Out-of-Treatment Room Set-Up for Patient Positioning in External Beam Radiotherapy

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Abstract—**The use of a transport system for out-of-treatment room set-up in external beam radiotherapy has been verified. We have looked into the vibrations which a patient is subject to during movement of the trolley as well as the accuracy achieved when using a reclining table for patient set-up and immobilization. The accuracy that can be achieved by the reclining approach is compared to conventional methods currently in use.**

Keywords—**Patient transport, reclining, repositioning accuracy.**

I. Introduction

In external beam radiotherapy it is customary to use patient set-up procedures were the patient is immobilized in the treatment room using a vacuum bag located on the treatment couch. This procedure has been in use for many years and is well-proven but it comes with several drawbacks in terms of repositioning accuracy as well as the problem for elderly people to easily enter the treatment position.

We have developed a concept allowing a patient to "step" into the immobilization device, while standing up, using a loading station. Once steadily adjusted to the cradle the device is reclined to horizontal position. This minimizes the need for adjustment of the patient position on the couch. Internal organs will thereby only be subject to gravitational movements and these are sought to be reproducible during the course of radiotherapy. This procedure may also be performed outside of the treatment room, thereby increasing patient throughput.

Radiotherapy using highly advanced conformal treatment techniques, e.g. IMRT and hadron therapy, will require verification of the planned treatment volume prior to treatment. This can be done at the treatment location using kVCT or MVCT or even outside of the treatment room with conventional diagnostic imaging tools, e.g. CT. Alternatively, the use of MRI may be an option as it will drastically reduce the dose to otherwise healthy tissue due to the verification procedures.

The out-of-treatment room set-up procedure requires means of transporting the patient in the immobilized position in between the imaging station and the treatment room and the patient positioning system.

II. Methods and materials

A. Transport System

The transport system is comprised of a trolley allowing the patient to be transported in-between the loading station or imaging device and the treatment room and its couch. The trolley is driven by electrical motors, one on each wheel, powered by a rechargeable battery. Depending on facility layout the transport roads may be quite complex and it is therefore paramount that trolley movements be smooth so that the set-up procedure is not invalidated. Suppression in vibration and jerk has been aimed for during system implementation [1]. We have investigated acceleration and vibrations on the moving trolley as well as those the trolley is subject to during the docking and undocking procedures.

B. Patient Set-Up

A patient positioning system has been constructed which allows the smooth translation from standing position into horizontal position by means of reclining a treatment table. A conventional whole body immobilization bag has been used as support for the patient and the bag was fitted to the patient in supine position. The same immobilization bag was used for both the reclining technique and the traditional set-up procedure.

The same patient was asked to perform the alignment procedure at three separate occasions during each day. The reclining as well as the conventional set-up procedure was performed consecutively. These procedures were performed at 30 occasions during 10 days, thus corresponding to a long term course of radiotherapy.

The immobilization bag is positioned on the indexed treatment table and the table is then tilted for the reclining positioning technique. Using the reclining technique, the patient is asked to enter the footrest in order to stand comfortably with the back against the cradle. The next step

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includes moving the patient from vertical to horizontal by means of an electric motor without any further patient assistance, see Fig. 1. This procedure takes less then one minute.

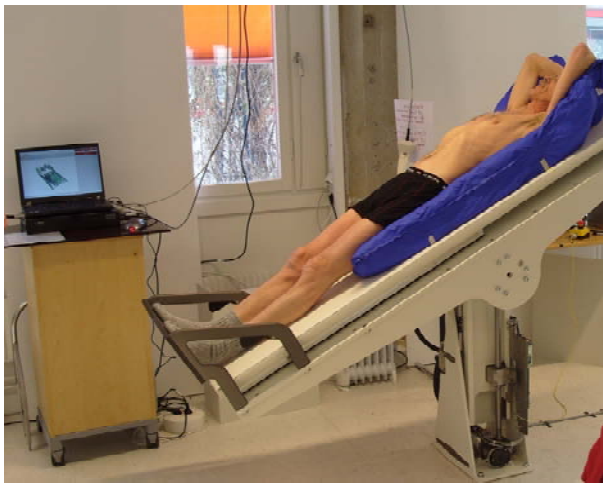

Fig. 1 Experimental reclining set-up

For the traditional set-up procedure, the same patient is asked to climb onto the couch with the immobilization device already in place. The patient then puts his body in the cradle and adjusts his immobilization to fit into the foam comfortably.

After each of the set-up procedures, the position is recorded using a laser scanning system.

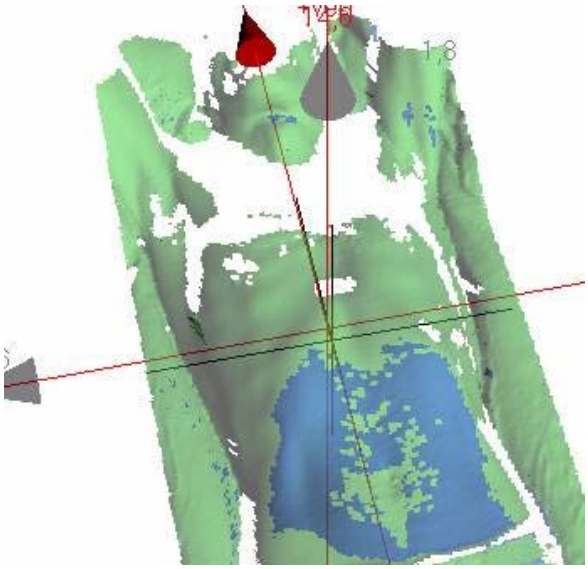

Fig. 2 Image displaying the region of interest used during patient set-up

The laser scanning system thereby generates a displacement vector in the x-, y- and z-directions (coordinate system according to IEC 61217 [2]). The comparison procedure is based on a comparison towards a reference image generated on the first day of immobilization. The region of interest used includes the surface from the pelvis and up to the beginning of the neck, see Fig. 2.

III. Results and Discussion

A. Transport System

The trolley has been undocked from the loading station and then moved 20 meters, according to a simulated maze transport pattern, before returning to the loading station for docking. The overall time for this procedure was 2.9 minutes. Table 1 shows the measured root-mean-square (RMS) velocity of the vibrations during each transport cycle.

Table 1 Maximum acceleration and jerk during trolley transport

Action	Time used [s]	Acceleration [m/s^2]	Jerk [m/s^3]
Undocking	25	0.15	0.16
Transport	115	0.25	0.26
Docking	35	0.15	0.14

The vibrations and jerk that a patient is subject to are quite low due to the integrated Ackerman compensation and differentiated speed control of each wheel during motion and an ultrasound positioning control system during docking and undocking. Our own limits of <1 m/s^2 for acceleration/deceleration and <0.3 m/s^3 for jerk have been met.

The largest forces are exhibited during trolley movements. The movements during the experiments have been performed on a standard industry floor in good shape but not purpose manufactured for trolley movements. The vibrations are therefore expected to be further reduced when floors are manufactured with higher tolerances.

B. Patient Set-Up

The set-up procedure using conventional set-up shows that the largest uncertainties appear in the y-direction, see Fig. 3. This effect appears in spite claims that the positioning procedure feels comfortable and appropriate by the patient.

The reclining technique results in an increased accuracy, see Fig. 4. The precision is also higher and this is especially evident in the y-direction.

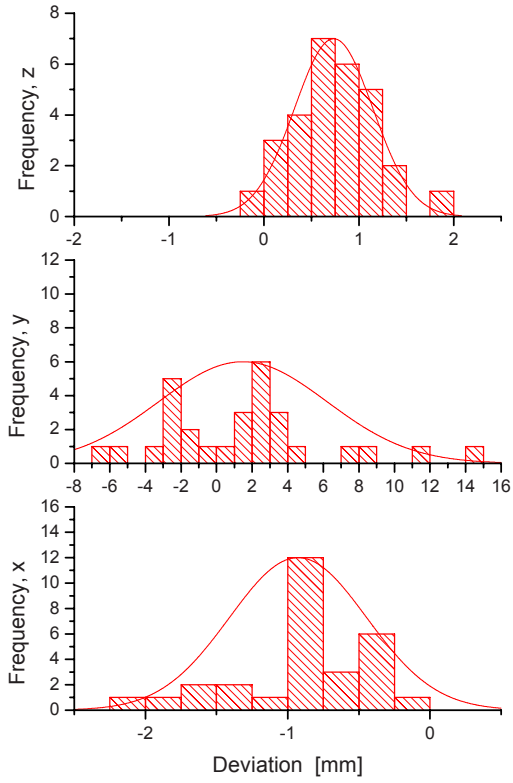

Fig. 3 Set-up procedure using conventional set-up

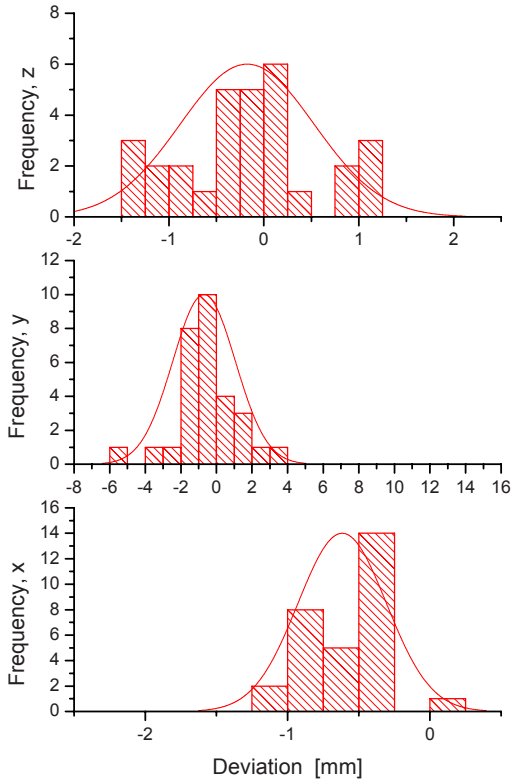

Fig. 4 Set-up procedure using reclining set-up

In general, the accuracy is improved using a reclining technique for set-up, see Table 2. During this initial phase, we have looked at the external contour but a secondary effect using the reclining technique is the potential for better localization of the internal organs as well. These improvements may be used for reducing margins during treatment planning or applying different adaptive procedures.

Table 2 Set-up displacements

Displacement	Conventional set-up [mm]	Reclining set-up [mm]
x-direction	-0.9±0.5	-0.6±0.3
y-direction	1.5±4.7	-0.7±1.8
z-direction	0.7±0.4	-0.2±0.7

IV. Summary and Perspective

The use of a reclining technique adds to a better patient positioning. The practice-changing approach of reclining the patient leads to a more reproducible set-up procedure while the accuracy during treatment is enhanced.

The reclining technique also allows using more flexible approaches in department design as the loading station may be located remotely and the patient transported between the radiotherapy station and the dressing area, or optionally pre-verification, thereby allowing higher patient throughput or alternative target verification methods.

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