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Couch height–based patient setup for abdominal radiation therapy

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ABSTRACT

There are 2 methods commonly used for patient positioning in the anterior-posterior (A-P) direction: one is the skin mark patient setup method (SMPS) and the other is the couch height–based patient setup method (CHPS). This study compared the setup accuracy of these 2 methods for abdominal radiation therapy. The enrollment for this study comprised 23 patients with pancreatic cancer. For treatments (539 sessions), patients were set up by using isocenter skin marks and thereafter treatment couch was shifted so that the distance between the isocenter and the upper side of the treatment couch was equal to that indicated on the computed tomographic (CT) image. Setup deviation in the A-P direction for CHPS was measured by matching the spine of the digitally reconstructed radiograph (DRR) of a lateral beam at simulation with that of the corresponding time-integrated electronic portal image. For SMPS with no correction (SMPS/NC), setup deviation was calculated based on the couch-level difference between SMPS and CHPS. SMPS/NC was corrected using 2 off-line correction protocols: no action level (SMPS/NAL) and extended NAL (SMPS/eNAL) protocols. Margins to compensate for deviations were calculated using the Stroom formula. A-P deviation $>$ 5 mm was observed in 17% of SMPS/NC, 4% of SMPS/NAL, and 4% of SMPS/eNAL sessions but only in one CHPS session. For SMPS/NC, 7 patients (30%) showed deviations at an increasing rate of $>$ 0.1 mm/fraction, but for CHPS, no such trend was observed. The standard deviations (SDs) of systematic error (Σ) were 2.6, 1.4, 0.6, and 0.8 mm and the root mean squares of random error (σ) were 2.1, 2.6, 2.7, and 0.9 mm for SMPS/NC, SMPS/NAL, SMPS/eNAL, and CHPS, respectively. Margins to compensate for the deviations were wide for SMPS/NC (6.7 mm), smaller for SMPS/NAL (4.6 mm) and SMPS/eNAL (3.1 mm), and smallest for CHPS (2.2 mm). Achieving better setup with smaller margins, CHPS appears to be a reproducible method for abdominal patient setup.

Introduction

The skin mark patient setup method (SMPS) is currently the standard procedure for patient positioning in radiation therapy. However, for abdominal cancers, SMPS is sensitive to skin movement caused by respiratory motion while patients' positions change during a treatment course. These disadvantages lead into considerable errors, both systematic and random. Moreover, SMPS causes progressive setup deviations from one treatment to the next, a phenomenon known as time trend (TT).[1] Consequently, there are concerns about the accuracy of the patient setup position when using SMPS for patients with abdominal cancers.

Online corrections during daily treatments reduce setup deviations (systematic errors, random errors, and TT), and therefore this procedure is regarded as yielding the most accurate results in modern radiation therapy.[2–4] However, it is often difficult to perform online corrections for many patients in clinical practice because such corrections are time consuming as they require several processes (image acquisition, analysis, and correction). Off-line correction protocols constitute one solution for improving

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setup accuracy with a smaller workload. The no action level (NAL) protocol, which is both simple and time efficient, obtains systematic errors of patient setup using images acquired during the first few sessions.[5] Thereafter, patient position is corrected depending based on the systematic errors obtained. However, NAL is less effective for patients with TT. To solve this problem, the extended NAL (eNAL) protocol has been introduced.[6] In addition to the corrections by NAL, eNAL acquires images on a weekly basis and updates the correction values. Although several investigators have reported that eNAL resulted in better setup accuracy than NAL, a greater workload is required for eNAL.[7-9]

Couch height patient setup (CHPS) is yet another solution for the improvement of setup accuracy. CHPS sets the couch height to reproduce patient position in the anterior-posterior (A-P) direction for simulation. Previous investigators have reported the effectiveness of CHPS in comparison with that of SMPS.[10,11] However, these studies focused on pelvic tumors such as prostate cancer that are not affected so much by respiratory motion. To the best of our knowledge, no studies have been reported on CHPS for tumors in the upper abdomen where considerable respiratory motion produces significant setup errors.

For patients with resectable pancreatic cancer, preoperative radiation therapy combined with chemotherapy has contributed to improvement of surgical outcomes.[12-14] It has been demonstrated that higher radiation doses are related to more favorable histopathological outcomes.[15] However, the volume of targets to which a high radiation dose can be delivered is limited for fear of irradiating surrounding organs at risk with lower tolerance for radiation. An accurate patient setup for daily treatments is therefore essential for preventing organs at risk from receiving a high dose.

The aims of this study were to compare the setup accuracy in the A-P direction for patients with pancreatic cancer and to determine margins that would compensate for deviations in 4 setup methods: SMPS with no correction (SMPS/NC), SMPS corrected with the NAL protocol (SMPS/NAL), SMPS corrected with eNAL (SMPS/eNAL), and CHPS.

Methods and Materials

Patients and CT simulations

For this study, we enrolled 23 patients who underwent preoperative 3-dimensional conformal radiation therapy for pancreatic cancer. Table 1 shows the subjects' characteristics. For CT simulation, each patient was immobilized with the Blue Bag immobilization system (Medical Intelligence, Schwabmuenchen, Germany) in a supine position and with the arms fixed above the head using molded side supports. Slight exhale and inhale breath-holding CT images were acquired with a GE LightSpeed (16 slices, GE Medical Systems, Waukesha, WI) to evaluate the magnitude of respiratory motion of the target. CT data were reconstructed in a field of view of 500 mm with a resolution of 512 × 512 pixels and a slice thickness of 2.5 mm. The exhale CT images were loaded into a workstation (GE Advantage Sim, GE Medical Systems). On exhale CT images, the isocenter was determined and the distance between the isocenter and the upper side of the CT couch was measured for use with CHPS. Wall-mounted lasers of CT simulation indicated the isocenter, after which anterior and bilateral skin marks were placed on patients.

Table 1
Patient characteristics

Number of patients	23
Male/female	13/10
Age (y), mean (range)	67.6 (55.2 to 80.4)
Height (cm), mean (range)	161 (145 to 181)
Weight (kg), mean (range)	57.5 (39.4 to 79.3)
BMI, mean (range)	21.7 (16.6 to 26.8)
TNM	
T3N0M0, *n* (%)	21 (91)
T3N1M0, *n* (%)	2 (9)
Location	
Head, *n* (%)	16 (70)
Body, *n* (%)	6 (26)
Tail, *n* (%)	1 (4)

The exhale and inhale CT images were transferred to a treatment planning system (Eclipse, version 8.9, Varian Medical Systems, Palo Alto, CA). The 2 clinical target volumes (CTVs) on the exhale and the inhale CT images covered the primary pancreatic tumor, retropancreatic soft tissues, the para-aortic region, the celiac and the superior mesenteric arteries, and some margins. The CTVs on both CT images were combined to form the internal target volume. To account for daily setup errors, the planning target volume was created by adding an isotropic margin of 5 mm to the internal target volume. The Clinac 2100C/D linear accelerator equipped with an aS1000 electronic portal imaging device (Varian Medical Systems) was used for treatment. Irradiation was delivered using 5 to 8 coplanar photon beams of 10 MV. Total prescribed dose was 50 to 60 Gy at the isocenter in 25 fractions.

Couch height–based patient setup

For treatment, patients were immobilized on the treatment couch in the same way as for CT simulations. First, SMPS was performed after alignment of skin marks and lasers in the treatment room in the 3 directions. Horizontal lines on either side were used for correcting the patient's rotation. After SMPS, the treatment couch was shifted so that the distance between the isocenter and the upper side of the treatment couch was equal to that indicated on the CT image. This patient setup was for CHPS, and the shift between SMPS and CHPS was measured (CHPS-SMPS shift). Each treatment was then performed with CHPS and free breathing. For the first treatment, the patient position was verified on electronic portal images. For every subsequent treatment, a time-integrated electronic portal image (TI-EPI), consisting of 22 to 24 images in total per patient, was acquired using a right or left (90 or 270 ± 10°) treatment beam. The matrix size of these images was 768 × 1024 and the pixel size 0.26 × 0.26 mm.

Setup deviation in the A-P direction for CHPS was retrospectively analyzed using Offline Review software (Varian Medical Systems). A TI-EPI (Fig. 1A) was used as a verification image, and a corresponding digitally reconstructed radiograph (DRR) created from the CT image (Fig. 1B) was used as a reference image for the manual registration of the anterior border of the vertebral body near the isocenter (Fig. 1C). We defined this patient position after registration as the benchmark and shifting of the couch in the A-P direction as CHPS deviation. The posterior direction of the couch shift in our study was positive. Moreover, for assessment of interobserver variations in CHPS deviation, 2 medical physicists independently registered 233 sessions for the 10 patients.

Calculation of setup deviations in SMPS

SMPS/NC of deviation was obtained from the following equation:

SMPS/NC deviation = CHPS deviation + CHPS-SMPS shift

In this study, SMPS/NC deviations were corrected by using 2 protocols: NAL (SMPS/NAL) and eNAL (SMPS/eNAL). For either protocol, SMPS/NC deviations were not corrected for the first 3 sessions. For NAL, the correction value that was equal to the mean of SMPS/NC deviations for the initial 3 sessions was used for correction of each SMPS/NC from the fourth until the final session. For the eNAL protocol, as described in a report by de Boer *et al.*, [6] initial correction was the same as for NAL. Thereafter, SMPS/NC deviations were measured weekly and SMPS/NC was corrected with a correlation formula calculated by using the measured SMPS/NC deviations.

Data analysis

The systematic (m_p) and a random (σ_p) error constituted the mean and the standard deviation (SD) of setup deviations, respectively, for each patient for all treatment sessions. Statistical values for all patients were designated thus: μ and Σ as the mean and the SD of the m_p, respectively, and σ as the root mean square of σ_p. Using these values, a margin (M) to compensate for deviations was calculated according to the following formula presented by Stroom *et al.*[16]: $M = 2.0\Sigma + 0.7\sigma$. The difference in the mean of setup deviations from repeated measurements for the 4 methods was analyzed by 2-way repeated measures analysis of variance (SPSS, version 16; SPSS Inc, Chicago, IL). In addition, TT analysis was performed in accordance with the definitions by de Boer *et al.* TT was represented as the increasing rate of > 0.1 mm/session throughout the entire treatment course without correction.

Results

Mean (± SD) interobserver variation of CHPS deviation was small at 0.1 (± 0.6) mm for 233 sessions for 10 patients, so that the subsequent setup deviation for all patients was measured by only 1 physicist.

Figure 2 shows cumulative frequencies of setup deviations for each method for 539 sessions for all patients. SMPS/NC resulted in