Setup accuracy and calculated setup margins for surface guided radiotherapy (SGRT) of target volumes of the head and neck, thorax, abdomen, and pelvis: A single-institutional retrospective analysis

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Research Article

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Abstract

Background:

The goal of the study was to evaluate the inter- and intrafractional patient setup accuracy of target volumes located in the head and neck, thoracic, abdominal, and pelvic regions when using AlignRT, by comparing it with that of laser alignment using patient skin marks, and to calculate the corresponding setup margins.

Methods:

A total of 2303 radiotherapy fractions of 183 patients were analyzed. All patients received daily kilovoltage cone-beam computed tomography scans (kV-CBCT) for online verification. Since opening of our radiotherapy department in 2019 until October 2021, the initial patient setup was performed using laser alignment with patient skin marks, and since November 2021 we started using AlignRT. The setup accuracy was measured by the six degrees of freedom (6DOF) corrections based on the kV-CBCT. The corresponding setup margins were calculated using the van Herk formula. Analysis of variance (ANOVA) was used to evaluate the impact of multiple factors on the setup accuracy.

Results:

The interfractional patient setup accuracy was significantly better using AlignRT compared to laser alignment with skin marks. The mean three-dimensional vector of the translational setup deviation of tumors located in the thorax, abdomen, and pelvis using AlignRT was 3.6 mm (95% confidence interval 3.3 mm to 3.9 mm) and 4.5 mm using laser alignment with skin marks (95% confidence interval 3.9 mm to 5.2 mm; p = 0.001). Calculation of setup margins for the combined inter- and intrafractional setup error revealed similar setup margins using AlignRT and kV-CBCT once a week compared to laser alignment with skin marks and kV-CBCT every other day. Furthermore, comparable setup margins were found for open-face thermoplastic masks with AlignRT compared to closed-face thermoplastic masks with laser alignment and mask marks.

Conclusions:

Surface guided radiotherapy (SGRT) opens the possibility to reduce the number of CBCTs while maintaining sufficient setup accuracy. The advantage is a reduction of imaging dose and overall treatment time. Open-face thermoplastic masks may be used instead of closed-face thermoplastic masks to increase the patient's comfort.

Introduction

Surface guided radiotherapy (SGRT) is a technology that uses an optical surface monitoring system like AlignRT for patient positioning, intrafraction motion monitoring and respiratory gating [1]. A three-dimensional live surface of the patient is generated by the combination of a projector with a set of
cameras. The patient’s live surface is compared to a reference surface in real time to derive shifts in six degrees of freedom (6DOF) – a measure of patient’s setup accuracy. A popular application of SGRT is the radiotherapy of left breast cancer using deep inspiration breath-hold (DIBH) technique [2-4]. The positioning of the left breast using DIBH is highly reproducible and intrafractional movement can be detected in real time with high accuracy due to the proximity of the target volume to the skin surface. For the same reason, the treatment of brain or head and neck tumors represents another promising application for SGRT [5-7]. An automated beam hold can be performed if the deviation of the target volume exceeds its predefined threshold. The value of SGRT for tumors not located close to the skin surface has not yet been clearly defined.

SGRT offers several advantages compared to IGRT using orthogonal X-ray imaging, portal imaging or cone beam computed tomography (CBCT). Firstly, AlignRT does not add radiation dose to the patient and therefore may contribute to the desired imaging dose reduction. Secondly, AlignRT allows monitoring of patient position during the treatment thus reducing intrafractional error. This cannot be achieved with X-ray based IGRT unless special technologies are installed, such as ExacTrac® X-ray system (Brainlab AG, Munich, Germany) or CyberKnife (Accuray, Sunnyvale, USA). Thirdly, AlignRT allows assessing and monitoring of patient position in non-coplanar couch angles. Finally, patient setup and overall treatment time is shorter with SGRT compared to CBCT [8].

Technological advances in radiotherapy like volumetric-modulated arc radiotherapy (VMAT) have enabled the delivery of highly conformal dose distributions in routine radiotherapy. Accurate patient positioning is critical to correctly deliver the planned dose distribution. The increasing use of hypofractionated protocols and stereotactic body radiotherapy (SBRT) enhances the importance of the patient positioning accuracy. The patient setup in routine radiotherapy is usually performed by alignment of in-room lasers with patient skin marks. A verification of the patient setup and its correction is usually performed using CBCT. Daily online verification using CBCT increases the dose to normal tissue and the overall treatment time resulting in a lower number of patients that can be treated per day. A lower frequency of online verifications requires larger setup margins to compensate for the interfractional patient setup error, and larger target volumes increase the risk of radiation toxicity. A possible strategy to reduce the number of CBCTs while maintaining sufficient patient positioning accuracy could be the use of SGRT.

In our retrospective study, we compared the patient setup accuracy of patients positioned using AlignRT with patients positioned using in-room laser alignment with patient skin marks. All patients received daily kV-CBCT for online setup verification, and the patient positioning accuracy was represented by the setup correction based on kV-CBCT. Population systematic and random errors were calculated [9] and the setup margins to compensate for the inter- and intrafractional error were estimated using the van Herk formula [10]. Our hypothesis was that the patient setup accuracy is better using AlignRT compared to laser alignment with skin marks for tumors treated in the thorax, abdomen, and pelvis. If the hypothesis is correct, SGRT could be an alternative for the patient setup using laser alignment to skin marks with the advantage of potentially reducing the inter- and intrafractional patient positioning error. In patients where
clinically appropriate, the increased patient setup accuracy may allow reducing the number of CBCTs thereby saving imaging dose and overall treatment time.

Patients And Methods

Workflow Since opening of our Department of Radiation Oncology in 2019 until September 2020, the patient setup was performed by aligning in-room lasers with patient skin marks. After installation of the SGRT system AlignRT (Vision RT Ltd, London, UK, Version 5.1.2) and completion of an extensive training program in October 2020, the workflow of the patient setup was modified. On the first radiotherapy fraction, patients were positioned using laser alignment with skin marks. Using AlignRT, patient’s live surface was positioned to match reference surface from CT-simulation. A kV-CBCT was performed, and the patient setup was corrected by adjusting the 6DOF treatment couch. A new reference surface was acquired using AlignRT to evaluate the intrafractional setup error. In cases where intrafractional deviations exceeded 5 mm, the beam was stopped manually, and the patient setup was corrected. No automated beam hold was activated. For the remaining radiotherapy fractions, the procedure of laser alignment with skin marks was omitted (fig. 1). In a small number of patients where the setup procedure using AlignRT took longer time, laser alignment with skin marks was used prior to AlignRT to speed up the patient setup time. In our department, all patients treated using VMAT received daily kV-CBCT for online verification. The patient setup accuracy was represented by the corresponding translational and rotational adjustment of the 6DOF treatment couch. Patients treated using DIBH (usually left-sided breast cancer patients) were excluded from the analysis as the patient setup procedure was different compared to treatment without DIBH. Data collection Patient and treatment related data were obtained from the hospital information system (HIS) and the integrated oncology management system MOSAIQ (Elekta AB, Stockholm, Sweden). The data were transferred into a custom-made database (Access, Microsoft, Redmont, USA). After completion of the data collection, data were anonymized and transferred into a statistical software program for statistical analysis (Statistica, TIBCO Software Inc., 2020. Data Science Workbench, version 14. http://tibco.com). AlignRT saves the patient’s real time delta data during treatment in the logfile. Real time delta is the deviation in 6 DOF between patient’s live surface and the reference surface imported from CT or captured by AlignRT. For the analysis of the intrafractional setup error, the real time data acquired during the beam delivery were obtained from the AlignRT log file and transferred into a statistical software program for statistical analysis (Statistica, TIBCO Software Inc., 2020. Data Science Workbench, version 14. http://tibco.com). Artefacts caused by blockage of cameras at certain gantry angles during beam application were removed manually. Patient positioning Head fixation was performed using closed-face thermoplastic masks or open-face thermoplastic masks (Civco Medical Instruments Co Inc. Orange, IA, USA). Positioning devices used for the thorax were breast board, wing board (Civco Medical Instruments Co Inc. Orange, IA, USA) and knee fix. For the abdomen and pelvis, a knee fix and feet fix were used. Patients receiving SBRT were positioned using a wing board. All patients were treated in supine position. No vacuum bag moulds were used. CT-simulation was performed using a Brilliance Big Bore CT (Philips, Amsterdarm, Netherlands). Slice thickness was 3 mm, for patients treated with SBRT was 2 mm. Contrast medium was used where indicated. For the treatment of lung and upper
abdominal tumors (predominantly liver and bile duct cancer) a 4D CT scan was performed. Breathing motion was monitored using Respiratory Gating for Scanners (RGSC, Varian Medical Systems, Palo Alto, CA, USA). Treatment planning Target volumes were contoured according to the corresponding RTOG atlas and NCCN guidelines. Automatic contouring of organs at risk (OAR) was performed using AccuContour Version 3.1 (Manteia Technology LTD, Xiamen, China). The treatment planning system was Monaco Version 5.40.03 (Elekta AB, Stockholm, Sweden). The independent dose check was performed using Mobius 3D Version 2.1 (Varian Medical Systems, Palo Alto, CA, USA). Quality assurance was performed using DoseLab Version 6.8 (Varian Medical Systems, Palo Alto, CA, USA), ArcCheck Version 8.0.0.11708 (Sun Nuclear Corporation, Melbourne, FL, USA) and MatriXX (Iba Dosimetry GmbH, Schwarzenbruck, Germany). Treatment Radiotherapy was delivered using VersaHD (Elekta AB, Stockholm, Sweden), with Agility MLC (5 mm leaves) and a Hexapod 6D treatment couch. Daily online verification was performed using kV-CBCT and translational and rotational errors corrected by adjusting the Hexapod 6D treatment couch. No abdominal compression or respiratory gating was used for the SBRT of lung or liver targets. Statistical analysis An analysis of variance (ANOVA) was performed to assess the impact of the patient setup technique (skin marks vs. SGRT), treatment location (thorax vs. abdomen vs. pelvis), gender (female vs. male), age (<=mean vs. >mean), weight (<=mean vs. >mean), BMI (<=mean vs., >mean), and fractionation regimen (hypofractionation vs. SBRT) on the interfractional setup accuracy. The interfractional setup accuracy was represented by the mean three-dimensional vector of the patient setup deviation f in the lateral, longitudinal and vertical direction for the ANOVA. A p-value \( \leq 0.05 \) was considered statistically significant. In addition, the patient setup accuracy was assessed by calculating the overall population mean setup error, population systematic and random error of the translational and rotational errors in three directions. The calculations were performed according to the report "On target: ensuring geometry accuracy in radiotherapy" by the Royal College of Radiologists [9]. Accordingly, the individual mean patient setup error \( M_{\text{individual}} \) was defined as the mean setup error for an individual patient. The overall population mean setup error \( M_{\text{pop}} \) was defined as the overall mean for the analyzed patient group. The population systematic error \( \Sigma_{\text{setup}} \) was defined as the standard deviation of the individual mean set-up error about the overall mean \( M_{\text{pop}} \). The individual random (daily) positioning error \( \sigma_{\text{individual}} \) was defined as the standard deviation of the setup error around the corresponding mean individual value \( M_{\text{individual}} \). The population random error \( \sigma_{\text{setup}} \) was defined as the mean of all individual random errors \( \sigma_{\text{individual}} \). The patient setup parameters were calculated for each direction (lateral, longitudinal, and vertical). Treatment margins to compensate for the patient setup error were estimated using the van Herk formula [10]. Therefore, the margin required to ensure 95% minimum dose to the PTV for 90% of the patients was given by \( M_{\text{PTV}} = 2.50\Sigma_{\text{setup}} + 1.64\sigma + 1.64\sigma_{\text{P}} \) where \( \Sigma_{\text{setup}} \) is the square root of the quadratic sum of the standard deviations of all contributing systematic errors, \( \sigma \) is the square root of the quadratic sum of the standard deviations of all contributing random errors, and \( \sigma_{\text{P}} \) is the standard deviation describing the width of the penumbra. In our analysis, \( \Sigma_{\text{setup}} \) was used as contributing systematic error, \( \sigma_{\text{setup}} \) and \( \sigma_{\text{P}} \) as contributing random errors \( \sigma = \sqrt{\sigma_{\text{setup}}^2 + \sigma_{\text{P}}^2} \). The representative standard deviation of the penumbra width \( \sigma_{\text{P}} \) of our linear accelerator was 3.2 mm. To evaluate the impact of the frequency of online verifications (once per week or every other day) on the
calculated setup margin, the patient set-up parameters were calculated assuming a patient setup error of 0 mm in all directions after online verification using kV-CBCT.

Results

Interfractional setup error

The interfractional patient setup error was assessed using 2303 CBCTs of 199 target volumes from 183 patients. There were 14 patients who had more than one tumor, located in different anatomical regions and treated in different radiotherapy series.

Table 1 shows that the relative distribution of possible relevant factors for the patient setup accuracy, anatomical region of the target volume, fractionation regimen, gender, age, weight, and BMI was similar between the compared patient groups interfractional setup error using laser alignment with skin marks, interfractional setup error using AlignRT, and intrafractional setup error using AlignRT. For fixation of the head, closed-face thermoplastic masks or open-face thermoplastic masks were used. All patients using open-face thermoplastic masks were treated using AlignRT. For patients using closed-face thermoplastic, AlignRT was not used. The most common diagnosis of patients using head fixation were brain metastasis and glioblastoma multiforme. For patients with target volumes in the thorax, most were breast cancer patients (free breathing position), in the abdominal region, hepatobiliary cancer and in the pelvic region, cervical cancer. The most common hypofractionation regimen consisted of 15 fractions and the most common SBRT fractionation regimen of five fractions.

The impact of the patient setup technique (AlignRT vs. laser alignment with skin marks) on the interfractional setup accuracy of target volumes located in the thorax, abdomen and pelvis was assessed using an analysis of variance (ANOVA). Dependent factor of the ANOVA was the three-dimensional vector of the patient setup deviation (lateral, longitudinal, and vertical direction). Independent factors were patient setup technique (AlignRT vs. laser alignment with skin marks), location of the target volume (thorax vs. abdomen vs. pelvis), fractionation regimen (conventional fractionation vs. hypofractionation vs. SBRT), gender (female vs. male), age (≤mean vs. >mean), weight (≤mean vs. >mean) and BMI (≤mean vs >mean). The ANOVA revealed the patient setup technique as the only significant impact factor on the interfractional setup accuracy (AlignRT: mean 3.6 mm, 95% confidence interval 3.3 mm to 3.9 mm; laser alignment with skin marks: 4.5 mm, 95% confidence interval 3.9 mm to 5.2 mm; p = 0.001).

Figure 2 and table 2 demonstrate that patients of the interfractional setup error using AlignRT group generally showed smaller population systematic errors compared to the interfractional error using laser alignment with skin marks group. The population systematic error is the most important factor because it has the strongest impact on the calculated setup margin to compensate for the patient setup error [10]. Furthermore, figure 2 suggests that in the vertical direction there may be an interfractional population systematic setup error of about 1 mm. A sagging of the treatment table was excluded by phantom measurements and no laser maladjustments were detected. The reason for this deviation is yet unclear. As expected, patients with head fixation showed on average smaller inter- and intrafractional population...
systematic and random errors compared to those treated in the thorax, abdomen, and pelvis. Fixation with an open-face thermoplastic mask show a similar interfractional setup accuracy compared to closed-face thermoplastic masks (tab. 2).

Intrafractional setup error

The intrafractional setup error was assessed using 819 radiotherapy fractions of the first 69 patients receiving AlignRT. The intrafractional population systematic and random errors were considerably smaller than the corresponding interfractional errors (fig. 2, tab 2). The impact of potentially relevant factors location of the target volume (thorax vs. abdomen vs. pelvis), fractionation regimen (conventional fractionation vs. hypofractionation vs. SBRT), gender (female vs. male), age (<=mean vs. >mean), weight (<=mean vs. >mean) and BMI (<=mean vs >mean) on the three-dimensional vector of the intrafractional setup error was assessed using an ANOVA. No statistically significant factor was identified by the ANOVA. The mean three-dimensional vector of the intrafractional setup error of the thorax was 0.9 mm (standard deviation 0.5 mm), abdomen 0.9 mm (standard deviation 0.3 mm), and pelvis 0.8 mm (standard deviation 0.4 mm).

Rotational setup error

The inter- and intrafractional rotational errors were analyzed using the same concept of overall population mean setup error, population systematic error and population random error as the translational setup errors. Figure 3 shows that the rotational errors were roughly in the same range in all tumor locations and directions. The mean absolute rotational setup error of the thorax, abdomen, and pelvis in the lateral, longitudinal, and vertical direction was 0.4 degrees (standard deviation 0.4 degrees) for the interfractional error group, and 0.4 degrees (standard deviation 0.5 degrees) for the intrafractional error group.

Calculated safety margin

The calculated setup margins decreased with increasing frequency of online verifications using kV-CBCT (tab. 3). Patients positioned using AlignRT required smaller setup margins compared to patients positioned using laser alignment with skin marks. For patients with target volumes in the thorax, abdomen, and pelvis the mean setup margin of the lateral, longitudinal and vertical direction was smaller on average by a factor of about 2/3, corresponding to a decrease of the setup margin for the combined inter-and intrafractional deviation on average by 1.9 mm without online verification using kV-CBCT, 1.3 mm for online verification once per week and 0.9 mm for online verification every other day. For example, patients positioned using laser alignment with skin marks and online verification every other day required similar setup margins as patients positioned using AlignRT and online verification once a week (mean setup margin for the combined inter-and intrafractional deviation 3.6 mm vs. 3.7 mm) (tab.3).
Our data show that for target volumes located in the thorax, abdomen, and pelvis the patient setup accuracy is significantly better using AlignRT compared to laser alignment with patient skin marks. Depending on the frequency of online verifications using CBCT, the calculated setup margins to compensate for the combined inter- and intrafractional setup errors are smaller on average by 1.7 mm (no online verification using CBCT), 1.2 mm (CBCT once a week) or 0.8 mm (CBCT every other day). Furthermore, the intrafractional setup error can be verified in real time using SGRT which is not possible using CBCT. The mean calculated setup margin in our study to compensate for the intrafractional error of target volumes located in the thorax, abdomen and pelvis is 1.6 mm.

A major advantage of SGRT for target volumes in the thorax, abdomen and pelvis is the ability to reduce the frequency of CBCTs while maintaining sufficient patient positioning accuracy where clinically appropriate. Reducing the frequency of CBCT scans reduces imaging dose and overall treatment time [8]. Our data show that daily AlignRT and CBCT once per week require similar setup margins compared to laser alignment with skin marks and CBCT every other day.

In agreement with our study, significantly smaller interfractional setup errors for target volumes of the CNS, head and neck, thorax and abdomen using AlignRT compared to laser alignment with skin marks were observed in a retrospective analysis of 16,835 treatment fractions of 696 patients [8]. The patients were treated using TomoTherapy. Megavoltage computed tomography (MVCT) scans were used as reference for the patient setup accuracy. While the interfractional systematic error for target volumes of the thorax and abdomen compared to our study was greater on average by a factor of almost two, the relative reduction of the interfractional systematic error using AlignRT was in the same range of our study (factor 0.7). An analysis of 335 fractions of 71 patients treated using SBRT and AlignRT for malignant thoracic or abdominal tumors showed that interfractional setup errors were small after SGRT setup (on average <5 mm and <0.5 degrees) suggesting that AlignRT may replace skin marks [11]. A study using SBRT for target volumes of the lung, liver, spine, pancreas, and lymph nodes analyzing 284 radiotherapy fractions of 63 patients revealed significantly smaller interfractional setup errors using AlignRT compared to laser alignment with skin marks [12]. The absolute median interfractional setup deviation was reduced on average by a factor of 0.7 using AlignRT compared to laser alignment with skin marks. Significantly smaller interfractional setup errors using AlignRT compared to laser alignment with skin marks for target volumes in the pelvis/lower extremities, abdomen, chest/upper extremities, and breast were found by a retrospective analysis of 6000 individual fractions [13]. The reported average magnitudes of the three-dimensional shift vectors using laser alignment with skin marks were larger on average by a factor of about two compared to our study, and AlignRT reduced the intrafractional setup error on average by a factor of 0.5. Comparable interfractional setup accuracy between AlignRT and laser alignment with skin marks was reported by two study groups analyzing 1902 radiation fractions of 110 patients with target volumes in the head, thorax, abdomen, and extremities [14] and 154 radiotherapy fractions of 25 patients with target volumes of the thorax, abdomen and pelvis [15].

Data concerning the intrafractional setup error using AlignRT for target volumes in the thorax (excluding breast), abdomen and pelvis are scarce in the literature. In a study of 335 fractions of 71 patients treated
with SBRT for tumors located in the thorax and abdomen in about 10% of the total fractions the intrafractional setup error exceeded the predefined threshold of 2 mm. The resulting shifts were performed prior to continuation of the treatment. The mean three-dimensional vector of the intrafractional setup error was 3.3 mm [11]. In an analysis of 792 fractions of 29 patients with target volumes in the pelvis, the mean three-dimensional vector of the intrafractional setup error was 1.9 mm [16].

For breast cancer radiotherapy following breast conserving surgery or mastectomy in free breathing position using AlignRT, a study of 2028 radiotherapy fractions of 104 breast cancer patients revealed a median three-dimensional vector of the intrafractional setup error during dose application of 1.6 mm [17], and another study of 99 fractions of 10 patients a corresponding intrafractional setup error of 1.1 mm. The median intrafractional rotational setup error was 0.4 degrees [18].

For comparison, the mean three-dimensional vector of the intrafractional setup errors in our study was 0.9 mm for target volumes of the thorax, 1.1 mm of the abdomen and 0.8 mm of the pelvis.

Our data suggest that open-face thermoplastic masks combined with AlignRT provides similar interfractional setup accuracy compared to closed-face thermoplastic masks and laser alignment to mask marks. Open-face thermoplastic masks are more comfortable for many patients. In a study of 415 fractions of 269 patients treated with cranial stereotactic radiosurgery (SRS) using open-face mask and AlignRT, an interfractional translational setup error of 1.0 mm (standard deviation 2.5 mm) and intrafractional rotational error of 0.1 degree (standard deviation 1.4 degree) was detected. The authors concluded that SGRT has sufficient accuracy to guide radiotherapy of brain and nasopharynx cancer with standard fractionation [19].

Limitations of our study include the general limitations of a retrospective and single-institutional study design. Furthermore, an assumption for the calculation of the population systematic and random error is a comparable number of radiotherapy fractions per patient. In our study, 64% of the patients were treated with hypofractionation (usually 15 fractions), 22% with conventional fractionation (usually between 30 and 35 fractions), and 14% with SBRT (usually five fractions). In addition, during a few radiation fractions, intrafractional deviations of >5 mm were observed and a manual beam shut-off performed before setup correction. Due to the relatively large total number of radiation fractions and target volumes examined it is expected that the corresponding statistical errors are small.

**Conclusion**

Our data show that for target volumes of the thorax, abdomen, and pelvis the patient setup accuracy using AlignRT is significantly better compared to laser alignment with skin marks. The use of AlignRT opens the possibility to reduce the number of CBCTs compared to laser alignment with skin marks while keeping the setup accuracy at a sufficient level. Reducing the frequency of CBCT scans reduces imaging dose and overall treatment time. Calculation of the required inter- and intrafractional setup margins showed that AlignRT and once weekly CBCT requires similar setup margins compared to laser alignment
with skin marks and CBCT every other day. Open-face thermoplastic masks may be used instead of closed-face thermoplastic mask to increase the patient's comfort.

**Abbreviations**

6DOF: six degrees of freedom; ANOVA: Analysis of variance; BMI: Body mass index; CBCT: Cone-beam computed tomography; CT: Computed tomography, DIBH: Deep inspiration breath-hold; IGRT: Image guided radiotherapy kV-CBCT: Kilovoltage cone-beam computed tomography; MVCT: Megavoltage computed tomography; PTV: Planning target volume, SBRT: Stereotactic body radiation therapy; SGRT: Surface guided radiation therapy; VMAT: Volumetric-modulated arc radiotherapy.

**Declarations**

Ethics approval and consent to participate

The Jiahui Health Institutional Review Board declared that the ethical approval can be waived for this retrospective study (A-JIHSCRJICC2022002-01).

Consent for publication

Not applicable

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Not applicable.

Authors’ contributions

All authors contributed to the study design, data collection, analysis and interpretation of the data. All authors read and approved the final manuscript.

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**Tables**

Tables 1 to 3 are available in the Supplementary Files section

**Figures**
Figure 1

Workflow of the patient setup procedure from opening of the department in 2019 until 2020/10, and since introduction of SGRT in 2020/11. AlignRT (1) denotes a surface scanning image to be matched with reference surface image from the CT-simulation, and AlignRT (2) a surface scanning image as reference to assess the intrafractional error.
Figure 2

Overall population mean setup error (rectangle), population systematic error (box), and population random error (whiskers) of the interfractional translational error using laser alignment with skin marks, interfractional translational error using AlignRT, and intrafractional translational error (mm) using AlignRT by direction and location of the target volume.
Figure 3

Overall population mean setup error (rectangle), population systematic error (box), and population random error (whiskers) of the interfractional rotational error using laser alignment with skin marks, interfractional rotational error (mm) using AlignRT, and intrafractional rotational error using AlignRT by direction and location of the target volume.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Table1.docx
- Table2.docx
- Table3.docx