Validation of forward projected EPID based transit dosimetry for daily In Vivo dosimetry in an automated workflow & evaluation of initial patient data

A.Haughey† M.Sc, S.Gilroy M.Sc and A.Reilly PhD

North West Cancer Centre, Western Health and Social Care Trust, N. Ireland.

Introduction

Radiotherapy has been evolving such that treatment plans and treatment delivery are increasingly complex and it is no longer intuitive to discover potential errors by evaluation of dose levels and field shapes. Therefore, there is increasing focus on performing *in vivo* measurements to verify the dose delivered to the patient and has become mandatory in some countries[1].

EPID based dosimetry has been widely investigated in radiotherapy for the purposes of patient specific pre-treatment quality assurance[2] of plan delivery and more recently for performing *in vivo* dosimetry measurements. EPID dosimetry has the advantages of fast acquisition, high resolution, digital format and using equipment generally already available on the treatment machine for the purpose of patient geometric alignment verification.

Most approaches have focused on back projected methods of transit dosimetry[3]. The Sun Nuclear Corporation (SNC) platform SunCheck utilizes forward projected EPID based absolute dosimetry for in vivo dosimetry which is integrated into an automated workflow such that transit dosimetry can be performed on all patients for every fraction without a burden on the medical physics resource. The transit dosimetry aspect of SunCheck is a recently released feature that we have attempted to validate in terms of dosimetric accuracy, ability to detect patient errors, workflow and resource burden.

Method

The SunCheck platform is configured such that the required data for processing an *in vivo* measurement is obtained by a query retrieve (Q/R) with Aria. During treatment delivery the MV panel deploys and collects an integrated image of the beam delivery. Once a fraction has been completed the Q/R returns the image and log data to SunCheck where the data is processed according to pre-defined criteria. If the tolerance criteria are not met the physicist can be alerted by email.

The EPID panels were calibrated for dosimetry and the PerFraction transit dosimetry calibration was performed involving collection of a set of images with scatter material between the beam and the panel at a range of depths and SSD. This creates a dose-per-signal conversion factor matrix for the panel[4].

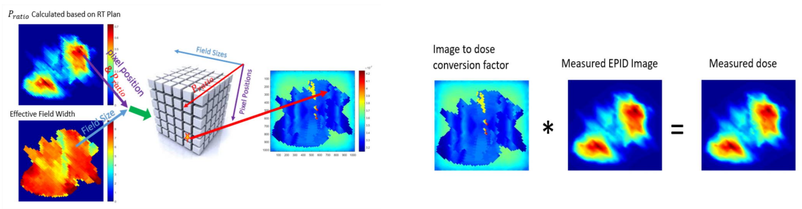


Figure 1: Suncheck calibration process creates a dose conversion matrix for the EPID panel

The expected dose is calculated by PerFraction by creating patient specific factors using the plan file and calibration matrix and projecting the planned beams through the planning CT dataset onto a virtual water slab at the plane of the EPID. The transit dosimetry performs a 2D planar gamma analayis of each individual delivered beam against the expected dose map.

Using a range of anthromorphic phantoms a series of static, IMRT and VMAT plans were created. The plans were delivered with intentional geometric, dosimetric or motion errors and allowed to process in PerFraction

The gamma difference from a plan delivered with no known error and an intention error was calculated and considered to be directly as a result of the intentional error if the difference was greater than 2% (the uncertainty in repeatability of measurements).

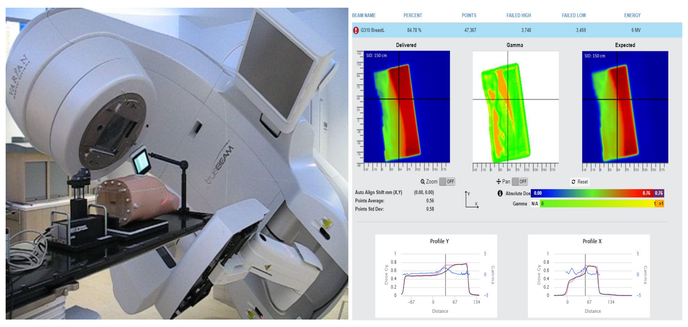


Figure 2:Transit dosimetry assessment of a phantom breast plan on a dynamic platform

Transit dosimetry was performed daily for all breast and palliative patients at NWCC. Patient data was assessed by capturing the gamma scores for delivered treatments in fractions 1-3, 10 and 15 and calculating the average scores and the standard deviations in the score across a treatment course

Results & Discussion

Using phantom measurements we have confirmed that the Suncheck transit dosimetry can detect machine errors such as incorrect MLC leaf position, incorrect beam energy or incorrect output. Patient set-up errors such as incorrect bolus placement, incorrect patient or plan and motion greater than 5mm during treatment are detectable. Geometric set-up errors of 2mm were detectable for static beam deliveries. For VMAT deliveries the transit dosimetry was not sensitive to these errors.

Error	Error Detectable	Sensitivity
Geometric discrepancy	Yes	Static 2 mm VMAT – not sensitive
MLC leaf position	Yes	Static 2mm
Linac Output	Yes	3MU
Correct Energy	Yes	-
Delivery of incorrect plan	Yes	-
Presence of bolus	Yes	5mm static 10mm VMAT
Wrong patient	Yes	-
Motion during treatment	Yes	5mm

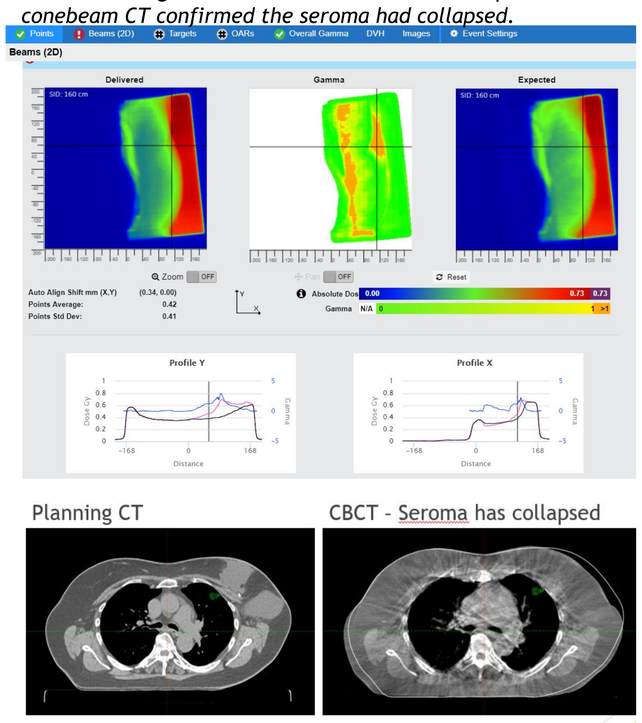
Table 1: Overview of detectable errors with forward planned transit dosimetry and sensitivity to errors

47 breast patients have had transit dosimetry during their course of treatment, including nodal and boost plans. The average gamma score for all fractions analyzed was 94.2 at 4%/4mm. The breast patients typically had a low standard deviation indication that their treatments were consistent throughout their course.

There is commonly a region of gamma points failing along the chest wall which was reproducible on the thorax phantom on a motion platform indicating that breathing motion is responsible for this. The transit dosimetry also detected changes in a seroma and slight variations in patient arm positions. The transit dosimetry is expected to help reduce time spent on performing dose assessments for replans. In challenging set-ups it also provided confidence that the delivered treatment was correct when reviewing the in vivo results just minutes after treatment.

Transit dosimetry for N=57 palliative patients was assessed for their course of treatment. The average gamma score for all fractions analyzed was 91.4 at 4%/4mm. There was some variation between fractions in this patient cohort, partially reflecting less reproducibility in set-up for some sites. Palliative head and neck had less variability between fractions as they are typically well immobilized and reproducible. Mobile gas is a large variable. In pelvis regions where gas varies daily and is therefore different than the planned CT the transit dosimetry gamma scores are typically lower. However, the transit dosimetry has revealed tumour shrinkage in one palliative patient and the impact of set-up variability can easily be assessed.

Figure 3: Fraction 1 transit dosimetry on a breast patient detected changes in the breast contour. A subsequent conebeam CT confirmed the seroma had collapsed.



Gamma Criteria	Average	SD
5%/5mm	97.2	1.2
4%/4mm	94.2	1.9
3%/3mm	88	2.8
Site	4%/4mmAvg	SD
BreastR	93.5	2.1
BreastL	94.1	1.8
SCFAx	95.4	1.6

Table 2: Analysis of N=47 breast patients In Vivo dosimetry. Standard deviation is an average of the standard deviation for individual patients throughout their course of treatment. There is no significant difference seen for right or left sided breast.

Gamma Criteria	Average	SD
5%/5mm	94.1	2.8
4%/4mm	91.4	3.2
3%/3mm	86.8	4.5
Site	4%/4mm Avg	SD
Spine	91.7	3.6
Lung	91.1	5.4
H&N	96.6	0.7
Bone	89.3	1.6

Table 3: Analysis of N=57 palliative patients In Vivo dosimetry. Standard deviation is an average of the standard deviation for individual patients throughout their course of treatment (for treatments of greater than one fraction)

Conclusion

Forward planned transit dosimetry with suitable analysis criteria can detect patient set-up and machine errors that can occur during a patient treatment. The sensitivity of detectable errors is sufficient for most *in vivo* applications. The automated workflow allows this to be utilized for all patients in a busy department.

References

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†aisling.haughey@westerntrust.hscni.net