

Evaluation of Patient-Specific Quality Control (QC) for Markerless Dynamic Tumor Tracking (MDTT) Deliveries

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INTRODUCTION

Dynamic tumour tracking (DTT) for stereotactic ablative radiotherapy (SABR) often requires fiducial marker insertion to localize and verify target positions. The Vero4DRT (Brainlab AG) linac also offers a *markerless* dynamic tumor tracking (MDTT) module which can eliminate the need for fiducial marker insertion by tracking soft tissue targets or other anatomical surrogates. The patient-specific Quality Control (QC) results for marker-based vs *markerless* DTT deliveries can be compared.

AIM

To report on patient-specific QC results for markerless dynamic tumour tracking (MDTT) deliveries in a phantom and compare to conventional marker-based deliveries for liver and lung SABR treatments.

METHOD

- Vero4DRT linac (Figure 1), delivered clinical plans, 5 – 7 fields step-and-shoot IMRT DTT plans to two commercially available motion phantoms, modified with in-house additions.
- Motion platforms were programmed with patient-specific respiratory motion traces acquired at 4DCT.

Vero4DRT quick description

- DTT achieved using a gimbal-mounted waveguide and collimation system
- Motion-correlation models are built between an external IR reflector signal and internal kV fluoroscopy-detected tracking structures (implanted markers or soft-tissue landmarks)
- Verification orthogonal kV image pairs are acquired during DTT delivery (at 1 Hz frequency)
- Image-detected vs model-predicted internal positions recorded in ExacTrac imager log files

Ion chamber point-dose measurement (Figure 2)

A 15 x 15 cm² acrylic phantom was placed on a Brainlab-supplied 1D moving platform. The phantom is equipped with:

- 0.6cc farmer chamber insert
- "Lung tumour" like object (imitation small bird egg) as MDTT tracking structure
- 3 implanted gold-seed fiducials (1 mm x 3 mm)

Film (Gafchromic™ EBT3 2D measurement (Figure 3)

Quasar™ respiratory motion phantom with an in-house acrylic cylindrical insert containing:

- 6.0 x 7.5 cm² film receptacle (coronal plane) with 3 puncture fixtures to mark corners
- "Liver Dome" shaped end-cap as MDTT tracking structure
- 3x gold-seed fiducial markers (1 mm x 3 mm)

Delivery: 5 clinical plans were delivered to both phantoms in the following modes:

- Static mode (no motion)
- Fiducial-marker DTT (conventional tracking)
- Markerless DTT (novel tracking):
→ Tracking Structure="Lung tumour" (egg) or "Liver Dome" (acrylic cap)

Analysis

- All chamber measurements were compared to RaySearch RayStation™ calculated dose
- 2D film distributions from marker- and markerless- DTT were compared to static deliveries
→ Epson Expression 10000 XL scanner, FILMQA™ PRO software, 2D gamma analysis
- Imaging log file statistics (3D vector deviations between detected vs predicted tracking structure locations) were collected for all plans.

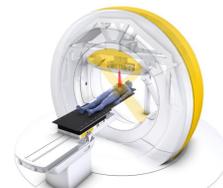


Figure 1. Vero4DRT system

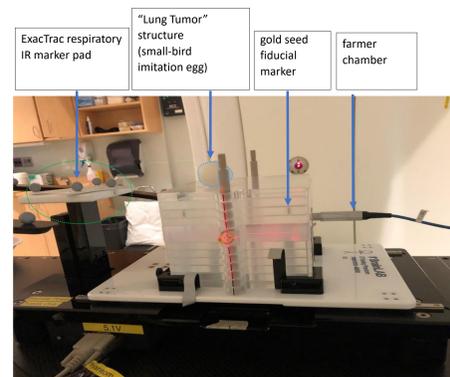


Figure 2. Brainlab DTT moving platform with acrylic phantom

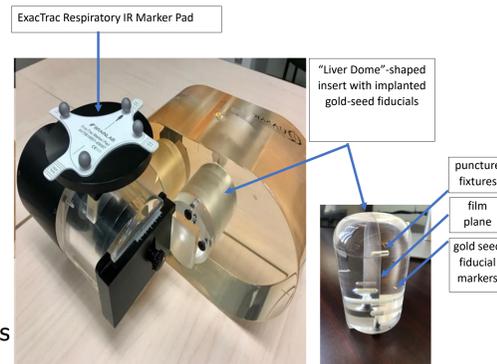
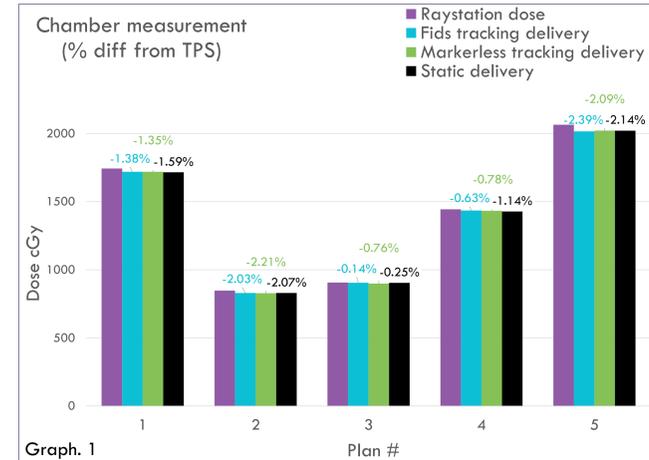


Figure 3. QUASAR motion phantom with IR respiratory pad and in-house insert. Inset: "Liver Dome" insert with film plane, puncture fixtures and fiducial markers.

RESULTS

Ion Chamber Measurement

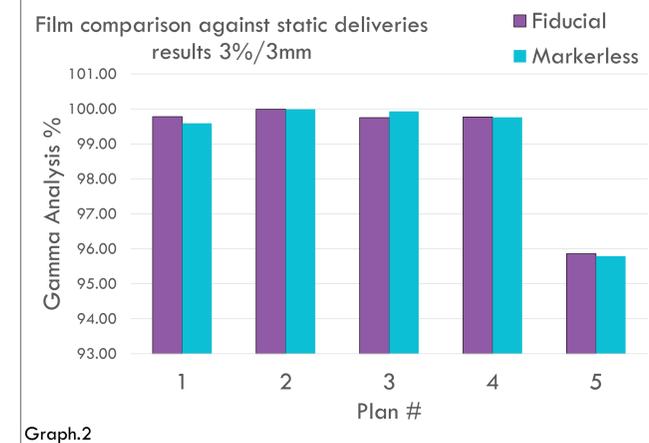
- All dose differences were <2.39% compared to the TPS
- Fiducial marker-based DTT vs markerless DTT average dose difference: **0.26% (range : 0.03-0.62%)**
- See Graph 1



Graph. 1

Film measurement

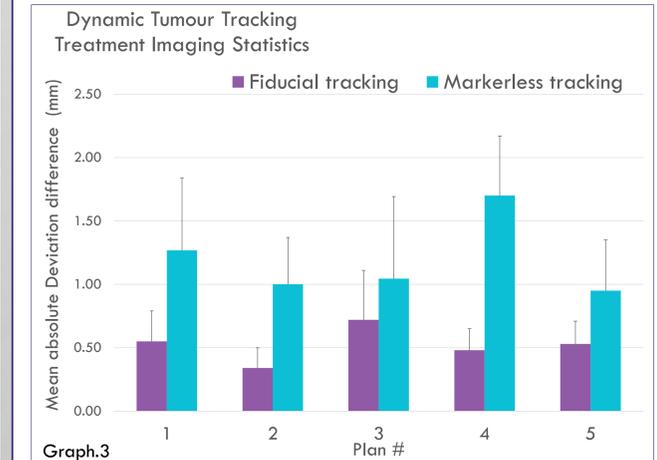
- Average 2D gamma pass rate against static deliveries:
3%/3mm/threshold:=10%:
99.03% (fiducial DTT)
vs
99.01% (markerless MDTT)
- 2%/2mm/threshold:=10%:
96.8% (fiducial DTT)
vs
96.25% (markerless MDTT)
- See Graph 2



Graph.2

ExacTrac DTT Imaging Statistics

- Each treatment plan contained between 5-7 fields step-and-shoot IMRT beams.
- The average 3D mean absolute deviation (lateral, longitudinal and vertical directions) between the image-detected and the model-predicted tracking structure location was reported for each delivered plan (Graph 3)
- 3D absolute deviation for 5 patients: average (SD)
Fiducial Tracking: **0.52 mm (±0.24 mm)**
Markerless Tracking: **1.19 mm (±0.50 mm)**



Graph.3

CONCLUSIONS

- Both tracking methods meet our institutional passing criteria for patient-specific QC
- Patient specific QC indicates that the 3D absolute deviations between image-detected versus predicted tracking positions are larger for markerless tracking compared to conventional fiducial-marker based tracking (based on log file analysis).
- However, no impact on dose delivery is observed (2D film measurements).
- Both tracking methods provide an equally viable treatment options.

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