# UPRIGHT PATIENT POSITIONING

FOR

PELVIC RADIOTHERAPY TREATMENTS

REPRODUCIBILITY | COMFORT | INTER-FRACTION | INTRA-FRACTION IMMOBILIZATION | PELVIC

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PUBLISHED PAPER

# Upright Patient Positioning for Pelvic Radiotherapy Treatments

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## Abstract

Radiotherapy is typically delivered in supine position. However, upright positioning may affect organ volume, positioning, and movement, compared to supine/prone positioning which might have beneficial impacts. In this study, we report patient positioning data in an upright positioning system designed by Leo Cancer Care®.

Sixteen patients with pelvic tumors were included in this study. They had 3 setups in an upright position: an initial setup with acquisition of reference optical images, and 2 repositioning setups. The intra-fraction motion was assessed during two 20-minute chair rotation sessions. The patient comfort in supine and upright position was assessed with a 5-point Likert scale questionnaire.

Eight women and 8 men treated on regular linacs between October 2021 and June 2022 were included. Their median age and weight were 62.5 years (35 to 81 years) and 75.1 kg (41 to 107 kg). The inter-fraction shift means were -0.5 mm (SD= 2.5), -0.4 mm (SD = 1.3) and -0.9 mm (SD = 2.7) in left-right (LR), antero-posterior (AP), and cranio-caudal (CC) directions, respectively. The intrafraction shifts after 20 min were 0.0 mm (SD = 1.5), 0.2 mm (SD = 1.1) and 0.0 mm (SD = 0.3) in LR, CC, and AP directions, respectively. Average global comfort was 4.1 (3 to 5) for the upright position and 3.9 (2 to 5) for the supine position.

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In conclusion, the first study on pelvic cancer patients positioned in upright position on a chair is promising, and it opens a potential new direction for the treatment of cancer patients. Evaluation of thoracic and head and neck tumors is ongoing, and imaging with vertical CT is expected to start soon.

## Introduction

For decades, photon radiotherapy treatments have been typically performed with patients in a recumbent position i.e. laying in a supine, prone or decubitus position, using a linear accelerator with the C-arm rotating around them. Immobilization devices have thus been designed for patients in the supine position; planning CTs are done in supine position, and on-board images with CBCT are also taken in supine treatment position. Several recent publications suggest that patient positioning in an upright position (sitting or standing) could improve treatment delivery and possibly patient outcome for several tumor locations (1–6).

It has been demonstrated that respiratory motion is reduced for upright positions compared to supine positions. In a study performed on 5 volunteers using a multi-position Magnetic Resonance Imaging-scanner (MRI), it was shown that on average, the cranio-caudal lung motion was reduced by 4 mm, and the exhale lung volume was larger when moving from supine to upright position (1). In a study on 100 volunteers using a supine and an upright CT, it has also been reported that the inspiratory and expiratory bilateral upper and lower lobe, and lung volumes were significantly higher in the standing and sitting positions than in the supine position with an increase between 5.3 and 14.7% (6). These data suggest that for lung irradiation, the upright positioning may be associated with a lower mean lung dose. One may extrapolate these data and anticipate a similar reduction in cranio-caudal movement for upper abdomen tumors such as liver or pancreatic carcinoma.

Regarding pelvic tumors, using a multi-position MRI-scanner, it has been showed that the bladder is more elongated in an anterior-posterior direction when volunteers were upright compared to supine; moreover, it was found that the distance between the sacrum and the bladder was reduced in the upright position compared to the supine position and that changes in bladder fill do not change the prostate position significantly (5). Altogether, these observations indicated that the small bowel may fall within the pelvic area less frequently in upright positions compared to supine; this may have positive consequences when irradiating pelvic tumors such as prostate tumors, by decreasing acute and late treatment morbidity.

McCarroll et al tested an upright positioning device on 5 patients with head and neck tumors showing an easy set-up, a good reproducibility, and improved patient comfort at the back level in the upright position compared to the supine position (4). Furthermore, in patients with head

and neck tumors, based on fiberoptic examination typically performed in seated patients, one could hypothesize that for some locations, such as the base of tongue, a space could be maintained between the tumor and the posterior pharyngeal wall in an upright position; in the supine position, the base of tongue is usually falling down touching the posterior pharyngeal wall as seen on planning CT. A space could also possibly be foreseen between the dorsal surface of the tongue and the soft-palate in upright position, which is typically not the case in the supine position.

In this context, Leo Cancer Care (LCC) proposed a change in paradigm in radiotherapy treatment, whereby the patient would be positioned, imaged, and treated in an upright position, i.e. sitting or standing. For this purpose, LCC designed a new system including an upright positioning system, a vertical CT and a horizontal linac (see more information on https://www.leocancercare.com). As per today, only the upright positioning system has been released. An early prototype of the "Eve" positioning system (so-called "the Chair") has been installed in the Radiation Oncology Department at Centre Léon Bérard, in Lyon, France. The ongoing research program includes several steps, the first being the validation of the upright positioning system for patients with various tumor locations. The main objective of the present study is to evaluate upright positioning and immobilization accuracy based on optical images, the setup time and comfort in patients with urological, gynecological, and lower gastro-intestinal tumors undergoing radiation therapy.

## Materials & Methods

### STUDY DESIGN AND PATIENT POPULATION

The study was designed as a prospective, single center, observational pilot study. All patients referred for pelvic radiotherapy with a curative intent and who were able to walk and to stand were eligible, i.e. patients with prostate, bladder, cervical, endometrial, rectal or anal canal cancer. These patients were treated according to standard institutional protocol on an Elekta® Linear Accelerator or a Tomotherapy Unit (Accuray®). The patients had to be at least 18 years old and able to give informed consent. The study was approved by local institutional review board (R201-004-258). All patients, included in this study, gave informed consent after reading written information.

### PATIENT POSITIONING DEVICE

The Chair is composed of different parts, which can be adjusted independently (Figure 1). The backrest inclination is adjustable between 5°, 10° or 15° forward or backward leaning (Figure 1(1)). The seat pan inclination can be modified between 0° (horizontal seat pan for the sitting position) and 50° (position close to the standing position) (Figure 1 (2)). The seat height can vary between 38 cm and 79 cm from the floor, and is initially defined based on the patient's leg length. The position of the shin rest (Figure 1 (3)) and the heel stop (Figure 1 (4)) are adapted so that patients are comfortably immobilized and sustained without effort. An arm support fixed to the edges of the backrest is added for patients to

rest their arms. Lastly, the Chair can rotate clockwise or counterclockwise at a gradual speed of 1 rotation per minute. All the devices can also move in the cranio-caudal direction up to a maximum of 70 cm. These 2 movements can be actioned simultaneously allowing the generation of a helical movement if necessary.

An optical guidance and tracking system (OGTS), developed by Leo Cancer Care has been used for patient positioning. This innovative optical guidance and Tracking system guides patient setups and tracks motions with 20 Mega Pixel high resolution optical cameras. The system comprises of up to 5 cameras, using 3 at a time to view the patient in the immobilized position. The cameras are orthogonal to each other with 4 cameras in the horizontal plane at isocenter level and one camera in the ceiling pointing down at the isocenter. In the configuration used in the study, only two OGTS cameras are fixed on the North and West walls of the room at the same height as the isocenter position, 90 ° apart from each other. Daily live images are compared in a proprietary and rapid manner with recorded reference images. Any mismatches between the live and reference images are displayed to the user and can be quantified by aligning the images in each camera view. The reference position appears in green, the current image in pink and when both positions are similar no green or pink light are visible (Figure 2). The high-resolution cameras allow for a detection limit of 0.3 mm in the image plane traversing the isocenter. The system is under IP protection review at this stage.

## PATIENT WORKFLOW

For conventional radiotherapy, patients included in this study were routinely setup in a supine position with a head support (CIVCO Radiotherapy, USA), the Kneefix-2 (CIVCO Radiotherapy, USA) and a minimum of 3 skin tattoos as routinely performed for the treatment of pelvic tumors in supine position.

The patients had 3 additional appointments planned during their radiation therapy course (on separate days), to test the upright positioning device. During the first appointment, the patients were setup by one or two radiation therapists (RTT) on the Chair. The patients were setup without pants, shoes, and pullovers. Previous tests on healthy volunteers showed that the most preferred inclination was with a 5° backward angle and so the backrest was typically positioned at 5° backward. The seat pan was inclined by 50° to keep the inguinal areas free. The seat height was adjusted according to the patient's leg length. The patient was then invited to approach the Chair, with their legs close to the seat pan and to maintain a standing position. The shin rest position was brought closer to the patient legs, providing support as the patient was asked to sit down. The shin rest position and the heel stop were properly adjusted to have the devices against the patient's legs and the heels respectively. A vacuum cushion was molded for each patient. The beads inside the vacuum cushion were pushed back as far as possible on each side of the cushion and at the level of the lumbar lordosis to mold the patient's pelvis and back. Last, a belt was positioned on the upper part of the abdomen, the arm support was installed at the level of the axilla, and a head rest set behind the head and neck. When the patient was properly set-up on the Chair (as shown in Figure 2), anterior and lateral optical images were acquired as references.

Patient positioning characteristics including setup parameters (seat height coordinate, seat pan inclination, shin rest and heel stop coordinates) were recorded in the database. No tattoo or landmarks were made on the patient' skin.

The patients were repositioned at the second and third appointments using the patient positioning characteristics. Then, the repositioning accuracy was verified based on the optical image reference system. After applying shifts, when necessary, a simulated treatment session was performed with several helical movements for 20 minutes, with positioning checks using optical images, performed every 4 minutes.

## DATA COLLECTION

The patient characteristics, including age, weight recorded at each upright positioning, tumor site, Karnovsky index, and surgical history, were collected. Positioning characteristics, including backrest angle, seat height coordinate, seat pan inclination, shin rest and heel stop coordinates, belt and arms support position, and head rest shape, were also recorded. The patient's cumulative radiotherapy dose on the day of the upright positionings test was collected as well.

The duration of the various steps was calculated as followed:

- First positioning: interval between the time when the patient was ready to be positioned on the Chair and the time the first optical acquisition was performed.
- Repositioning time: interval between the time when the patient was ready to be repositioned on the Chair and the time when the positioning had been checked using the optical system.
- Uninstallation time: interval between the end of the Chair rotation and the time when the patient had left the Chair.

The inter-fraction positioning shifts were calculated after manual registration between the reference optical images and the images taken during the repositioning. Image registration was performed using the skin surface at the level of the thighs and pelvis. After image matching, right-left deviations (x-direction), anterior-posterior deviations (y-direction), and cranio-caudal deviations (z-direction) were calculated by the OGTS software; deviations in pixels were converted into deviation in millimeter after calibration of the system. Negative values were set for left, posterior and caudal displacements in the x-, y- and z-direction, respectively. Deviations were collected before they were applied to the Chair.

Intra-fraction motion was assessed during the 2 repositioning tests using the same method than for assessing the inter-fraction motion. The deviations were calculated between the reference image and the images captured every 4 minutes during the Chair rotation.

Lastly, a qualitative assessment of the immobilization was performed using a 5-points Likert scale (from 1 (very painful / very difficult / very unstable) to 5 (very comfortable / very easy / very stable) questionnaire including 10 questions (see appendix 1). Patient comfort (in global and on the different parts of the body), ease of setup, and perceived stability in supine and upright positions were assessed. The questionnaire was given to the patients at the end of the first setup session, and they returned it a few days after their last upright repositioning session.

### DATA ANALYSES

The mean, standard deviations (SD), minimal and maximal values of positioning and repositioning durations, and the mean, SD, minimal and maximal values of inter-fraction position deviations were calculated. A Mann Whitney test was used to compare the first positioning duration, the repositioning duration and the time to get out of the device, with one versus two RTTs. For inter-fraction position deviations, the proportion of values larger than or equal to 5 mm and 3 mm were also calculated. Lastly for the intra-fraction shift, means, SD, and minimal and maximal values at 4, 8, 12, 16 and 20 minutes after repositioning were calculated. The proportion of values larger than or equal to 3 mm was also calculated. Regarding the questionnaire, the mean scores were calculated for the global comfort, the easiness to get in and get out of the device, and the patients' score proportion for each answer and for each sub-site were reported. An Exact Fischer test was used to compare the proportion of each answer in supine position and in upright for each sub-site.

## Results

From October 2021 to June 2022, a total of 16 patients (8 men and 8 women) with prostate, bladder, rectal, endometrial or cervix/uterine corpus tumors were included in this study. A summary of the patients' characteristics is provided in Table 1. Their mean age, height, and weight at the first upright positioning were 62.5 years (from 35 to 81 years), 166 cm (from 152 to 182 cm) and 75.1 kg (from 41 to 107 kg), respectively. Three patients had post-operative radiotherapy including 1 patient who had a concomitant chemotherapy; 7 patients had chemo-radiotherapy and 7 patients had radiotherapy exclusively. Three patients had previous knee surgery including 1 patient with a knee prothesis. One patient underwent an abdomino-perineal amputation with coccyx resection and colostomy 2 years before for a recurrent tumor. Between the first and the last upright positioning, 1 patient gained 1 kg, 1 patient gained 2 kg, six patients lost 1 kg each and the other patients had no weight change. On average, patients had received 19.1 Gy (from 6.1 to 49.2 Gy), 25.9 Gy (from 10 to 55.2 Gy) and 34.3 Gy (from 14 to 57.5 Gy) at their first, second and third upright positioning, respectively.

### PATIENT SETUP TIME

The first 10 patients were setup by one RTT alone for all upright positionings and the subsequent six patients were set-up by two RTT.

On average, 14.4 minutes (from 12.0 to 17.0 min.) were required for the first positioning with one RTT and 5.0 min (from 4.0 to 5.9 min) with two RTTs; the difference is significant (p<0,0001). Subsequent re-positionings took on average 4.9 min (from 3.0 - 9.0 min) with one RTT and 2.9 min (from 2.0 to 4.6 min) with two RTTs; the difference remains significant with a p-value of 0.008. The mean time to unload patients was 2.5 min (from 2 to 4 min) and 0.6 min (from 0.3 to 1 min) with one RTT and two RTTs, respectively. This difference is significative with a p value <0.0001.

## INTER-FRACTION AND INTRA-FRACTION SHIFTS

Fourteen patients had three upright setups including two repositioning setups with a simulated treatment and two patients had only two upright setups (one upright setup, and one repositioning setup with a simulated treatment) due to an interruption of radiotherapy treatment for one patient and a technical issue with the optical imaging software for the other patient.

The results of the inter-fraction are presented in Table 2. Right-left (X), antero-posterior (Y) and cranio-caudal (Z) inter-fraction shifts were on average of -0.5, -0.4, -0.9 mm, respectively, with a standard deviation equal to 2.5, 1.3, 2.7 mm, respectively. One patient had shifts larger than 10 mm in right-left (12 mm) and cranio-caudal (11 mm) direction for his second repositioning. Ninety percent (90%) and 95% of right-left shifts, 95% and 98% of anterior-posterior shifts, and 90% and 93% of cranio-caudal shifts were smaller than or equal to 3 mm and 5 mm, respectively.

Twenty minutes after repositioning and chair helical movements, the right-left, antero-posterior and cranio-caudal intra-fraction shifts mean were 0.0, 0.2 and 0.0mm respectively with a standard deviation equal to 1.5, 1.1 and 0.3 respectively. After this time, 93%, 90% and 100% of intrafraction shifts were smaller than or equal to 3 mm in right-left, anterior-posterior and cranio-caudal direction, respectively. On all intrafraction shifts assessed every 4 minutes during the 20-minutes chair helical movements, 98%, 96% and 98% were smaller than 3 mm in right-left, anterior-posterior and cranio-caudal direction. Figure 3 is a graphic representation of the intrafraction shifts proportion in function of the value and the direction. In total, five simulated treatment sessions of these 30 sessions had at least one shift larger than or equal to 3mm. The maximum shift was 6 mm and was observed for 3 simulated treatment sessions. These largest shifts were observed after 12 minutes of chair rotation.

## PATIENT SATISFACTION IN UPRIGHT AND IN SUPINE POSITION

Fifteen patients completed the questionnaire (Table 3). One patient was not able to return her questionnaire because her treatment was interrupted.

Overall, 87% of patients felt globally comfortable or very comfortable in the upright position; the corresponding figure for supine positioning was 73% (p = 0.6) and 1 patient even found the supine position very painful. The mean scores for global comfort were 4.1 in the upright position and 3.9 in the supine position. Specifically looking at the sub-sites, slightly more patients were comfortable or very comfortable at the arm and shoulder level (80%), and at the neck and back level (86%) in the upright position; corresponding figures for the supine position were 60% and 73 %, respectively (p= 0.8 and 0.6 respectively); 2 patients (13%) at each level even felt pain in the supine position. On the other hand, slightly more patients felt comfortable or very comfortable at the head level (87%) and at the abdomen level (86%) in the supine position; corresponding figures for the upright position reached 80% and 80%, respectively (p=0.4 and 0.3, respectively). For hip and leg comfort, no substantial

difference was observed between the 2 positionings (p=0.3). Patients all found it comfortable or very comfortable (100%) to breathe in the upright position compared to 87% in supine position, but the difference was not significant (p=0,7).

In terms of the ease of setup, between 1 meaning very hard and 5, meaning very easy, the mean score was 4,3 in the upright position and 3,9 in supine position. Thirteen patients (87%) indicated that it was easy or very easy to be setup in the upright position and ten patients (67%) indicated it was easy or very easy to be setup in supine position (p=1) with one patient even indicating that it was hard to be setup in the supine position. Regarding the ease of getting out of position, the mean score was 4.4 for the upright position and 3.5 for the supine position. Fourteen patients (94%) considered it to be easy or very easy to get out the upright position and nine patients (60%) considered it to be easy or very easy to get out the supine position (p=0.6). Four patients (27%) found it to be hard or even very hard to get out the supine position. Finally, thirteen patients (87%) felt stable or very stable in upright position while ten patients (67%) felt stable or very stable in supine position (p=1).

## Discussion

The data presented in this study are the first comprehensive analysis of the merit of the Leo Cancer Care upright positioning system for radiotherapy treatments. The data showed 1) that upright positioning was associated with a reasonable first positioning and repositioning time when 1 RTT was involved, and a much shorter duration when 2 RTT were involved, 2) that inter-fraction repositioning was on average below 1 mm accuracy, 3) that intra-fraction motion was within 3 mm for more than 90% of patients in a 20-minute time frame, and 4) that patient's subjective assessment of the upright positioning was at least as good, and for some items even better, than in supine position.

The 1st positioning was used to set-up all the parameters both for the patient (e.g., seated or standing position, presence of vacuum cushion mold) and the Chair (e.g. seat angle, backrest angle, position of the shin rest and the heel stopper), which are typically actions that are done in the CT scan room. During this preparation phase, a vacuum cushion was molded for all patients. It did bring additional comfort at the patient's seat level and, thus might have contributed somehow to the patient repositioning and stability. Whereas it took close to 15 minutes with 1 RTT, it significantly decreased to sightly over 5 minutes with the presence of 2 RTTs. For the subsequent positionings, the duration dropped by a factor of 3 with one RTT and by a factor of 2 with 2 RTT. Although the advantage of the presence of an additional RTT is fully understandable, we cannot rule out that when the 2nd RTT came on board, the first one already gained confidence and expertise, which might have also contributed to the time saving. These data clearly suggest that a pre-positioning in the CT scan room might be a way forward to maximize the utilization of the Chair in the treatment room, as one does in a standard radiotherapy process. Minimal data have been published on the patient set-up time in supine position, but our results are in line

with available materials. The study of Mannerberg et al. indicated that with the use of surface images, repositioning of prostate cancer patients treated in supine position took on average 2:50 min (range of 1:35 – 6:56 min) (7). In that study, they also reported that the mean time to unload the patients from the lying position with 2 RTTs, was only 0.6 min, which is very quick.

The upright positioning system allowed an accurate repositioning (< 3mm in 90% of the tests) at least within the 3 set-ups tested. One patient was an outlier, but he was repositioned with a full bladder, whereas his 1st set-up was done with an empty bladder. As for supine positioning, control of patient's physiological parameters will have to be performed to maximize positioning accuracy.

Nowadays, in a supine position, patient have skin marks and RTTs move the patient to align these marks with the lasers in treatment room for each session. Even when optical images like Surface Guided Radiation Therapy (SGRT) systems are used, RTTs still need to slightly move the patients in order to have them in the same position as the reference image. In our study, the repeat setups were performed only using the immobilization devices and the Chair positioning, including the coordinates of the different parts of the Chair. No skin marks were used and RTT did not move the patient to obtain these results. With the shin rest, the heel stop, and the vacuum cushion, very little pelvic movements are possible, and patients almost "naturally" re-installed themselves in the right position. This advantage might not be seen when positioning the thorax or the head and neck, although for the latter, an immobilization mask will be used. The absence of skin marks is a comfort for the patient.

SGRT is now widely used to quantify set-up reproducibility in Radiotherapy. Krengli et al analysed setup reproducibility of sixteen patients undergoing prostate radiotherapy in the supine position using SGRT (8). They reported the correlation between SGRT and an Electronic Portal Imaging Device (EPID). Based on bony registration, a good correlation between both devices was found. Ploeger et al analysed setup error of 22 patients undergoing prostate radiotherapy by comparing the shifts detected by video images with those obtained with an EPID in right-left direction and also reported a good correlation between both devices (9). Bartocini et al also assessed the correlation between SGRT and EPID for 19 patients treated by prostate radiotherapy. They reported both systems showed similar shifts for a threshold level of 5mm. Putting together these data and the inter-fraction accuracy data obtained in our study, it looks like upright positioning definitely warrants further consideration. In particular, investigations are needed to confirm that the promising skin set-up accuracy also translates into benefit in term of organ positioning and motions (10).

The intra-fraction positioning stability was excellent in the upright position, at least within a 20-minute time frame. In all 3 directions, the average deviations were within 1 mm and more than 90% of the control points were within a 3 mm deviation. Considering that beam-on time for typical VMAT irradiation in supine position are within 2-3 minutes, the upright positioning should allow a safe treatment delivery.

Lastly, regarding the subjective assessment of the upright position, the scores suggested positively in favor of the upright positioning system or at least similar, although none of the differences were statistically significant.

The difference between the 2 set-ups were however not dramatically different, and one needs to be careful not to overstate the difference especially when using a subjective assessment scale. Patients appreciated the easiness of getting in and out of the Chair, they could breathe more easily, and most patients felt more stable in the upright position. The belt will have to be redesigned as some patients did not feel comfortable at the level of their belly. Also, improvements will need to made regarding head positioning. Along this line, a chair has also been designed at MD Anderson Cancer Center in Houston, Tx (USA) to help the positioning of patients with head and neck tumors not amenable to the supine position [4]. On the contrary to the design of the chair evaluated in the present study, seated patients were resting their forehead, their face, and their anterior thoracic wall on the front panel of the seat, with their arms embracing the anterior part of the system, freeing the posterior aspect of their head, their neck, and their back. Overall, patients felt comfortable especially on their back and their arms, but the overall score was in favor of the supine position. In future work we will investigate a new backrest for our system that has been optimally designed to position the head and the neck.

There are a few shortcomings in our study that need to be outlined. Firstly, only 16 patients were enrolled in the study,and for each of them a maximumof3set-ups were tested. As patients were not treated in the upright position, we could reasonably not ask them to be tested more often. But care was taken to test the patients at early, mid-, and late phases of their treatment. This being acknowledged, the data were consistent even with only 16 patients, and set-up recommendations could already be drawn for future studies. Secondly, we could only assess the positioning accuracy based on the skin match. This does not guarantee that internal organs and tumors will also be adequately position and repositioned throughout the treatments. This will have to be tested using the upright CT, which will be installed on our system momentarily.

However, correlations between surface markers and bone position have been reported for prostate cancer patients as discussed earlier. Thirdly, our study only dealt with pelvic positioning and repositioning, and it will have to be conducted for patients with thoracic and head and neck tumors. For these locations, upgrades of the Chair are currently being made especially related to the shape of the backrest and the arm support system, and data should be generated soon. Last, an additional perspective should be added to the study, i.e. the change in the patient-RTT relationship with the change in patient's positioning. Such a change will definitely require adaptations for both patients and RTTs.

## Conclusion

In conclusion, the first study on pelvic cancer patients positioned in upright position on a chair is promising, and it opens a potential new direction for the treatment of cancer patients. Evaluation of thoracic and head and neck tumors is ongoing, and imaging with vertical CT is expected to start soon.

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# Tables

**Table 1: Patient's characteristics**

| | |
|---|---|
| **NUMBER OF PATIENTS** | n = 16 |
| **GENDER** | |
| Male | n = 8 |
| Female | n = 8 |
| **AGE** | |
| Mean | 62.5 years |
| Range | 35-81 years |
| **TUMOR SITE** | |
| Prostate | n = 8 |
| Cervix/uterus | n = 4 |
| Rectum | n = 4 |
| **HEIGHT (IN CM)** | |
| Mean | 166.3 |
| Range | 152-182 |
| **WEIGHT AT THE FIRST POSITIONING (IN KG)** | |
| Mean | 75.1 |
| Range | 41-107 |
| **BMI** | |
| Mean | 27 |
| Range | 17-41.4 |
| **KARNOVSKY INDEX** | |
| 100 | n = 11 |
| 90 | n = 0 |
| 80 | n = 4 |
| 70 | n = 1 |

**Table 2: Mean, median, standard deviation, minimum and maximum inter-fraction shifts**

| | Inter-fraction shifts (in mm) # | | |
|---|---|---|---|
| | X (right-left) | Y (ant-post) | Z (cranio-caudal) |
| Mean | -0.5 | -0.4 | -0.9 |
| SD | 2.5 | 1.3 | 2.7 |
| Minimum | -12 | -6 | -11 |
| Maximum | 4 | 2 | 3 |
| % of values ≤ 5mm | 93% | 98% | 93% |
| % of values ≤ 3mm | 90% | 95% | 90% |

# negative values are for left, posterior and caudal direction

## Table 2: Mean, median, standard deviation, minimum and maximum inter-fraction shifts

| | Inter-fraction shifts (in mm) # | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Very comfortable** | | **Comfortable** | | **Uncomfortable** | | **Painful** | | **Very painful** | |
| | UPRIGHT | SUPINE | UPRIGHT | SUPINE | UPRIGHT | SUPINE | UPRIGHT | SUPINE | UPRIGHT | SUPINE |
| Head comfort | 3/15 (20%) | 6/15 (40%) | 9/15 (60%) | 7/15 (47%) | 3/15 (20%) | 2/15 (13%) | 0/15 (0%) | 0/15 (0%) | 0/15 (0%) | 0/15 (0%) |
| Arm and shoulder comfort | 4/15 (27%) | 4/15 (27%) | 8/15 (53%) | 5/15 (33%) | 3/15 (20%) | 4/15 (27%) | 0/15 (0%) | 2/15 (13%) | 0/15 (0%) | 0/15 (0%) |
| Hip and leg comfort | 3/15 (20%) | 4/15 (27%) | 10/15 (67%) | 9/15 (60%) | 1/15 (7%) | 1/15 (7%) | 1/15 (7%) | 0/15 (0%) | 0/15 (0%) | 1/15 (7%) |
| Neck and back comfort | 2/15 (13%) | 3/15 (20%) | 11/15 (73%) | 8/15 (53%) | 2/15 (13%) | 2/15 (13%) | 0/15 (0%) | 2/15 (13%) | 0/15 (0%) | 0/15 (0%) |
| Abdomen comfort | 10/15 (67%) | 8/15 (53%) | 2/15 (13%) | 5/15 (33%) | 3/15 (20%) | 2/15 (13%) | 0/15 (0%) | 0/15 (0%) | 0/15 (0%) | 0/15 (0%) |
| Global comfort | 3/15 (20%) | 3/15 (20%) | 10/15 (67%) | 8/15 (53%) | 2/15 (13%) | 3/15 (20%) | 0/15 (0%) | 1/15 (7%) | 0/15 (0%) | 0/15 (0%) |

| | **Very easy** | | **Easy** | | **Not easy, not hard** | | **Difficult** | | **Very difficult** | |
|---|---|---|---|---|---|---|---|---|---|---|
| | UPRIGHT | SUPINE | UPRIGHT | SUPINE | UPRIGHT | SUPINE | UPRIGHT | SUPINE | UPRIGHT | SUPINE |
| Easiness to breath | 8/15 (53%) | 6/15 (40%) | 7/15 (47%) | 7/15 (47%) | 0/15 (0%) | 2/15 (13%) | 0/15 (0%) | 0/15 (0%) | 0/15 (0%) | 0/15 (0%) |
| Easiness to setup | 6/15 (40%) | 4/15 (27%) | 7/15 (47%) | 6/15 (40%) | 2/15 (13%) | 4/15 (27%) | 0/15 (0%) | 1/15 (7%) | 0/15 (0%) | 0/15 (0%) |
| Easiness to get out | 7/15 (47%) | 4/15 (27%) | 7/15 (47%) | 5/15 (33%) | 1/15 (7%) | 2/15 (13%) | 0/15 (0%) | 3/15 (20%) | 0/15 (0%) | 1/15 (7%) |

| | **Very stable** | | **Stable** | | **Not unstable but not stable** | | **Unstable** | | **Very unstable** | |
|---|---|---|---|---|---|---|---|---|---|---|
| | UPRIGHT | SUPINE | UPRIGHT | SUPINE | UPRIGHT | SUPINE | UPRIGHT | SUPINE | UPRIGHT | SUPINE |
| Easiness to breath | 5/15 (33%) | 4/15 (27%) | 8/15 (53%) | 6/15 (40%) | 2/15 (13%) | 4/15 (27%) | 0/15 (0%) | 1/15 (7%) | 0/15 (0%) | 0/15 (0%) |

# Figures

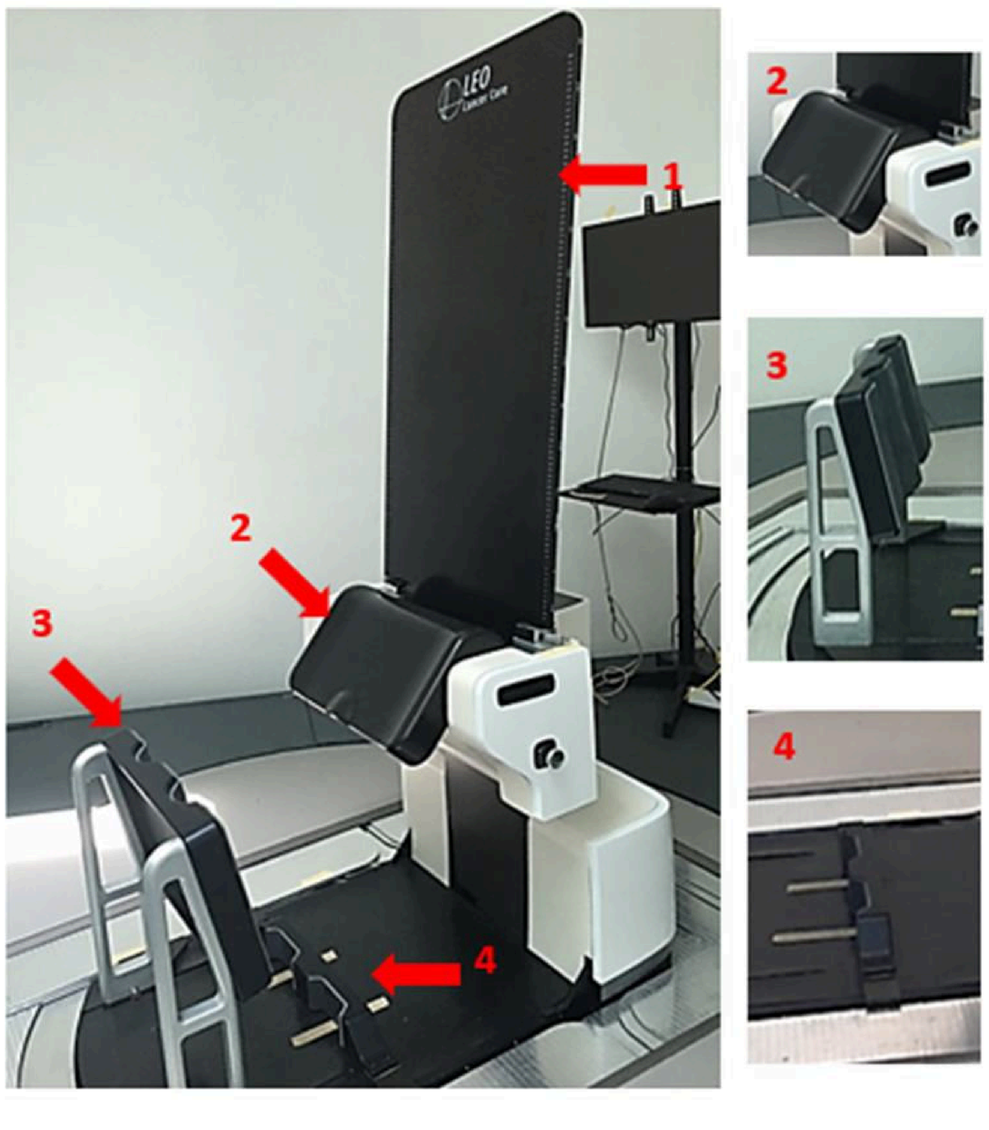



Figure 1: view of the Chair for patient positioning in upright position. The various components are (1), the backrest, (2) the seat pan, (3) the shin rest, (4) the heel stop, and (5) the arm support.




Figure 2 : A view of the Chair with a patient seated on the vacuum cushion. B: view with the optical positioning system. The absence of green or pink light on the skin surface at the pelvic level illustrate the perfect patient repositioning

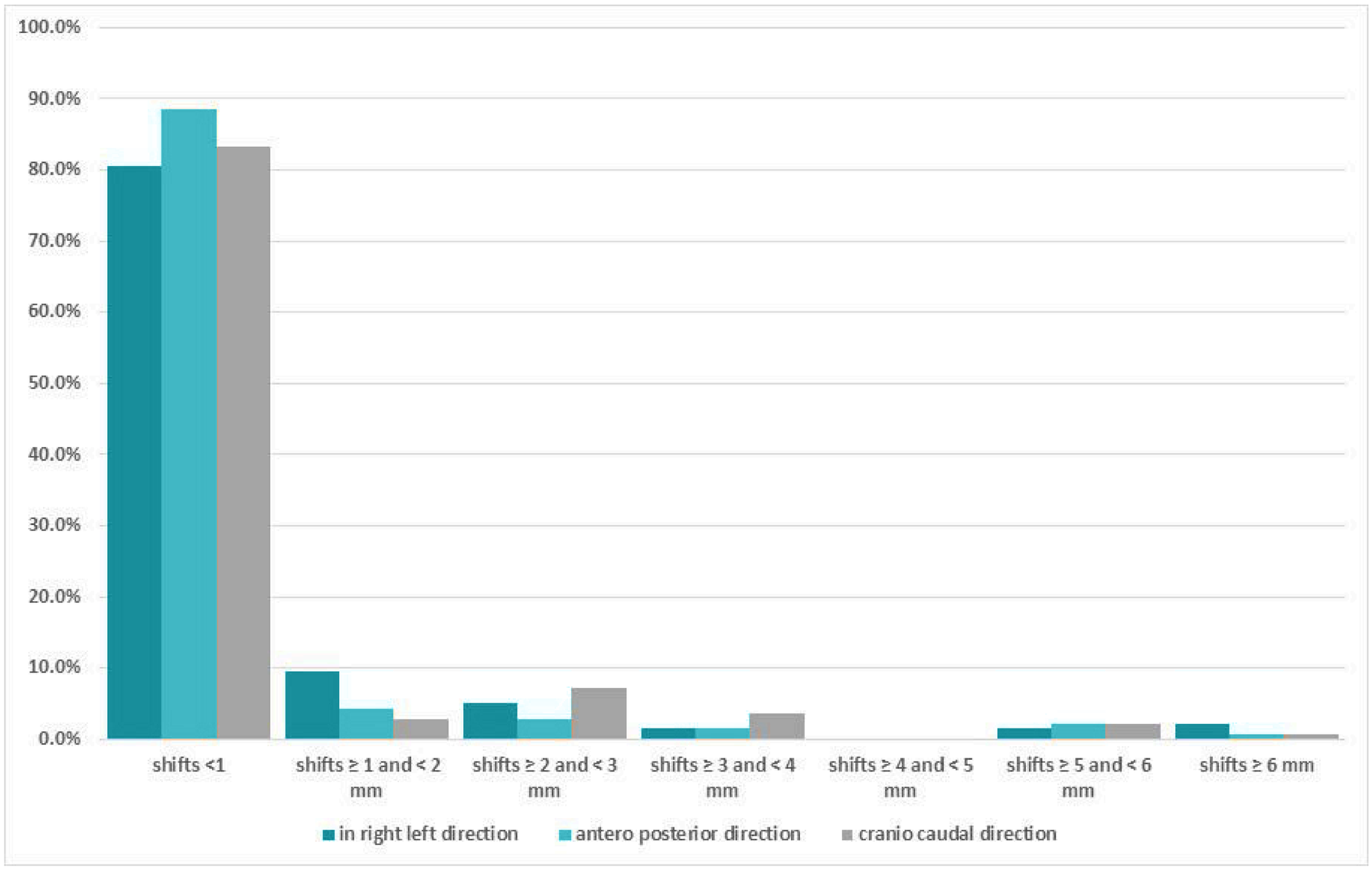



Figure 3: Proportion of intrafraction shifts in function of the value and the direction

# Appendix

Patient's comfort assessment (English translation of the French questionnaire)

List of 10 questions filled both after supine and upright position set-ups. Only one answer was accepted per question.

1. Were you globally comfortable?

2. Were you comfortable at the level of your head?

3. Were you comfortable at the level of your neck and back?

4. Were you comfortable at the level of your shoulder and arm?

5. Were you comfortable at the level of your abdomen?

6. Were you comfortable at the level of your hips and legs?

7. How did you feel your set-up was?

8. Was is easy to get out of your set-up position?

9. Was it easy to breath in your set-up position?

10. Did you feel stable in your set-up position?

Questions 1 to 6 were answered as followed:

(1) very painful, (2) painful, (3) not comfortable, (4) comfortable, (5) very comfortable

Questions 7 to 9 were answered as followed:

(1) very hard, (2) hard, (3) not easy but not hard, (4) easy, (5) very easy

Question 10 was answered as followed

(1) very unstable, (2) unstable, (3) not unstable but not stable, (4) stable, (5) very stable

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This whitepaper was commissioned by the team at Leo Cancer Care to support the development of their upright radiation therapy products find out more at

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