Realtime Method to Locate and Track Targets in Radiotherapy

a report by

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Over the last decade the ability to precisely deliver radiotherapy (RT) treatments has advanced dramatically. Imaging technology has evolved to facilitate better target delineation during treatment planning. Treatment delivery techniques have advanced to enable intensity modulated RT (IMRT) treatments that provide radiation doses, tightly conforming to the target volumes. These advancements have been driven by the dual goals of maximizing the radiation dose to the tumor volume while minimizing the radiation dose to the surrounding normal tissue.

The ability to expand the use of these techniques to deliver higher doses in fewer fractions is now largely limited by changes in the tumor position from day to day and even during treatment, and so the ability to precisely locate the tumor throughout the course of RT has become a topic of concern within the radiation-oncology community.

For RT to be delivered as planned, the treatment beam must be accurately aligned with the tumor. During the course of treatment, the location of a tumor can change for a variety of reasons, including daily variations in patient set-up and organ motion. Recently, tumor targeting technology has become available to ensure that the tumor position at the time of treatment better matches the tumor position used to develop the patient's treatment plan.

Imaging technologies such as ultrasound, kilovoltage (kV) X-rays, and computed tomography (CT) are now available to verify the patient position at the time of treatment, but the time to acquire, analyze, and interpret the images can be significant. There are additional limitations with these methods. For example, cone beam (CB) CT can determine the shape and position of a target immediately prior to treatment, thus providing the target position during a 'snapshot in time', but cannot produce continuous imaging in realtime during treatment delivery. Realtime fluoroscopic kV X-rays with implanted gold fiducials can be highly effective for imaging moving targets. However, fluoroscopy exposes patients to high skin doses during extended procedures found with highly conformation treatment plans.

Target Localization and Tracking with AC Electromagnetics

The Calypso® 4D Localization System is an investigational system that uses an alternative localization method, which provides accurate information on both inter-fraction and intra-fraction target motion through the use of alternate current (AC) electromagnetics. The Calypso System utilizes AC electromagnetic fields to accurately and continuously locate and track implanted fiducials, called Beacon® transponders, providing realtime target position information to clinicians for initial patient set-up and during RT treatment delivery.

This technology has been developed for body-wide application, with the first clinical application focussed on the prostate. An investigational study of this system's use for prostate localization and realtime intra-fraction tracking is being conducted under institutional review board-approved protocols at five centers in the US, including M.D. Cancer Center, Orlando, and The Cleveland Clinic.

The Calypso System Target Localization Process

Prior to acquisition of the treatment planning CT, Beacon transponders are implanted in the patient's prostate under transrectal ultrasound guidance. The Beacon transponders are passive resonators designed for permanent implantation; each implanted transponder emits a uniquely identifiable signal when activated by the Calypso System. During the treatment planning process, the positions of the transponders are identified relative to the treatment isocenter position, and this information is entered into the Calypso System prior to the first patient localization.

During patient localization and treatment, the Calypso System provides the clinician with information on the target position relative to the machine isocenter. The transponder positions are detected by an array that is positioned over the patient. The position of the array relative to the machine isocenter is known through the use of infrared cameras that track optical targets on the array. The array detects the positions of the transponders relative to the target isocenter, and the position of the target relative to the machine isocenter is reported to the therapist (see *Figure 1*).

The target position information is displayed on an easy-to-use, objective interface that can be used to initially set up the patient (see *Figure 2*). The system reports the offset of the target position from the machine isocenter in the lateral, longitudinal, and vertical directions. While the patient is moved into position, the system provides immediate feedback to the therapists, enabling them to quickly align the patient to the machine isocenter. As the set-up guidance is both immediate and objective, therapists would be capable of rapidly completing the initial patient positioning. In fact, in the initial clinical study even novice users have been able to complete initial patient set-up in less than two minutes.

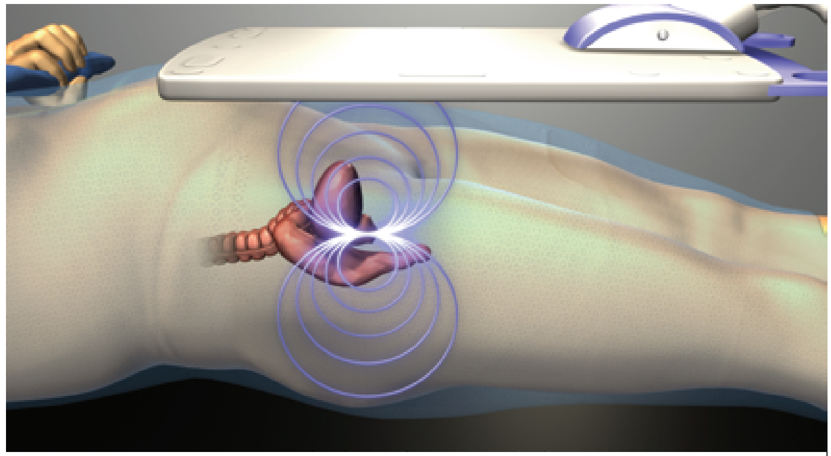
After initial positioning, the system is designed to be left in place during treatment delivery (see *Figure 3*). The target position relative to the isocenter is updated at a rate of 10Hz, enabling continuous monitoring of the target position during treatment. Any intra-fraction target motion is immediately observable on the tracking station monitor positioned in the control area for the linear accelerator (LINAC). If the target position moves beyond user-specified thresholds, the therapist is alerted and the patient can be repositioned if necessary.

The accuracy of this system for localization and tracking has been tested extensively under bench-top conditions.[1] For the typical range of isocenter positions (+/- 8cm from the center in the plane of the array and up to 27cm away from the array), sub-millimeter accuracy is maintained. Additional measurements obtained in a treatment room with a linear accelerator in operation demonstrate that this accuracy is maintained during machine motion and irradiation.

Observations on Intra-fraction Target Motion

An initial study of prostate motion in non-treatment conditions was conducted under institutional review board approval at two centers—the M.D. Anderson Cancer Center Orlando and the University of Michigan Medical Center. This study showed variable amounts of intra-fraction target motion—both show drifts over time and larger transient motions (see *Figure 4*).[2]

Figure 1: Implanted Beacon Transponder Sends Signal to the Array



Investigational Device. Not for sale.

Figure 2: Treatment Set-up Software Interface

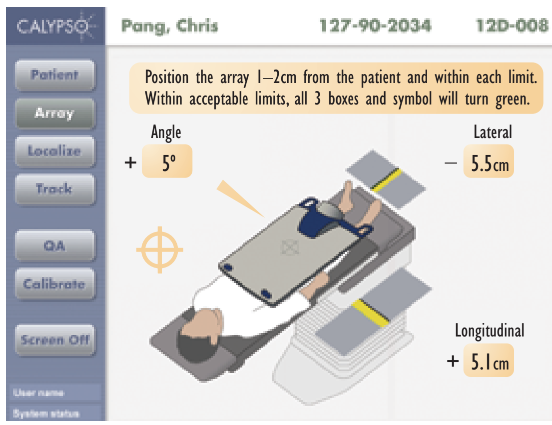


Figure 3: Treatment Set-up with the Calypso System

1. *Balter J M, Wright J N, Newell L J, Friemel B, Dimmer S, Cheng Y, Wong J, Vertatschitsch E, Mate TP, "Accuracy of a wireless localization system for radiotherapy",* Int. J. Radiation Oncology Biology Physics *(2005);61(3): pp. 933–937.*
2. *Willoughby T R, Kupelian P A, Pouliot J "Target Localization And Real-Time Tracking Using The Calypso® 4-D Localization System In Patients With Localized Prostate Cancer",* Int. J. Radiation Oncology Biol. Phys. *(article in review).*

Figure 4: Sample Target Tracking Data from Early Clinical Study of the Prostate

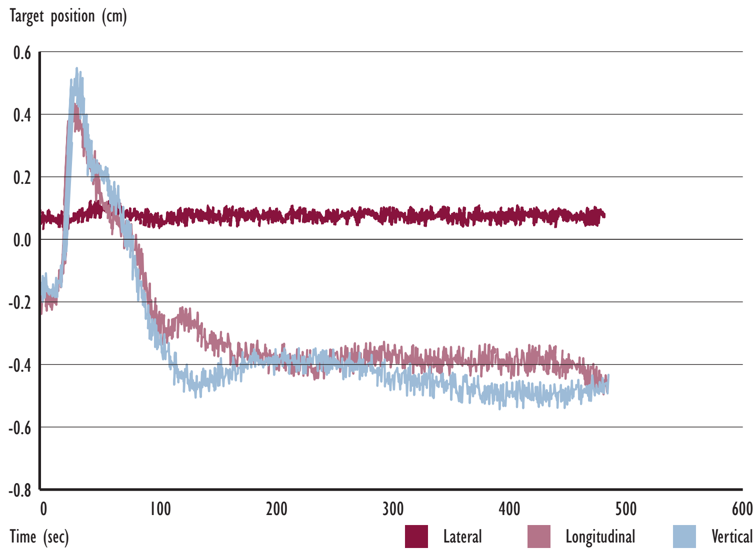
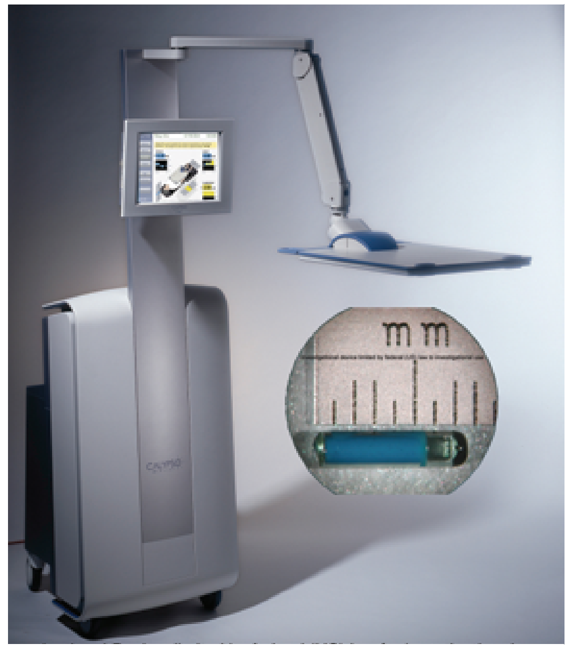


Figure 5



Investigational device, limited by federal (US) law for investigational use. Not for sale.

The current study of Calypso System use for prostate localization during RT is not yet complete. Preliminary observations from the current study warrant analysis to understand the clinical relevance of prostate motion. This pivotal study is expected to serve as an important source for fully understanding treatment set-up variability and intra-fraction realtime prostate motion and its impact in how RT is delivered to targets, such as the prostate. Additionally, it appears that prostate motion cannot be predicted from patient to patient or from day to day in a single patient.

It is expected that the availability of realtime target tracking data will contribute to further improvements in precise delivery of RT. Future use of target motion data may be used in treatment planning, set-up protocols, immobilization, and treatment delivery algorithms that incorporate retrospective data analysis.

Oncology Events 2006/2007

February 23–25, 2006
ACRO Annual Meeting 2006
Disney's Contemporary Resort, Orlando, Florida, US
www.acro.org/content/meetings_updates/2006meeting.cfm

March 3–9, 2006
Controversies in Prostate Cancer Detection and Treatment— Advances in Tumor Marker Discovery
Hawaii, US
www.mdanderson.org/conferences

March 12–15, 2006
3rd International Conference on Translational Research and Pre-Clinical Strategies in Radiation Oncology
Lugano, Switzerland
www.iosi.ch/ictr2006.html

March 23–26, 2006
Society of Surgical Oncology Cancer Symposium
San Diego, California, US
www.surgonc.org

April 1–5, 2006
American Association for Cancer Research Annual Meeting
Washington DC, US
www.aacr.org

June 2–6, 2006
ASCO 2006 Annual Meeting
Atlanta, Georgia, US
www.asco.org

June 22–24, 2006
Multinational Association of Supportive Care in Cancer/International Society for Oral Oncology 18th International Symposium of Supportive Care in Cancer
Toronto, Canada
www.mascc.org/index.php?load=pro_symposia&page=index&page_id=126

July 8–12, 2006
UICC World Cancer Congress 2006
Washington DC, US
www.worldcancercongress.org

November 5–9, 2006
48th Annual Meeting of the American Society for Therapeutic Radiology and Oncology
Philadelphia, Pennsylvania, US
www.astro.org

April 21–25, 2007
American Association for Cancer Research Annual Meeting
Boston, Massachusetts, US
www.aacr.org

CALYPSO® MEDICAL

The Calypso® 4D Localization System employs very small implanted sensors called Beacon® transponders that pinpoint the location and motion of tumor targets receiving external beam radiation therapy.

This investigational device is designed to provide, for the first time, an efficient non-ionizing method for real-time target localization and tracking with sub-millimeter accuracy. We are committed to providing a full continuum of target localization solutions throughout the body so clinicians can be knowledgeable about target motion and ensure treatment is ON TARGET, allowing patients to get ON WITH LIVING.

On Target, On With Living™

www.calypsomedical.com