International Journal of Radiation Oncology biology • physics

www.redjournal.org

Physics Contribution

Clinical Evaluation of a Laser Surface Scanning System in 120 Patients for Improving Daily Setup Accuracy in Fractionated Radiation Therapy

Torsten Moser, PhD,* Gregor Habl, MD,† Matthias Uhl, MD,† Kai Schubert, PhD,† Gabriele Sroka-Perez, PhD,† Jürgen Debus, MD, PhD,† Klaus Herfarth, MD,† and Christian P. Karger, PhD*

**Department of Medical Physics in Radiation Oncology, German Cancer Research Center, Heidelberg, Germany; and †Department of Radiation Oncology, University Hospital Heidelberg, Heidelberg, Germany*

Received Jul 4, 2011, and in revised form Apr 25, 2012. Accepted for publication May 16, 2012

Summary

Setup corrections from a surface imaging system were evaluated in 120 patients. Compared with megavoltage computed tomography (MVCT)-based corrections, the system showed more reliable corrections when we used an optical reference surface generated at the first fraction after applying the MVCT corrections, whereas when we used the DICOM (Digital Imaging and Communications in Medicine) surface contour, systematic deviations were found. Although additional MVCT imaging

Purpose: To evaluate the clinical suitability of a specific optical surface imaging system to detect setup errors in fractionated radiation therapy.

Methods and Materials: The setup correction accuracy of a 3-dimensional laser imaging system was analyzed for 6 different tumor locations with 20 patients each. For each patient, the setup corrections of the megavoltage computed tomography (MVCT) images of a TomoTherapy unit (TomoTherapy, Madison, WI) were compared with those of the laser system for the first 10 fractions. For the laser system, the reference surface either was obtained from the DICOM (Digital Imaging and Communications in Medicine) surface structure delineated on the planning computed tomography images or was acquired with the system itself at the first fraction after the MVCT-based setup correction. Data analysis was performed for both reference types.

Results: By use of the DICOM reference image, systematic shifts between 3 and 9 mm were found, depending on the tumor location. For the optical reference, no clinically relevant systematic shifts were found. MVCT-based setup corrections were detected with high accuracy, and only small movements were observed during treatment.

Conclusions: Using a reference image acquired with the laser system itself after MVCT-based setup correction appears more reliable than importing the DICOM reference surface. After generation of the optical reference, the laser system may be used to derive setup corrections over a certain number of fractions, but additional radiologic imaging may still be necessary on a regular basis (eg, weekly) or if the corrections of the optical system appear implausibly large. Nevertheless, such a combined application may help to reduce the imaging dose for the patient.

Reprint requests to: Torsten Moser, PhD, Department of Medical Physics in Radiation Oncology (E040), German Cancer Research Center, Im Neuenheimer Feld 280, 69120 Heidelberg, Germany. Tel: +(49) 6221-56-37976; Fax: +(49) 6221-56-4631; E-mail: t.moser@dkfz.de

Conflict of interest: This research was partly funded by LAP (Lüneburg, Germany) and the Federal Ministry for Education and Research (Bundesministerium für Bildung und Forschung) of Germany (KVSF; 03NUK004A,C; and 06HD156).

Supplementary material for this article can be found at www.redjournal.org.

Acknowledgment—The authors gratefully acknowledge the support of their colleagues from the Radiological University Clinic Heidelberg, where the study was performed.

0360-3016/$ - see front matter
http://dx.doi.org/10.1016/j.ijrobp.2012.05.026

may still be necessary, the use of the optical system can help to improve daily setup accuracy while reducing the imaging dose for the patient.

Introduction

In conformal radiation therapy, accurate and reproducible patient setup is required. In this regard, initial setup (IS) accuracy, as well as day-to-day setup variation, still poses a clinically relevant problem. Meanwhile, most linear accelerators are able to acquire images (eg, kilovoltage/megavoltage setup images or cone beam computed tomography [CT] scans) that allow correlation of the actual patient position with that during treatment planning CT. By use of such image guided radiation therapy techniques, the potential benefit for the patient has to be weighed against the additional risk associated with the imaging dose (1). For this reason, nonradiologic techniques to verify the setup position of the patient are of great interest.

Optical surface imaging systems are able to reconstruct a 3-dimensional (3D) surface model relative to the isocenter position. A setup correction is calculated by registering actual images with reference images stored in the system beforehand. Although the technical accuracy of such systems has been shown to be quite high (2-5), their suitability for clinical application depends on additional aspects, in particular on a fixed spatial relation between the surface and target region. As a measure of reliability, the corrections derived by the optical systems should agree with those from 3D radiologic imaging, which is the current gold standard in image guided radiation therapy.

In this study we investigated a specific laser-based surface scanning system in 120 patients treated at 6 different tumor locations. The setup corrections obtained with the optical system were compared with those obtained from routinely performed megavoltage computed tomography (MVCT).

Methods and Materials

Surface scanning system

The Galaxy 3D laser scanning system (distributed by LAP Laser, Lüneburg, Germany, but originally developed by C-RAD, Uppsala, Sweden; the system was further developed by C-RAD under the product name Sentinel) has been installed in line with the treatment table on a TomoTherapy unit (Hi·Art System; TomoTherapy, Madison, WI) at the Radiological University Clinic in Heidelberg, Germany. The system projects laser lines (wavelength, 690 nm) to scan the surface of the patient, and their reflections are recorded by a camera. The system is calibrated to the treatment machine's isocenter. One scan takes 1-5 seconds, depending on the selected system settings and region of interest. The maximum scan volume is approximately 670 × 950 × 490 mm (lateral [LAT], longitudinal [LNG], and vertical [VRT]). The spatial resolution is 0.2 mm for LNG and VRT and 0.5 mm for LAT.

The acquired images are used to create a 3D surface model that is registered with a previously generated reference image to derive a setup correction by use of an iterative closest-point algorithm (4). The reference model either can be acquired with the laser system itself or may be obtained by importing the contoured skin through a DICOM (Digital Imaging and Communications in Medicine) interface from the treatment planning CT system.

The setup corrections are calculated with 6 degrees of freedom (DOFs). They include translations in the lateral (LAT), longitudinal (LNG), and vertical (VRT) directions, as well as rotations around the vertical (ROT), longitudinal (roll [ROL]), and lateral (pitch [PIT]) axes. For comparison of 2 measurements, their corresponding radial deviation (RAD) was calculated as follows:

$$RAD = \sqrt{(LAT)^2 + (LNG)^2 + (VRT)^2}.$$

Data acquisition

The study was approved by the ethical board of the University of Heidelburg. Informed consent was obtained from all patients' before inclusion into the study. Measurements with the optical system were evaluated retrospectively and had no influence on the patients' treatment.

The study included 120 patients treated at 6 different tumor locations (brain, head and neck, thorax, breast, upper abdomen, and pelvis) (20 patients each) between December 2008 and August 2010. Patient characteristics are given in Table 1. Brain and head-and-neck patients were fixed by use of a mask system. For all other patients, only supportive devices such as custom-molded vacuum cushions or knee rolls were used. All patients were initially set up by use of skin marks and then received an MVCT scan, which was registered to the treatment planning CT scan in the target region. Because there was no possibility to apply ROT or PIT corrections on the TomoTherapy device, only a 4-DOF correction was obtained from the MVCT registration. Besides the translations, the ROL correction can be applied by modifying the gantry starting angle.

At the first 10 fractions, each patient also received 3 scans with the optical system. The first scan was taken after conventional setup with skin marks and room lasers and before the MVCT scan (t_0) (IS); the second after the MVCT-based correction was applied (t_0 + approximately 5 minutes) (corrected setup [CS]); and the third at the end of the treatment (t_0 + approximately 20 minutes)

Table 1 Patient characteristics

Tumor location	Age (median [range]) (yr)	Male/female gender
Pelvis	70 (59-78)	19/1
Upper abdomen	58 (39-72)	8/12
Thorax	56 (19-72)	15/5
Breast	50 (28-86)	0/20
Head and neck	64 (47-80)	13/7
Brain	56 (27-87)	11/9