2026 JULY 19–22 VANCOUVER, BC
JOINT AAPM | COMP MEETING

Infrared Marker-Based Tracking and Quality Assurance Methods for Holographic Patient Alignment

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INTRODUCTION

Purpose: To investigate infrared (IR) marker-based tracking for holographic patient alignment in radiation therapy and to establish quality assurance (QA) methods for the technique.

Holographic patient alignment provides a more cost-effective alternative to surface guided radiation therapy (SGRT) by superimposing a patient-specific surface model onto the direct patient view through an optical see-through head-mounted display.[1] This novel method has been demonstrated in a first-in-human clinical trial and found comparable to external skin mark alignment.[2]

Prior holographic patient alignment employed a HoloLens 2 (Microsoft Corp., Redmond, WA) with marker-based tracking enabled to detect a cube fiducial bearing quick-response (QR) codes.[1,2] The fiducial marker attached to a treatment machine gantry (Fig.1A), and the known geometry relative to isocenter position was utilized for placement of the holographic surface in the space. To further improve holographic alignment accuracy, a novel marker-based tracking approach employing retro-reflective spheres as infrared (IR) fiducials was established, as well as quality assurance (QA) methods for holographic alignment.

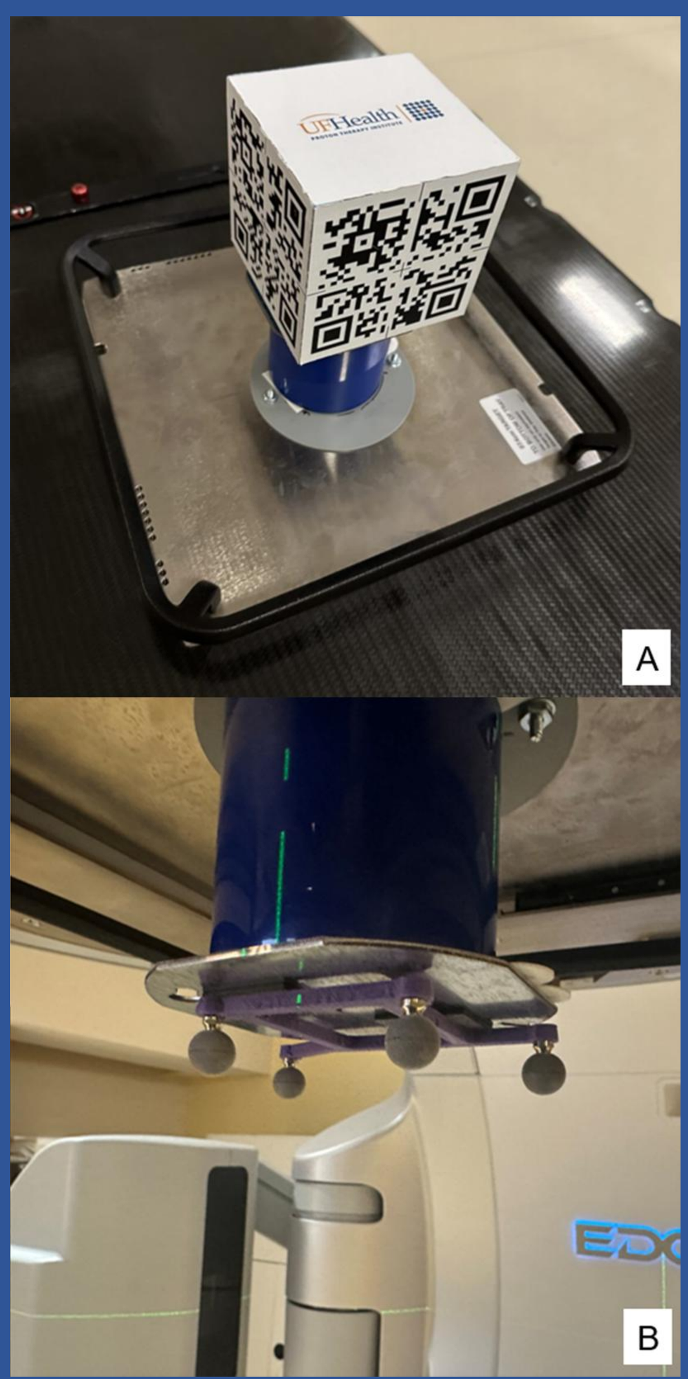

Figure 1. A) QR code fiducial marker and B) IR fiducial marker attached to gantry mount

METHODS AND MATERIALS

Four IR spheres were attached to a 3D printed marker array which was magnetically attached to a treatment machine gantry mount (Fig.1B). The known fiducial geometry relative to isocenter informs the placement of holographic visualizations.

A thorax phantom was established for end-to-end testing and evaluation against prior results with QR marker-based alignment. A computed tomography (CT) scan of the thorax phantom was obtained, the surface was contoured, and the structure set was exported in DICOM (Digital Imaging and Communications in Medicine) format and converted to .obj (object) format with 3D Slicer (Brigham and Women's Hospital, Harvard Medical School, Boston, MA). The phantom surface object along with the array and IR fiducial model were added to the Unity game engine (Unity Technologies, San Francisco, CA) where applications were built for the Microsoft HoloLens 2. Fresnel-derivative (Fig.2A) and silhouette (Fig.2B) visualization techniques were chosen to display the phantom hologram. The phantom was physically aligned to its hologram on the treatment couch by one user for two trials of each visualization technique. Offsets were determined from SGRT and evaluated against prior work with quick response (QR) marker-based alignment.

QA applications were developed to evaluate daily and periodic performance of the system by visualizing a 5mm thick silhouette surface around an isocentrically aligned machine performance check (MPC) phantom, and additionally a multi-sphere array consisting of fifteen 5mm radius spheres placed 20cm apart horizontally, and 10cm apart vertically. The array can be evaluated against a field calibration plate. Both applications visualize a crosshair to represent isocenter position.

RESULTS

Preliminary results of thorax phantom alignment with IR tracking are summarized in Table 1. The root mean square (RMS) offsets ranged from 0.43cm to 0.69cm, comparable to prior QR alignment results.

QA applications were effectively demonstrated to verify daily functionality against the MPC phantom (Fig.3) and evaluate geometrical accuracy with the multi-sphere array against a field calibration plate (Fig.4). Virtual crosshairs can be quickly evaluated against room lasers.

Table 1. Alignment Offsets of Initial IR Testing

Visualization Technique	Trial	Vrt (cm)	Lng (cm)	Lat (cm)	Rtn (degrees)	RMS (cm)
Fresnel	1	0.17	-0.39	0.17	-1.60	0.46
	2	0.30	-0.34	0.19	-2.00	0.49
Silhouette	1	0.13	-0.22	0.35	-0.50	0.43
	2	0.17	-0.59	0.31	-0.30	0.69

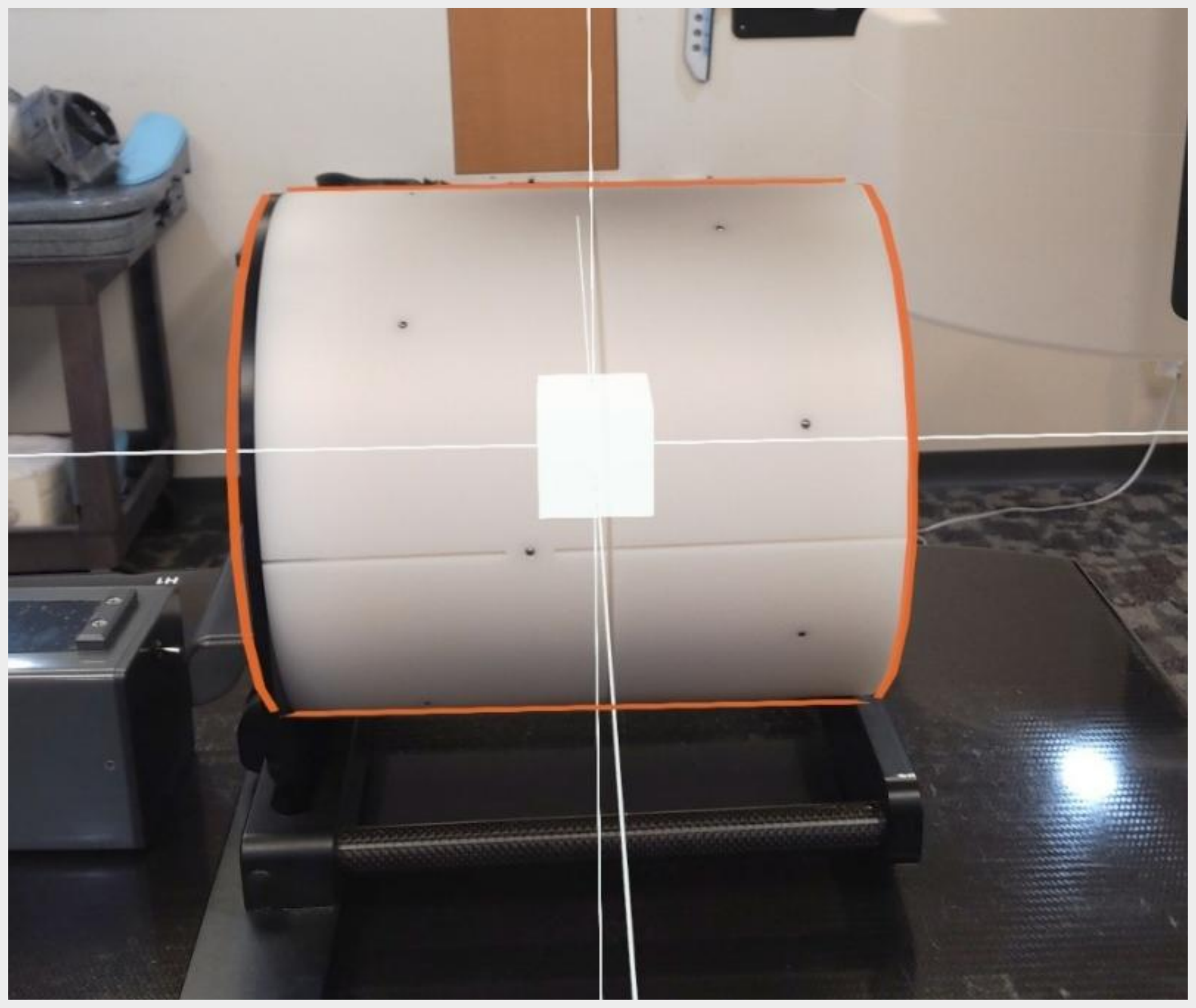

Figure 3 . MPC phantom viewed through HoloLens 2 with 5mm thick silhouette outline

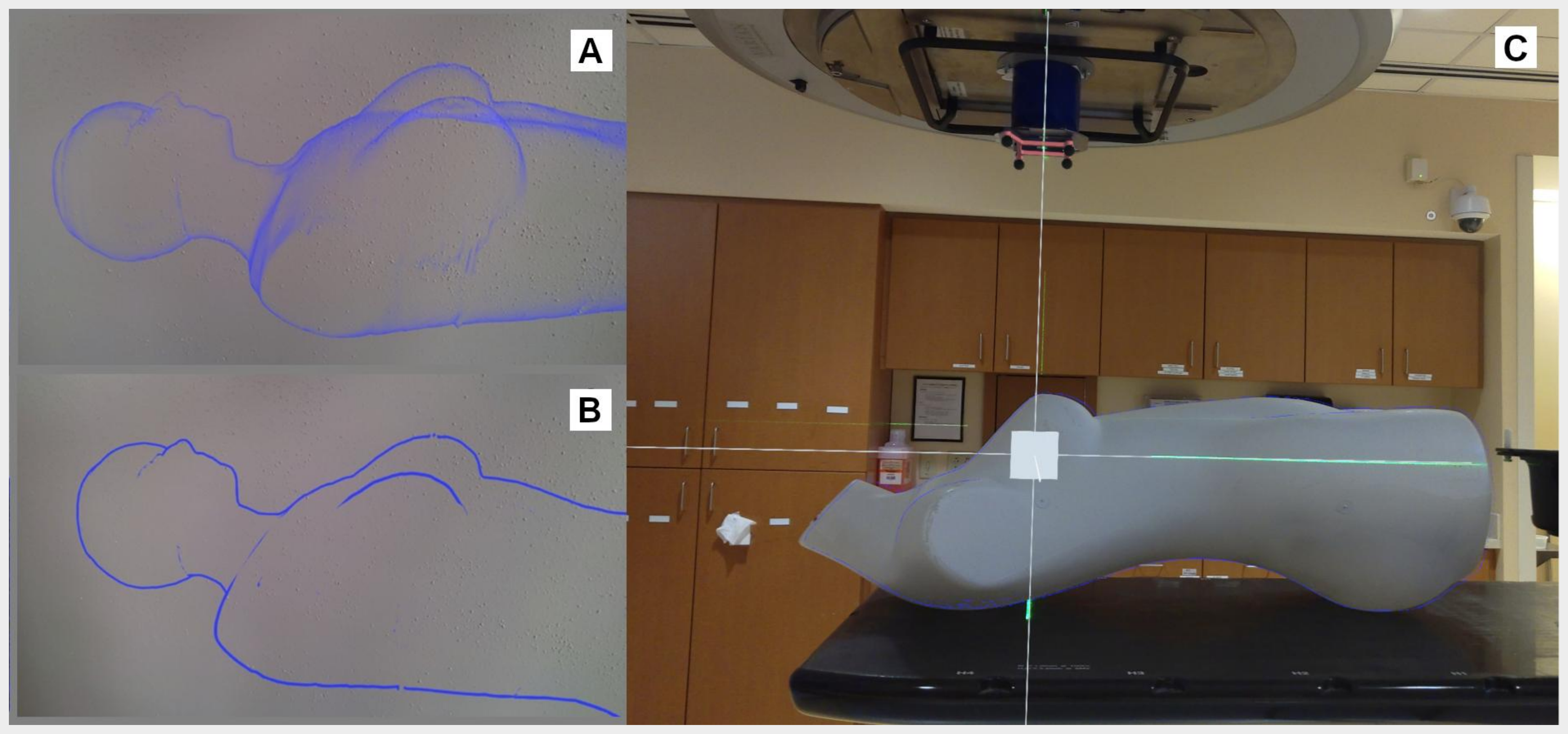

Figure 2. A) Fresnel-derivative and B) silhouette visualization techniques of thorax phantom with C) thorax phantom setup as seen through HoloLens 2 view

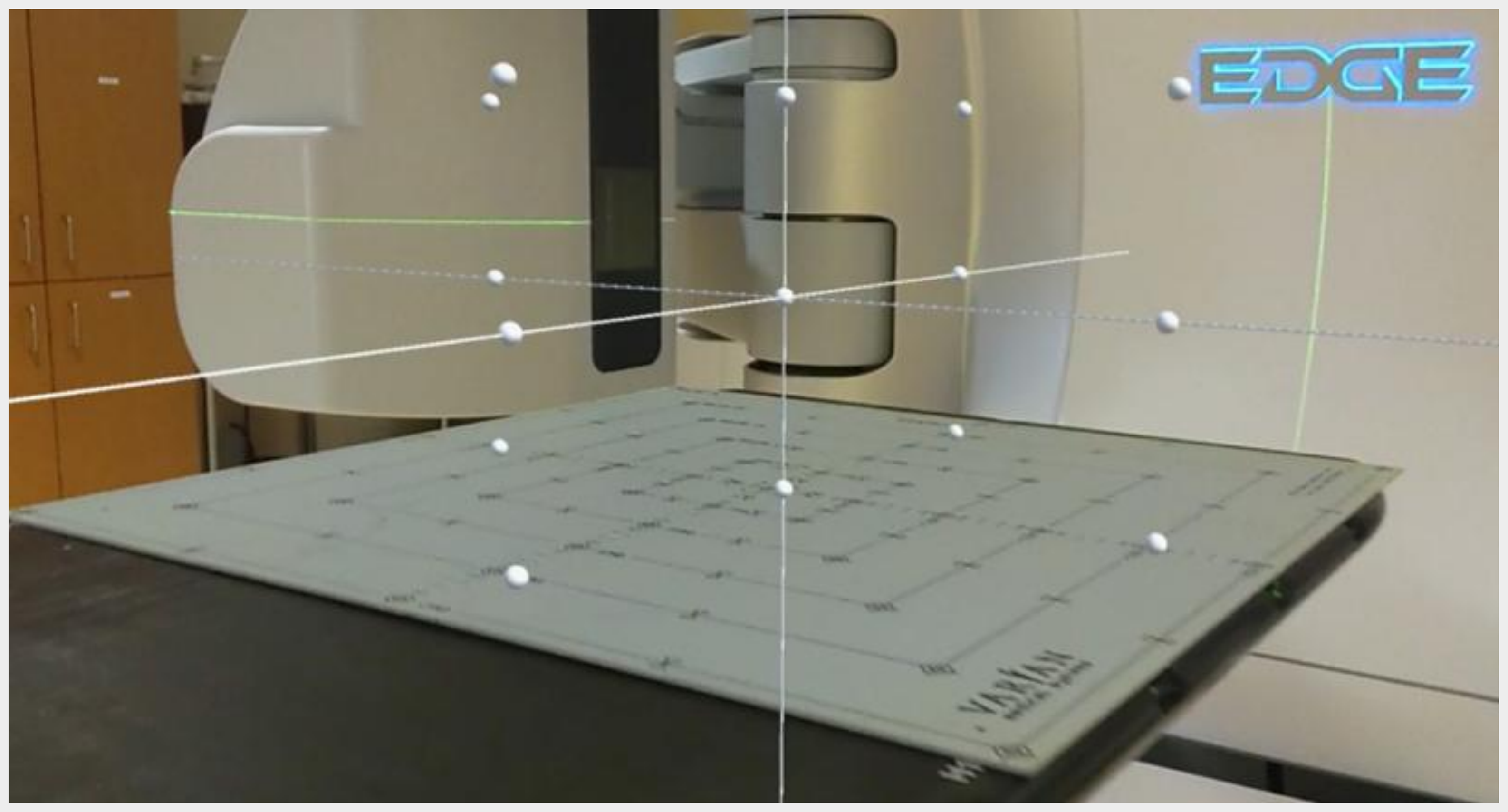

Figure 4 . Array of 5mm radius spheres viewed against a field calibration plate.

DISCUSSION

This work is the first example of infrared (IR) marker-based tracking for holographic alignment in radiation therapy. While only demonstrated with phantoms, this method can be extended to patient treatment setup and provide a more intuitive surface guided alignment with a see-through head mounted display.

Limitations with hologram jitter are seen with both QR and IR marker-based tracking. While QR marker-based tracking degrades in low lighting conditions, IR marker-based tracking is largely unaffected by room lighting and offers a larger tracking field-of-view. Improvements in IR array design such as geometry and number of IR spheres, visibility for all user heights, and distance from isocenter may offer improvements for performance.

CONCLUSIONS

Preliminary testing indicates that IR marker tracking provides comparable alignment accuracy to QR marker tracking, but further testing is required to validate this result. Daily holographic alignment verification can be conveniently performed with an existing daily QA phantom. More extensive QA with a multi-sphere array and crosshair visualization allows more precise confirmation of geometric alignment.

REFERENCES

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2. Johnson PB, Bradley J, Lampotang S, et al. First-in-human trial using mixed-reality visualization for patient setup during breast or chest wall radiotherapy. Radiat Oncol. 2024;19(1):163. doi:10.1186/s13014-024-02552-0

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