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Commissioning and performance testing of the first prototype of AlignRT InBore, a Halcyon™-dedicated Surface Guided Radiation Therapy platform

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INTRODUCTION

Over the past decade, Surface Guided Radiation Therapy (SGRT) has been increasingly used to provide live and continuous supplementing information to Image-Guided Radiation Therapy (IGRT) at no additional X-ray exposure. Abundant literature indeed describes the benefits of SGRT proving faster and more accurate patient setup compared to tattoos, increased patient comfort and well-being post-radiotherapy through open-faced masks and tattoos avoidance, and reduced use of daily port/X-ray imaging [1-4]. SGRT has been leveraged across a broad range of clinical applications including breast (both in free breathing and deep inspiration breath hold - DIBH), stereotactic radiosurgery (SRS), stereotactic body radiation therapy (SBRT), head and neck, sarcomas, paediatrics, etc. [5-10]. However, for closed bore Linacs such as Halcyon™ and Ethos™ (Varian, Palo Alto, USA) or Tomotherapy (Accuray, Sunnyvale, USA), the use of ceiling mounted SGRT solutions remains scarce and limited to improving setup accuracy with the cameras being unable to track the patient motion inside the bore due to optical line of sight limitations [11-12].

AIM

This work tests the suitability and performance of the first prototype of AlignRT InBore™, a new Halcyon™ and Ethos™-dedicated SGRT solution from Vision RT (Vision RT Ltd., London, UK) capable of tracking patient motion during treatment delivery.

METHOD

The performance of AlignRT InBore™ was extensively tested to determine:

- The stability of the new cameras and any thermal drift;
- The accuracy of the InBore™ cameras in detecting patient motion;
- The correspondence between ceiling mounted cameras (used for SGRT setup outside the bore) and InBore™ cameras (for SGRT tracking inside the bore) and the optimal co-calibration process;
- The surface coverage, quality and resolution;
- The frame rate and processing speed of the system.

Materials used to perform the above cited tests include:

- The calibration plate;
- The Vision RT SRS MV cube;
- Varian's MPC;
- Emily and KERi™ mannequin;
- A human volunteer.

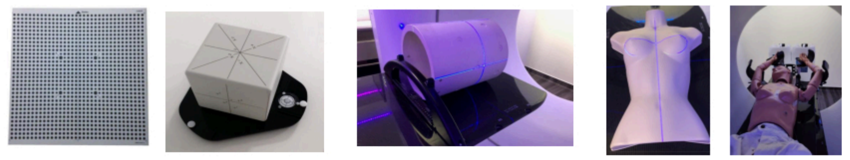


Figure 1. List of equipment used to assess the performance of AlignRT InBore™.

RESULTS

Thermal stability

InBore™ cameras showed sub-0.3 mm and 0.2° variability of Real Time Deltas (RTDs) when continuously monitoring Varian's MPC cylinder phantom for >30 minutes (cf. Figure 2).

InBore™ cameras were found to offer higher stability compared to the ceiling cameras where a 0.4 mm thermal drift was previously reported [10].

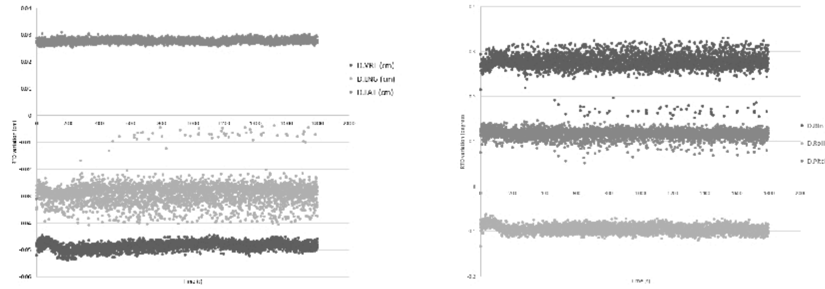


Figure 2. System stability test showing the variation of translations (left) and rotations (right) for ~30 minutes of monitoring. Data shown here is not normalised.

Accuracy

System's accuracy was tested with the Halcyon™ couch mechanically shifted to known positions while monitoring the MV Cube or Emily phantom.

The InBore™ system showed sub-0.5 mm and sub-0.3° accuracy as confirmed on CBCT images. This is equivalent to the standard ceiling-mounted cameras accuracy.

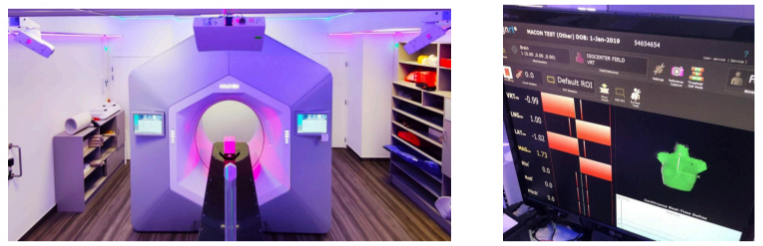


Figure 3. Accuracy tests of InBore with MV Cube and Emily phantom

Surface quality and coverage

Frame rate and surface resolution are dependent on the software version used (AlignRT v. 5.1) and were hence equivalent for both ceiling and InBore™ systems (e.g. 2-5 fps and 10 pixels/vertex for breast).

InBore™ cameras offer a tracking surface coverage of ~60 x 40 x 25 cc with no occlusion thanks to the dedicated design for the Halcyon™ geometry.

Ceiling cameras have a wider field of view (100 x 65 x 35 cc) being farther from virtual isocentre but are susceptible to shadow/occlusions (heavy patients, large breasts/belly, etc.).

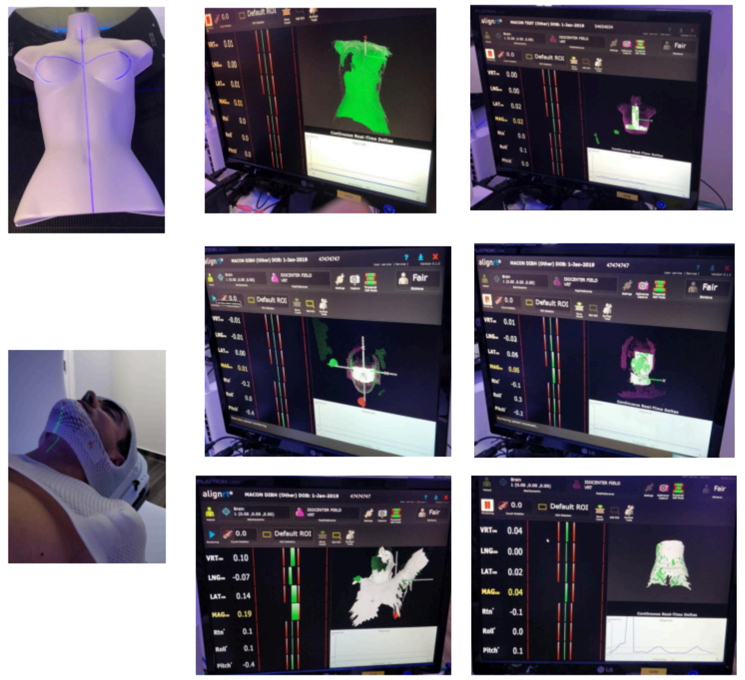


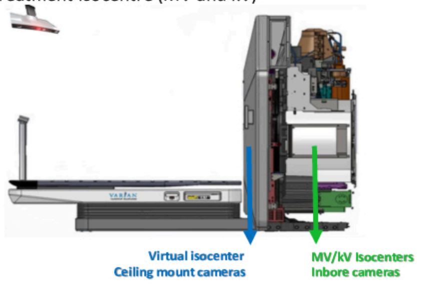
Figure 4. InBore™ surface quality and coverage with: Emily phantom (top), volunteer and SRS with Vision RT head adjuster, H&N with open mask (middle), breast and pelvis localisations (bottom)

Co-calibration process

Co-calibration is a critical step to ensure smooth transition from virtual to treatment isocentres and to match the camera isocentre to treatment isocentre (MV and kV)

AlignRT plate calibration relying on Halcyon™ lasers showed possible Linac-to-camera isocentre mismatch of up to 1.3 mm likely due to laser inaccuracies

Using SRS MV cube and the same set of port images (0°, 90°, 180° and 270°), it was possible to co-calibrate camera isocentre to treatment isocentre within 0.3 mm and 0.2°



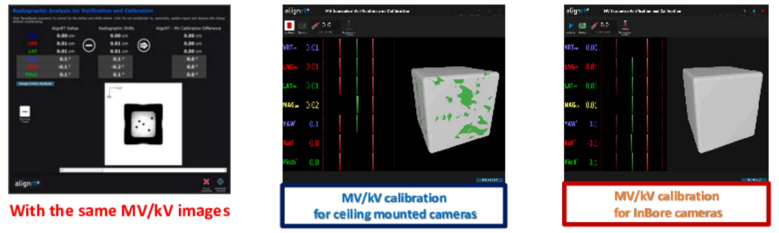


Figure 5. Schematic representation of co-calibration process (top) and MV Cube calibration steps (bottom).

Limitations

As this is a prototype system, ceiling and InBore™ cameras are currently handled as two stand alone systems. The software needs to be upgraded to manage both systems simultaneously.

Frame rate and surface resolution are dependant on the software version, these should improve with the new AlignRT Advance software release to allow for faster DIBH coaching and motion tracking.

MV Cube calibration proved necessary to allow sub-mm accuracy, however, this can be time consuming and an alternative co-calibration approach is needed.

CONCLUSIONS

The study proved the first prototype of AlignRT InBore™ to have an overall performance similar to the standard AlignRT SGRT solution. Surface coverage was found to be sufficient for all clinical applications without suffering from occlusions/shadow areas. SGRT on Halcyon™ is particularly relevant for patient setup to correct for gross rotational shifts while in-bore tracking and monitoring intra-fraction patient motion shall allow for advanced treatment techniques such as DIBH to be performed on Halcyon™. Several software enhancements as well as some improvements to the overall calibration process are expected to render this solution fully compatible with routine clinic.

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