Performance Assessment of Two Motion Management Systems for Frameless Stereotactic Radiosurgery

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INTRODUCTION

This work is to assess the accuracy and sensitivity of two distinct motion monitoring systems used for frameless SRS.

AIM

Frameless stereotactic radiosurgery (SRS) requires dedicated systems to monitor patient motion in order to avoid inaccurate radiation delivery due to involuntary shifts. The purpose of this study is to assess the accuracy and sensitivity of two distinct motion monitoring systems used for frameless SRS.

METHOD

A surface image-guided system known as Optical Surface Monitoring System (OSMS), and a fiducial marker-based system known as High Definition Motion Management (HDMM) as part of the latest Gamma Knife Icon® were compared with each other. A 3D printer-based cranial motion phantom was developed to evaluate the accuracy and sensitivity of these two systems in terms of: (1) the capability to recognize predefined shifts up to 3cm, and (2) the capability to recognize predefined speeds up to 3cm/s. The performance of OSMS, in terms of different reference surfaces, was also evaluated.

RESULTS

Translational motion could be accurately detected by both systems, with an accuracy of 0.3mm for displacement up to 1cm, and 0.5mm for larger displacements. The reference surface selection had an impact OSMS performance, with flat surface resulting in less accuracy. HDMM was in general more sensitive when compared with OSMS in capturing the motion, due to its faster frame rate, but a delay in response was observed with faster speeds. Both systems were less sensitive in detection of superior-inferior motion when compared to lateral or vertical displacement directions.

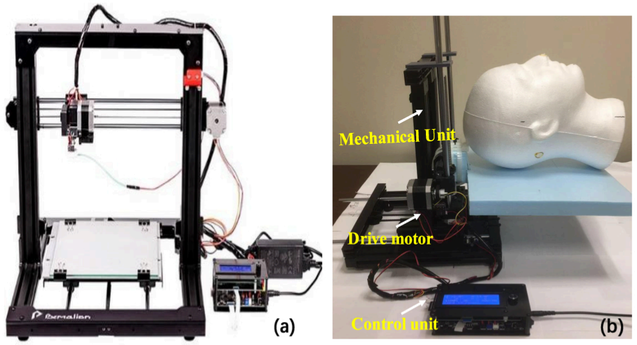

Figure 1. The 3D printer based moveable phantom. (a) the modified frame-base of a 3D printer, with extruder removed from the original base and the vertical frame moved to a moveable carriage; (b) The final design of the phantom which includes a mechanical unit with attached form head, a drive motor and a LCD control panel. The phantom movement can be controlled along three translational directions.

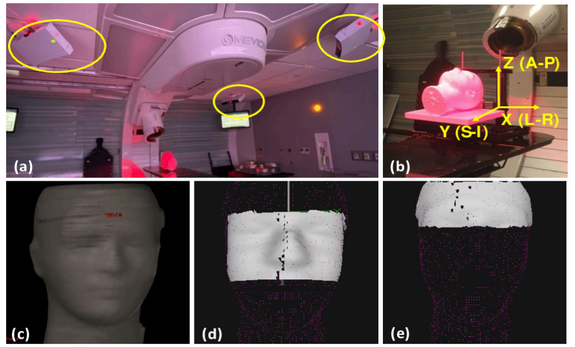

Figure 2 (a) The setup of Optical Surface Monitoring System (OSMS), which consists of three ceiling camera pods; (b) each camera projects a red light speckle on the patients; (c) a reference surface is generated by imposing the body contour from planning CT dataset; and (d) a region of interest (ROI) is selected and rigidly aligned with the reference surface, with central face selected as the ROI, or (e) forehead can be selected as the ROI.

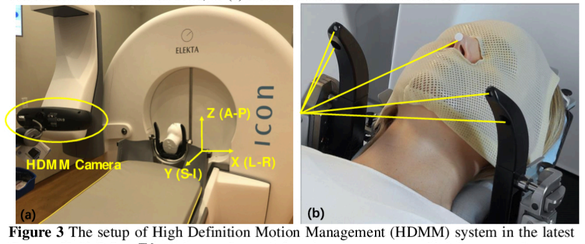

Figure 3 The setup of High Definition Motion Management (HDMM) system in the latest Gamma Knife® Icon™: (a) it contains an infrared camera system which is mounted onto an arm attached to the couch; and (b) it tracks the relative position of the patient marker, attached to the patient's nose nip, with respect to four reference markers fixed on the mask adapter that locks to the unit.

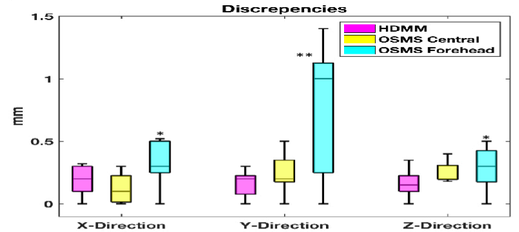

Figure 4 The boxplot showing the deviations between pre-defined positions and recorded positions from different measurement systems. *: The OSMS forehead showed significant differences compared to other modalities in both X- and Y-direction measurement; **: The Y-direction measurement showed significant differences compared to other directions when using forehead as ROI for OSMS management.

CONCLUSIONS

Translational motion can be accurately and sensitively detected by OSMS and HDMM real-time monitoring systems. However, performance variations were observed along different motion directions, as well as amongst the selection of reference images. Caution is needed when using real-time monitoring systems for frameless SRS treatment.

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HW, YZ and KN participated in the study design and coordination, and drafted the manuscript. KG, HW, and KN designed and made the 3D Printing Movable Phantom. HW, ZX, YZ, TC, YZ, BL, XW, IV, MR and KN participated in acquisition of data. All authors critically edited and approved the final manuscript.

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