample size. Further optimization of the SID may be required before a full clinical implementation.

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