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Reducing patient posture variability using the predicted couch position

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ABSTRACT

A method is presented in which the couch position is predicted before the treatment instead of obtaining a reference position at the first treatment fraction. This prevents systematic differences in patient posture between preparation and treatment. In literature, only limited data are available on couch positioning. We position our patients at the planned couch position, allowing a small difference between skin marks and lasers, followed by online imaging. For a 3-month period, our standard deviations (mm) in couch position in the vertical, longitudinal, and lateral directions were head and neck—1.6, 2.8, and 2.5; thorax —2.9, 5.5, and 4.5; breast—3.0, 4.1, and 4.0; and pelvis—3.5, 4.0, and 4.7, respectively. We have improved the reproducibility of patient posture in our institute by using the predicted couch position. Our data may serve as a reference for other institutes because the couch position variation is less than that published in literature.

Introduction

Accurate and reproducible patient positioning on the treatment couch is essential for high-quality radiotherapy. The verification of the treated couch position is used to prevent errors in radiation delivery.[1-3] Tolerance limits are used to detect errors in patient setup. Regarding patient safety, one can consider the verification of the couch position as one of the defensive layers in the Swiss cheese model by Reason.[4]

In the past, we used offline imaging protocols such as extended no action level,[5] no action level, and shrinking action level[6] to position the patients. Currently, we perform online imaging for every treatment fraction. One may question whether it is still important to spend much time on patient positioning and couch position verification, because any differences in position are corrected by online couch shifts. However, changes in patient posture cannot be corrected by online imaging. In this article, we show how we use the couch position to improve the reproducibility of our patient posture.

In general, one uses the couch position during the first fraction as a reference. Hadley *et al.*[2] describe a method in which the cumulative average over previous fractions is taken as the planned couch position. However, this may still differ from the couch position during planning computed tomography (CT). In our method, the couch position is predicted from the planning CT and the treatment plan.

Day-to-day variations in couch position give an idea of the reproducibility of patient posture for specific immobilization devices. Data on couch position variations for multiple immobilization devices have been published by Hadley *et al.*[2] Data for head and neck immobilization have been published by Vakaet *et al.*[7] Engelsman *et al.*[8] use the couch positions to determine the interfractional patient motion for head and neck immobilization devices. Most studies on interfractional patient motion are based on imaging[9-11] and do not report the variation in couch position.

Methods and Material

To use the couch position for verification or positioning, it is of course necessary to homogenize the patient immobilization devices. Small differences in the fixation of the immobilization devices to the couch lead to differences in couch position. Table 1 gives an overview of the immobilization devices for the main treatment sites used in our institute.

We preferably mark patients on anatomically stable reference points. The point in the CT scan defined by these skin marks is the patient setup point (P).

Figure 1 shows the patient setup point P in the CT, with the geometric features described as follows. The CT coordinates (x,y,z) are according to the Digital Imaging and Communication in Medicine (DICOM) standard. Before each CT scan is taken, the couch length is "zeroed." This is done at a fixed position of the Exact Couch Top (Varian Medical Systems) indicated by "S0." The patient is positioned with the patient setup point on the longitudinal laser outside the CT bore. A lead mark is placed on this position to be able to check the value in the CT images. The difference between the longitudinal laser outside the bore and the center of the CT (500 mm in our case) is taken into account, and the couch length position for the patient setup point (C_{Length}) is noted in our electronic patient file, Process2Cure

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Table 1
Patient immobilization devices for different treatment sites (CIVICO medical solutions)

Treatment site	Immobilization devices
Head and neck	Posifix-2 base plate with a 3-point head mask or a 5-point head and shoulders mask Individual or standard head support
Thorax	Posirest-2 arm support system
Breast	C-Qual Breastboard
Pelvis	Combifix lower extremities positioning board

(Centric). The couch height (C_{Height}), as indicated on the CT, is also noted. The couch height indicates the distance of the center of the CT to a fixed point on the bottom of the CT couch. For our purpose, the exact position of this point does not matter, because we are interested in the distance of the center of the CT to the Exact Couch Top (H_p). Possible laser shifts in vertical (L_{Height}) and lateral directions ($L_{Lateral}$) are also noted.

A dedicated in-house developed software tool "Planinfo" calculates the DICOM coordinates of the patient setup point (P) in the CT from the values in the electronic patient file, taking the characteristics of the CT into account.

If y = 0 at the center of the CT (as is the case for our CTs; Fig. 1), then

$$x_p = L_{Lateral} \quad (1)$$

$$y_p = -L_{Heigth} \quad (2)$$

$$z_p = C_{Length} \quad (3)$$

If y = 0 moves with the height of the CT couch (as is the case for our positron emission tomography-CT), then

$$x_p = L_{Lateral} \quad (4)$$

$$y_p = -L_{Height} - C_{Height} + \Delta_1 \quad (5)$$

$$z_p = C_{Length} \quad (6)$$

with Δ_1 denoting a CT-specific difference between the y-coordinate at the center of the CT and C_{Height}.

The height of P above the flat couch top (H_p) is given as follows:

$$H_p = L_{Height} + C_{Height} - \Delta_2 \quad (7)$$

with Δ_2 denoting a CT-specific difference between C_{Height} and the distance of the center of the CT to the flat couch top (Fig. 1).

The couch coordinates at the LINAC are indicated by the notation used by ARIA (Varian Medical Systems). The lateral couch position is indicated by LAT (increases as couch moves toward gantry at 90°), the longitudinal coordinate by LNG (increases as couch moves toward stand), and the vertical coordinate by VRT (increases as couch moves up). The values of the setup point P in the CT (Fig. 1) are translated to the couch position for which this point in the patient CT is at the isocenter of the LINAC.

The couch coordinates of P (in mm) are given as follows:

$$LAT_p = -x_p + \Delta_3 \quad (8)$$

$$LNG_p = -z_p + 1400 + \Delta_4 \quad (9)$$

$$VRT = -H_p + \Delta_5 \quad (10)$$

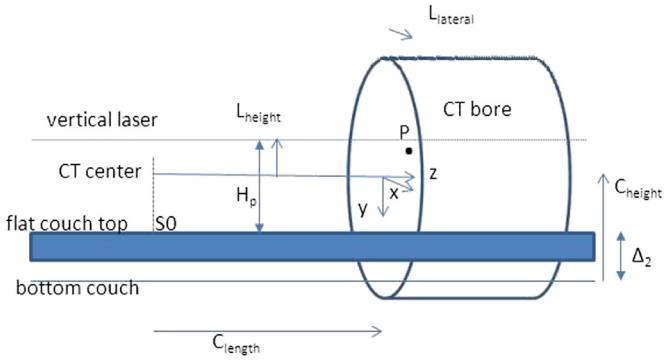

Fig. 1. CT scan with coordinates of laser, couch, and patient.

with Δ_3, Δ_4, and Δ_5 denoting the given differences between a specific immobilization device on the CT and the LINAC. Planinfo uses a table with values of Δ_3, Δ_4, and Δ_5 for each immobilization device. For example, sometimes the breast board is shifted laterally at the CT by a fixed amount of 30 mm to enable scanning of a large patient with breast cancer. For "breast board left" $\Delta_3 = 30$ mm, which corrects for the breast board not being shifted laterally at the LINAC. In general, the values of Δ_3 and Δ_4 are zero. The couch sag at the LINAC is taken into account in Δ_5. The value of 1400 mm in Eq. (9) is the longitudinal couch position when the "S0" indication on the couch top is in the plane of the isocenter at our LINACs.

The "user origin" in our treatment planning system Eclipse (Varian Medical Systems) is defined as the patient setup point with coordinates (0,0,0). The isocenter coordinates in the treatment plan (I) are relative coordinates regarding the patient setup point. The isocenter coordinates are read by "Planinfo," which calculates the couch coordinates to align the isocenter of the plan in the patient with the isocenter at the LINAC:

$$LAT_I = LAT_p - x_I \quad (11)$$

$$LNG_I = LNG_p - z_I \quad (12)$$

$$VRT_I = VRT_p + y_I \quad (13)$$

These values are manually registered in the record and verify module of ARIA and a standardized setup note is copied, containing the couch position of the patient setup point. "Planinfo" verifies the manual transfer of values by comparing the values in the ARIA database with the calculation.

At the LINAC, the patient is positioned with the immobilization device. The couch is shifted to the predicted couch position of the patient setup point P according to the setup note. The therapists check the lasers with the patient marks and, if needed, instruct the patient to move toward the desired direction. A deviation of 5 mm between the laser and skin marks is accepted in a given direction, as long as it is equal along a laser line to prevent unwanted rotations. Then, the couch is shifted to the couch position of the isocenter I, using the relative couch shift option Delta Couch (Varian Medical Systems) or a manual shift when Delta Couch is not available. Finally, an online imaging procedure is performed before treatment. Our method implies that we cannot interpret the online couch shifts as a combination of systematic and random setup errors in the usual sense,[12] because we do not position the patient with the skin marks on the laser.

Results and Discussion

We have improved our patient positioning by taking the following sequential steps:

(1) Patient setup is based on skin marks, relative couch shifts, and offline imaging protocols.
(2) The immobilization devices are homogenized on the different CTs and LINACs.
(3) Online imaging protocols are introduced for every treatment site.
(4) The couch position is predicted from planning CT and treatment planning. The predicted couch position is used for verification of patient setup; patient setup is with the lasers on the skin marks.
(5) The predicted couch position is used for patient setup. The couch position is the predicted couch position before online imaging. Lasers may differ from the skin marks.

We have analyzed the accuracy of couch positioning by comparing the predicted couch position with the treated couch position for all fractions in the period December 2013 to February 2014. Figures 2 to 5 show the results for different immobilization devices (tolerance tables).

Table 2 summarizes the results for the 4 treatment sites and corresponding immobilization devices (Table 1). As expected, the distributions in the vertical direction are more narrow than in the other directions. The distributions show that it is possible to position the patient in such a way that after an online couch shift, the difference between the treated and the planned couch position is less than 1.5 cm in any direction: VRT, LNG, or LAT.

Our head and neck treatments consist of cranial irradiations with a 3-point mask and head and neck irradiations with a 5-point mask. The average standard deviation for head and neck