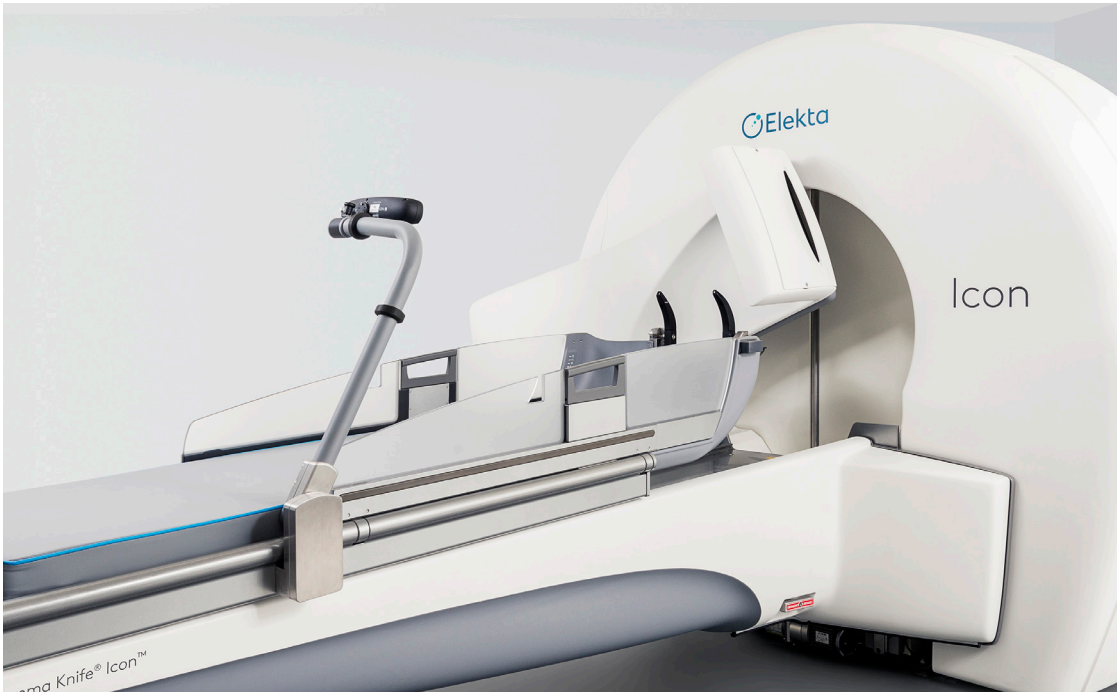
White Paper

High Definition Motion Management.

Enabling stereotactic Gamma Knife® radiosurgery with non-rigid patient fixations



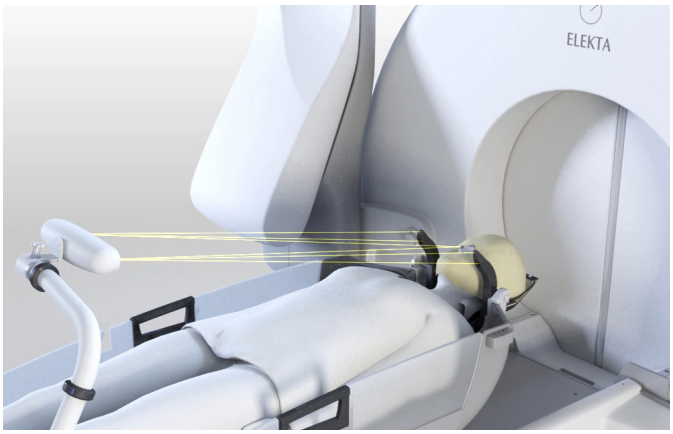


Figure 1.
The HDMM system

Introduction

In this paper, a real-time patient tracking system for Leksell Gamma Knife® Icon™ is analyzed. This system monitors patient movements with submillimeter accuracy in 3D and enables the use of non-rigid fixations, while keeping high treatment accuracy and confidence.

System description

The High Definition Motion Management (HDMM) system consists of an infrared stereoscopic camera, a set of reference markers, and a patient marker. The system continuously tracks patient movement during treatment with non-rigid fixations. If large movements are detected, sources are moved to an **off** position and the operator is alerted. A gating function resumes the treatment if the patient returns to treatment position within a specified time. Otherwise, the treatment is paused and the operator can resume the treatment.

The infrared camera is mounted onto an arm on the couch. This arm can be folded up when the HDMM system is used and folded down to stow away the camera when not in use (see FIgure 2).

A number of markers attached to the mask adapter are tracked at a frequency of 20Hz (see FIgure 3). These markers define a reference coordinate system in which patient movements are measured. The reference system is necessary to reduce noise and any effect of camera movements. Patient movement is presented as a graph that is updated in real time (see Figure 4).

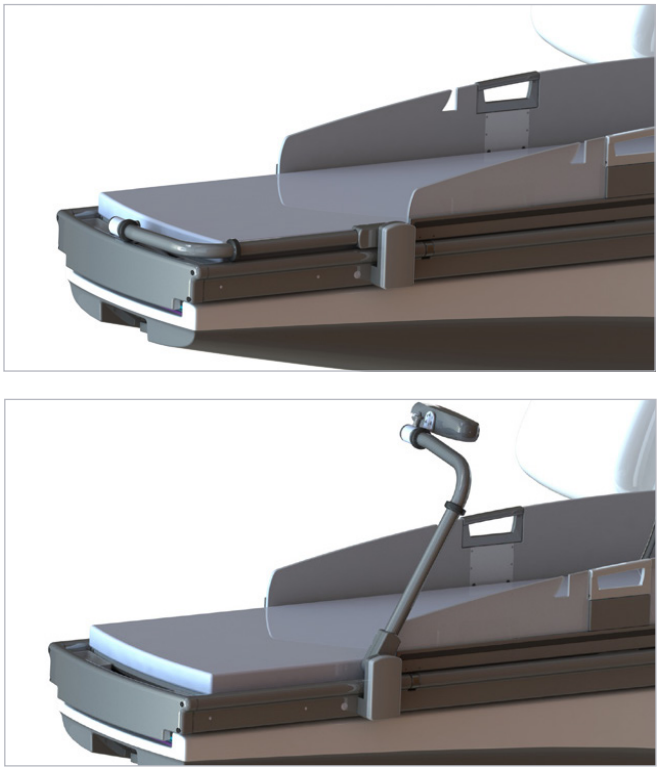


Figure 2.
HDMM arm with the infrared stereoscopic camera stowed away and folded up.

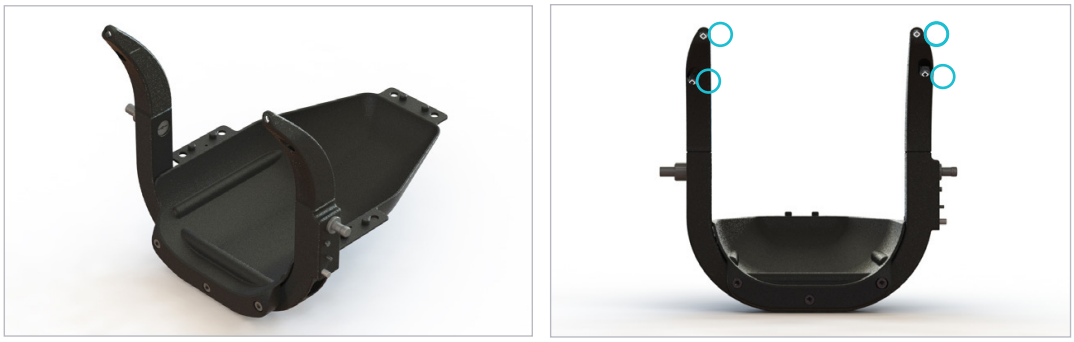


Figure 3.
The mask adapter—the integrated markers are highlighted with blue circles.

The patient marker is attached to patient's nose with adhesive (see FIgure 5). The patient is immobilized with a thermoplastic mask over the face. To gain access to the nose, the mask has a nose opening, sufficiently large to reduce any influence of the mask on nose movements.

Accuracy

The accuracy of the method was studied by moving the patient marker, positioned as on a patient's head during a treatment, in steps of 0.1 mm. The position was controlled by an independent measuring device with a guaranteed accuracy of 0.01 mm and compared with the movement measured by the camera. The result is shown in Figure 6.

Figure 6 shows that the patient can be tracked with an accuracy of 0.1 mm, or better in ideal conditions. The accuracy may become 0.15 mm when including disturbances, e.g., those caused by couch movements and vibrations of HDMM arm.[1]

Correlation between nose and target movement

Using nose movements as an approximation of target movements assumes that nose movements are well correlated with, and have larger amplitude than, target movements. This hypothesis has been investigated in a prospective clinical study performed at Princess Margaret Cancer Centre.[2] In this study, patients were tracked using both this HDMM system and Cone Beam CT (CBCT).

The movement of the target inside the skull was calculated in CBCT images taken before and after fractions and compared to HDMM measurements of nose movements. The study concluded that the movements detected with the HDMM system and CBCT correlate well and that these movements are generally larger than or equal to actual target movements.

Summary

Investigations show that tracking the movements of a patient's nose using an infrared stereoscopic camera is a feasible HDMM method to track submillimeter target movements during Gamma Knife® radiosurgery with mask immobilization.

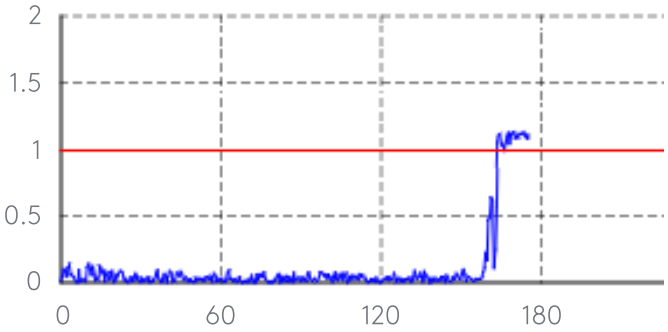


Figure 4.
HDMM GUI. The red line marks the user-defined movement allowed.

Figure 5.
Patient with marker in mask adapter.

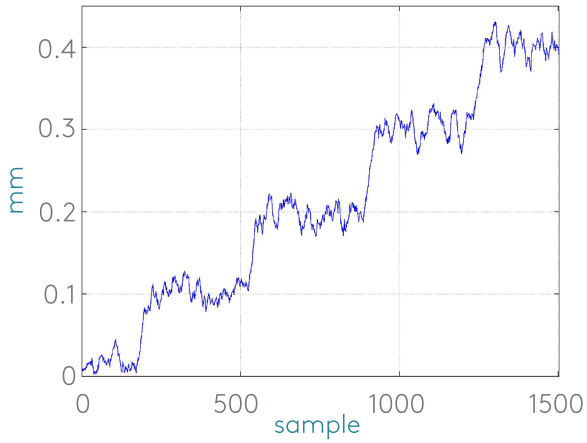


Figure 6.
The plot shows the 0.1 mm steps measured with the HDMM system. The 0.1 mm steps can be clearly distinguished in the plot.

References

1. Knutson NC, Hawkins BJ, Bollinger D, et al. Characterization and validation of an intra-fraction motion management system for masked-based radiosurgery. J Appl Clin Med Phys. 2019;20(5):21-26. DOI: 10.1002/acm2.12573
2. Chung C, Li W, Bootsma G, et al. Clinical Evaluation of a Novel Thermoplastic Mask System with Intrafraction Motion Monitoring using IR Tracking and Cone-beam CT for Gamma Knife® Radiosurgery. Poster presented at 2014 ASTRO annual meeting, San Francisco.

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