Automated HDR QA tests using an organic plastic scintillator

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Purpose:

To automate a series of quality assurance tests used in HDR Brachytherapy, using a novel organic scintillator camera apparatus.

Materials:

A 15mm thick organic plastic scintillator (Eljen Technology, TX, USA) was used in combination with our Perma-Doc Phantom (RPD Inc., MN, USA) to verify source positional accuracy. The scintillator was sufficiently thick to release enough visible light when irradiated by a 5-10 Ci Ir-192 source to be detectable, yet thin enough to visualize the graticule built into the Perma-Doc. A novel apparatus which combines a miniature camera and single board computer (https://www.raspberrypi.com) into an enclosure was constructed. This minimized ambient light and was rigidly mounted to the Perma-Doc in order to remove systematic shifts between independent measurements. (See Figure 1)

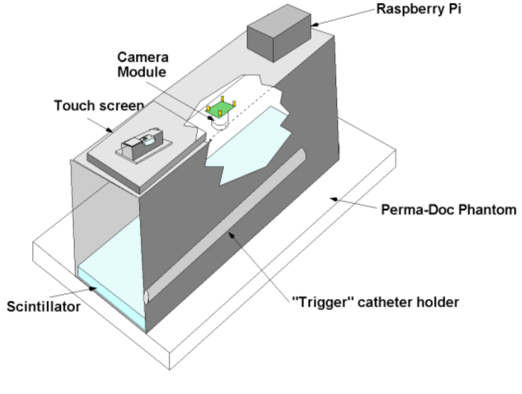

Figure 1: HDR QA Device

Methods:

Continuous video was recorded using a framerate of ~32 fps, with a resolution of 1280 pixels by 720 pixels. This resulted in a spatial resolution of 0.23 mm/pixel and 31 ms/frame.

We recorded approximately 130 seconds of video with zero frame-loss. For each frame, the image was corrected for lens nonlinearities, the centre of mass of the scintillating glow was found and converted to a physical position. A sample frame is shown in Figure 2.

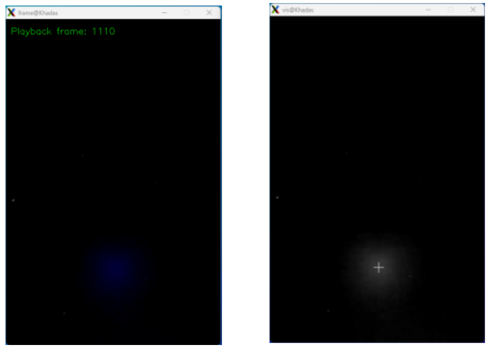

Figure 2: Sample video frame: full colour (left); blue channel (right)

Residual positional inaccuracies were corrected by applying an empirical correction to the pixel position : physical location calibration curve using a linear regression fit model. A sample data set for the entire video is shown in Figure 3. Any value >100 mm is beyond the camera's field of view. Clearly, the dwell positions, dwell times and transit times can be extracted from the video analysis.

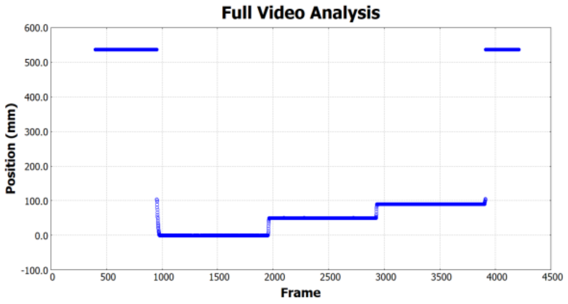

Figure 3: Complete analysis of video file

The system was tested by having the HDR source remain stationary at 130, 125 and 121 cm for 30 seconds at each dwell position. Further the position resolution was evaluated by introducing a positional deviation of -2, -1, 0, +1 and +2 mm for each of the dwell positions except for 130 where only the retracted deviations could be applied. Similarly, deviations were introduced to the dwell time by -0.6s (-2%), -0.3s (-1%), 0.0, +0.3s (+1%) and +0.6s (+2%).

Results:

The absolute mean error between the detected location and the known positions was 0.3mm, however, this was not uniform across all positions. The mean error for position 130cm was -0.1 ± 0.3 mm, position 125cm was 0.1 ± 0.2 mm and position 121 cm was 0.5 ± 0.2 mm. This is more than sufficient to detect positional errors of 1mm or more. See Figure 4. For the timer accuracy, the overall average deviation

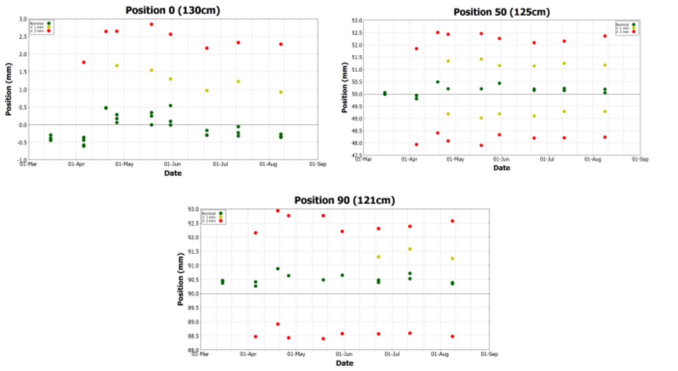

Figure 4: Dwell Position results

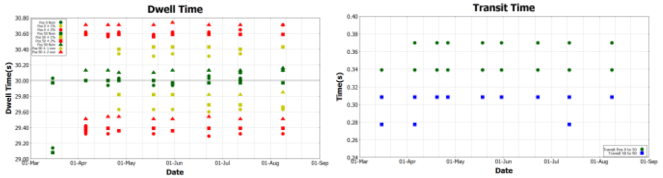

Figure 5: Dwell time (left) and Transit Time results (right)

was -0.03s (-0.09%), -0.04s (-0.1% for Position 130 cm), -0.09s (-0.3% for Position 125cm) and 0.05s (0.2% for position 121cm). We also found the transit time to be 0.35 ± 0.01s between position 130 cm and position 125 cm and 0.30 ± 0.01s between position 125 and position 121 cm.

Conclusions:

Our system can automatically detect the HDR source dwell locations and times within 0.5 mm and 0.3%, respectively. Although we see some systematic errors in one position (121cm) the results are below action levels of current recommendations. In conclusion, we have presented a completely automated method that can be easily adopted by busy brachytherapy clinics.

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