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Evaluating the Accuracy of Varian IDENTIFY Surface-Guidance System for High Precision Treatment Delivery and Motion Management

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ABSTRACT

Surface-guided radiation therapy (SGRT) is increasingly used for high-precision patient setup and intrafraction motion management, including deep inspiration breath-hold (DIBH) workflows. However, respiratory signals acquired at simulation may use different hardware and software than those used at treatment, complicating breath-hold parameter transfer. This study evaluated Varian IDENTIFY™ 5.0 setup localization and breath-hold amplitude accuracy using a phantom-based simulation-to-treatment workflow.

End-to-end setup localization was evaluated using QUASAR Penta-Guide, RUBY Head, and Dynamic Thorax phantoms. Each phantom was aligned using IDENTIFY, sent into the Ethos bore, imaged with CBCT, and shifted based on registration to the planning CT. IDENTIFY residual offsets were recorded as setup localization accuracy. Surface amplitude accuracy was evaluated using the Dynamic Thorax Phantom programmed with free breathing and intermittent 15 s breath-holds at 1.00, 1.10, and 2.00 cm. IDENTIFY-measured amplitudes were compared with programmed values and with Varian RGSC traces acquired at simulation.

IDENTIFY setup residuals were within 1 mm, consistent with TG-302 commissioning principles for SGRT localization. IDENTIFY breath-hold amplitudes agreed closely with programmed values, with a mean difference of –0.15% and maximum difference of 0.026 mm. RGSC systematically underestimated programmed amplitudes by approximately 4%.

These findings support IDENTIFY as an accurate platform for DIBH amplitude monitoring and highlight the need to characterize cross-system bias before transferring breath-hold thresholds between simulation and treatment.

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INTRODUCTION

IDENTIFY 5.0 is a surface-guided radiation therapy (SGRT) system with capabilities that include automated beam hold for Ethos and Halcyon systems, automated couch shifts, and phase-based generation of patient surfaces using learned respiratory patterns. We are evaluating system performance within the commissioning framework outlined in AAPM TG-302 [1].

This study presents preliminary results from a multisystem motion-management workflow using Varian RGSC 1.1 during CT simulation and IDENTIFY during treatment. Two performance metrics are evaluated: setup localization accuracy and respiratory amplitude detection accuracy. IDENTIFY measurements are compared with RGSC measurements and programmed respiratory signals, with the programmed signals serving as the ground truth.

METHODS AND MATERIALS

We evaluated end-to-end SGRT setup localization accuracy using three phantoms: two static phantoms—the QUASAR Penta-Guide Phantom and the RUBY Head Phantom—and one dynamic phantom, the Dynamic Thorax Phantom. We simulated each phantom on a Philips Big Bore RT CT simulator and generated treatment plans using Eclipse 15.6 and Ethos Treatment Management 3.0. We used ARIA 15.6 for record-and-verify functionality.

Setup Accuracy

We manually positioned each phantom on an Ethos 3-DoF couch within the IDENTIFY camera field of view to compare live position with reference surface position. We used the IDENTIFY auto-couch shift feature to auto-align the phantom to the reference surface at virtual isocenter outside the bore, then sent the phantom into the bore with a zero delta couch shift. We acquired a CBCT and translated the couch based on registration to the planning CT, which we treated as the ground-truth setup. We recorded the translational offsets of the IDENTIFY surface relative to CBCT alignment and calculated the 3D displacement offset as setup accuracy. Measurements were repeated five times for each phantom.

Breath-Hold Accuracy

We evaluated surface amplitude accuracy using the Dynamic Thorax Phantom programmed with free-breathing motion (amplitude = 2.5 mm, period = 5 s) and intermittent 15 s breath-holds at 10, 11, and 20 mm amplitude. We acquired respiratory traces with RGSC at simulation and IDENTIFY at treatment. We used an in-house MATLAB R2021a code to compare IDENTIFY amplitudes with programmed amplitudes to assess accuracy, and with RGSC amplitudes to assess cross-platform consistency. We calculated breath-hold amplitudes as the mean signal value during each breath-hold and reported mean amplitude differences.

RESULTS

Mean setup 3D displacement magnitudes and standard deviations were 0.30 ± 0.00 mm (0.30 mm max), 0.66 ± 0.18 mm (0.77 mm max), and 1.25 ± 0.14 mm (1.39 mm max) for the QUASAR, RUBY, and Dynamic phantoms, respectively. We observed systematic rotational offsets for each phantom; because the Ethos couch has only 3-DoF, these rotational offsets could not be corrected for post-CBCT. Mean yaw, pitch, and roll and their standard deviations were 0.00 ± 0.00°, -0.20 ± 0.00°, -0.06 ± 0.01°; 0.06 ± 0.10°, -0.02 ± 0.05°, -0.11 ± 0.04°; and 0.14 ± 0.05°, -0.08 ± 0.08°, 0.22 ± 0.13° for the QUASAR, RUBY, and Dynamic phantoms, respectively.

IDENTIFY-measured breath-hold amplitudes demonstrated excellent agreement with programmed values, with a mean amplitude difference of –0.15% across all breath-hold levels and a Pearson correlation coefficient of 0.99. The largest recorded difference was a 0.03 mm underestimation of the 20.00 mm breath hold. In contrast, RGSC systematically underestimated programmed amplitudes by an average of –4%; the largest recorded difference was an 0.80 mm underestimation of the 20 mm breath hold.

Table 1. Setup accuracy of QUASAR phantom with IDENTIFTY.

Direction	Mean (mm)	Standard Deviation (mm)	Maximum (mm)
Anterior—Posterior	-0.24	0.05	-0.30
Superior—Inferior	-0.02	0.04	-0.10
Left—Right	+0.16	0.05	+0.20
Magnitude	0.30	0	0.30

Table 2. Breath-hold amplitude measurements across platforms

Programmed Amplitude (mm)	IDENTIFY Amplitude (mm)	RGSC Amplitude (mm)
10	9.981	9.561
11	10.987	10.601
20	19.974	19.205

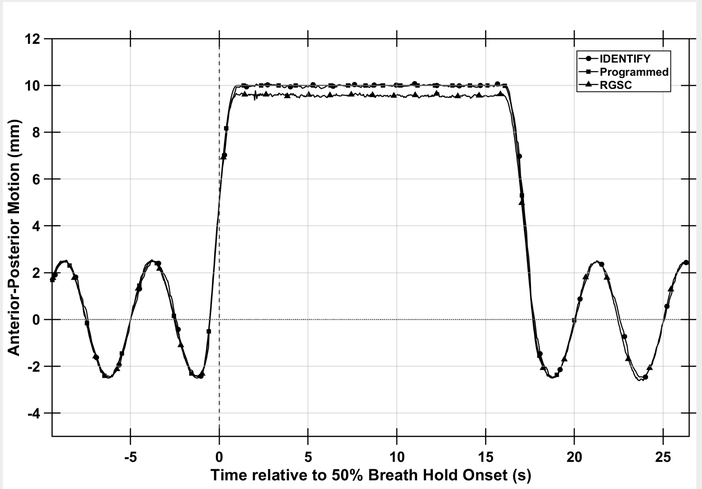

Figure 1. Breath-hold traces for 10 millimeter amplitude.

DISCUSSION

The resulting IDENTIFY setup error, as compared to the planning CTs, averaged less than 1 mm for the two stationary phantoms and 1.25 mm for the dynamic phantom. The IDENTIFY respiratory signals showed a near-exact match with the programmed signals, outperforming the accuracy of RGSC, which consistently underestimated actual amplitudes. These results inform clinical workflows translating DIBH information from simulation to treatment. Future work includes investigation into supra-millimeter setup error for the dynamic phantom, followed by complete commissioning of the system as described in TG-302.

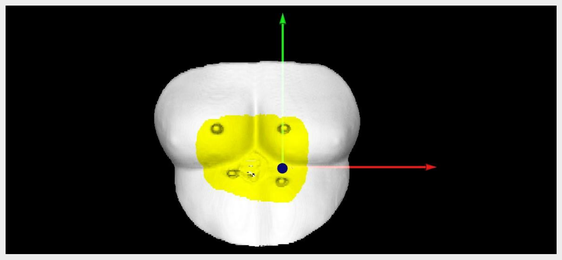

Figure 2. Region of interest (ROI) highlighted on Dynamic Thorax Phantom surface in IDENTIFY

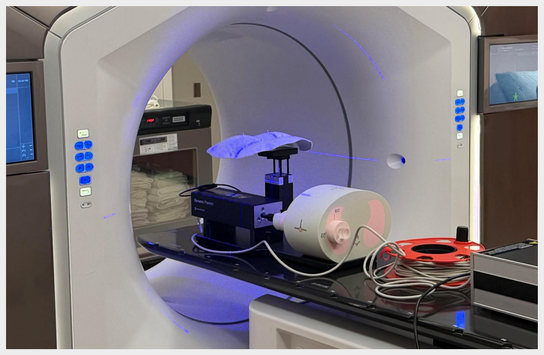

Figure 3. Dynamic Thorax Phantom setup on Ethos for measurements.

CONCLUSIONS

IDENTIFY 5.0 evaluation on Ethos 4.0 demonstrates sub-millimeter setup accuracy for the static phantoms (0.30–0.66 mm) and excellent respiratory amplitude detection, with breath-hold measurements matching programmed values far more closely (–0.15% mean difference, r = 0.99) than the RGSC system (–4% mean difference). The Dynamic Thorax Phantom setup error (1.25 mm) while clinically acceptable, is currently under investigation. Resolution of this issue and subsequent commissioning per TG-302 are planned next steps.

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