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Short Communication

Whole-brain radiation therapy without a thermoplastic mask

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ABSTRACT

The aim of the study was to investigate the clinical feasibility of whole-brain radiation therapy without a thermoplastic mask. Positioning and intra-fractional motion monitoring were performed using optical surface scanning. The motion threshold was 3 mm/3 degrees. The group mean vector deviation was 1.1 mm. The roll was larger compared to pitch and rotation. Two patients out of 30 were not able to lie still. All other patients completed their treatment successfully without a mask. With a probability of success of 93%, we concluded that irradiation without a mask is a clinically feasible method.

1. Introduction

Radiation therapy to the brain requires both a reproducible position of the patient and minimal intra-fractional motion. A thermoplastic mask is commonly used. Although the method is technically appropriate, improvements can be made concerning patient comfort, since the mask tightly encloses the head and connects to the skin. Patients complain about this tightness and experience anxiety when the mask firmly encloses the head [1]. Especially for patients suffering from claustrophobia, wearing a mask can be intolerable. A treatment method without the necessity of fixating the head is of advantage for patients.

Alternatives to the use of a full-head mask are the use of partial or open-face masks. In a study of Zhao et al. the patient-reported comfort appeared to be high [2]. Li et al. concluded that the comfort and tolerability was improved by using an open-face mask [3]. Even though an open-face mask causes less discomfort compared to a full-head mask, no mask at all would be even better [4,5].

The aim of the current study was to investigate the clinical feasibility of radiation therapy without a thermoplastic mask. To ensure a reproducible position and to control intra-fractional motion, optical surface imaging was used. Various studies showed the added value of optical surface scanning for positioning and motion monitoring [6–8].

2. Materials and methods

To participate in the study, the following inclusion criteria were applied: the therapy was palliative and consisted of whole-brain radiation therapy in a treatment scheme of 5 × 4 Gy [9]; and according to the judgement of the radiation oncologist, the patient was capable to participate in the study. The exclusion criterion was suffering from trembling or shaking of the head, for example caused by Parkinson's disease. In case of participation, informed consent was signed. The study was approved by the medical ethics committee METC Brabant (CCMO register NL61854.028.17).

Patients were instructed to lie as still as possible on the treatment couch. All patients were positioned on a breast board at a 10 degrees angle, with both arms along the body. Stabilization of the head was achieved by choosing the best fitting head cushion. If it became clear a patient was not able to lie still during the treatment, a thermoplastic mask was made and the treatment was continued by using a mask. The surface scanner used for this study was the Catalyst™ (C-RAD AB, Sweden), consisting of a single camera.

The couch position was predicted from the planning-CT and patients were positioned with respect to the breast board [10]. The reference surface was created using the planning-CT surface information and this

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was compared with the real-time surface for positioning. After positioning the patient, an online matching procedure was performed. If the difference between the DRR and the anterior-posterior and medio-lateral kV-images was more than 1 mm, a couch shift was executed. Subsequently, a new reference surface was made by the Catalyst™ system. The posture was verified by kV images to be sure the patient had not moved during the couch movement.

Intra-fractional motion monitoring started as soon as the patient was positioned correctly. The real-time surface of that moment was used as the reference. The threshold for motion of the head was set to 3 mm or 3 degrees (rotation, roll, or pitch), since this is an acceptable deviation taking the CTV-PTV margin of 5 mm into account. In case motion exceeded the threshold, the radiation technologist manually interrupted the radiation beam. If the patient did not return to a position within the threshold, the radiation technologist repositioned the patient on the treatment couch, such that the position matched with the reference surface of the CT-scan, and the procedure started all over again.

The movement data was evaluated to assess the intra-fractional movements. The measurement started when the couch shift based on the matching procedure had been performed. The motion measurements are divided in displacements in lateral, longitudinal, and vertical direction, and pitch, roll, and rotation. Moreover, the vector deviation for the isocenter was determined. The group mean vector deviation was calculated as the mean of the averaged movement for each patient.

The primary endpoint was clinical feasibility of the treatment. When more than two repositioning procedures were required, that fraction was labelled unsuccessful. The treatment of a patient was labelled successful when three or more fractions had been successful and the treatment was finalized without a thermoplastic mask. Clinical feasibility was defined as: more than 70% of the population can complete the radiation treatment successfully. This was tested by using a one-tailed binomial test with a significance level of 0.05 (null hypothesis: the probability of success equals 0.7). A power analysis had been performed using an exact proportion test and the success of the treatment was expected to be 0.9 [11].

3. Results

In total 30 patients were included (13 men), with mean age of 62.2 years (range 46–78) and almost all of them used dexamethasone. Two out of the 30 patients were not able to lie still and continued the treatment by using a head mask. For one of them it was already decided to make a mask at the time the CT was made. The other patient completed a successful and an unsuccessful fraction without a mask, before it was decided to use a mask for the remaining fractions. All other patients completed their treatment successfully. In 16 out of the 28 patients who completed the treatment without a head mask, repositioning was needed at least once during the treatment. In total 24 repositioning procedures in 19 fractions were needed out of a total of 140 fractions. In 16 fractions repositioning was needed once, in 2 fractions 2 repositioning procedures were needed. Only one fraction was unsuccessful with four repositioning procedures. With a probability of success of 93% (28 out of 30), we reject the null hypothesis and conclude that more than 70% of the patients can complete radiation treatment successfully without a thermoplastic mask (p value is 0.0021, 95% confidence interval for the probability of success is [0.80–1.0]).

The group mean vector deviation is 1.1 mm. The movement data with respect to the isocenter is given in Table 1. The data shows a larger value of intra-fractional systematic error concerning the roll, compared to the pitch and rotation around the isocenter, which corresponds to the observation of the technologists that the head of the patient sometimes slightly fell aside during the treatment. However, with respect to the lateral treatment beams and the shape of the PTV, the dosimetric effect of a roll was expected to be small, in contrast to a pitch of the head.

Relevant statistics per patient are given in a boxplot in Fig. 1. Patient 20 shows an exceptionally large 5%-95% interval. The mean of the vector deviation of patient 20 was 1.9 mm. This corresponds to the large measured vector deviations and multiple repositioning procedures that were needed for this patient.

4. Discussion

To improve patient friendliness and comfort of whole-brain radiation therapy a new method of positioning and stabilizing the patient has been developed. Optical surface imaging was used to ensure a reproducible position and to control intra-fractional motion. This is the first time this method of irradiation without using a mask is tested in a clinical feasibility study. With a success rate of 93% it is concluded that radiation therapy without a thermoplastic mask is clinically feasible (95% confidence interval for the probability of success is [0.80–1.0]).

A surface scanner determines deviations of and around the isocenter with six degrees of freedom. The displacement in any other point of the head differs from that in the isocenter. The largest deviations are seen on the surface, away from the isocenter. This is explained by a rotation around the back of the head, that results in a displacement of the surface of the object. The Catalyst™ system presents this as a displacement of and rotation around the isocenter. For example, the maximum distance from the isocenter to the border of the CTV was in general approximately 140 mm. Consequently, a roll of 1 degree around the isocenter will result in a displacement of 2 mm of a point at the surface.

Immobilization devices cannot fully eliminate intra-fractional movements of a patient. Tryggestad et al. used CBCT, that was made before and after intra-cranial radiation treatment, to determine movements of the head in a thermoplastic head mask [12]. The mean intra-fractional motion was 1.1 mm (± 1.2 mm), which is comparable to our result. However, our result is based on a continuous measurement of intra-fractional motion. Hoogeman et al. also concluded that movements are still possible despite of the fixation of the head in a thermoplastic mask [13]. Their results showed an overall mean that was lower than 0.2 mm and a standard deviation that increased to 0.8 mm in a period of 15 min. Another way to determine intra-fractional head motion in a mask is to measure motion of the nose tip with infrared tracking [14]. The mean intra-fractional motion was 0.56 mm (± 0.51 mm), with a maximum of 3.2 mm. Based on CBCT, the intra-fractional motion of the same patients was 0.41 mm (± 0.36 mm).

In the current system, the threshold is defined for the displacement of the isocenter or the rotation around the isocenter, but ideally the threshold is defined for the Hausdorff distance, which is the maximum distance between two structure sets.

After positioning a patient, a small difference remains between the current posture and the posture during CT-scan. In this study,

Table 1
Given displacement of the isocenter in lateral, longitudinal, and vertical direction (mm), as well as the rotation, roll, and pitch (degrees) around the isocenter.

	Lateral (mm)	Longitudinal (mm)	Vertical (mm)	Rotation (degrees)	Roll (degrees)	Pitch (degrees)
Group mean	−0.01	0.03	−0.05	0.05	0.1	−0.03
Intra-fractional systematic error (standard deviation of patient mean)	0.3	0.3	0.2	0.2	0.5	0.2
Intra-fractional random error (group mean patient standard deviation)	0.9	1.4	0.3	0.8	1.2	0.3

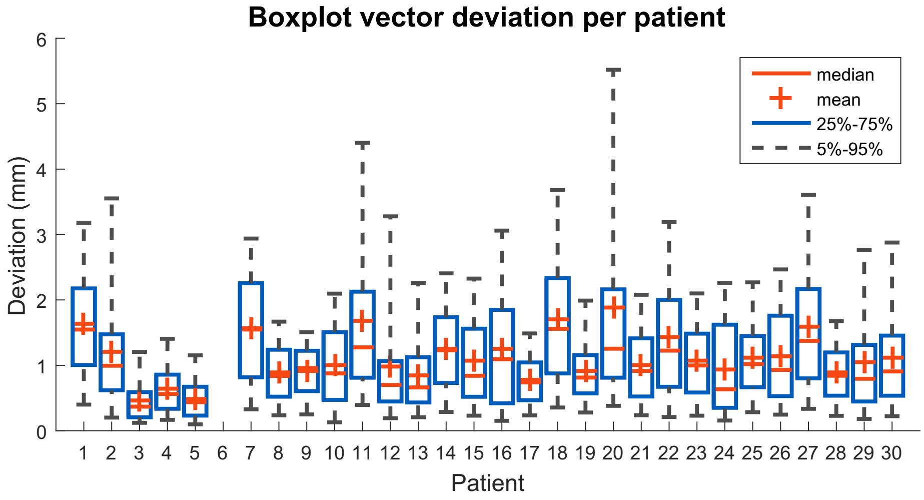

Fig. 1. The mean per patient, together with the median, the 25%–75% interval and the 5%–95% interval are given in the boxplot of the vector deviation per patient. Note that patient 6 used a head mask during all five fractions and patient 7 completed fraction 1 and 2 without a head mask and the remaining fractions with a mask. The results for treatments fractions with a mask are not included.

positioning of patients using the optical surface scanner was always followed by online imaging consisting of a mediolateral and an anterior-posterior kV-image. Unfortunately, a deviation in pitch and roll cannot be corrected, since our couch can only be rotated around a vertical axis. Since the treatment consists of two opposing lateral fields with a CTV-PTV margin of 5 mm, this is acceptable. Ideally, set-up errors can be corrected by rotating the couch also around the horizontal and lateral axis.

The measured intra-fractional motion is small, but we do not exactly know the accuracy of the measurement. The surface is expected to be predicted at the correct position, but it is difficult for the single-camera system to distinguish between a small translation or rotation of the head. This causes an increasing uncertainty in the predicted position of points more dorsal to the surface. Extensive phantom measurements are needed to determine the accuracy of this prediction and thus the accuracy of the values in Table 1.

The disadvantage of a single-camera system is that some parts of the body are situated in the ‘shadow’ and are not shown on the surface image. Especially patients with a large abdomen can be a problem. To prevent this loss of sight patients were positioned on a breast board, raising their head slightly above the rest of the body. A system consisting of three cameras has a larger field of view, hence the problem of shadow will not occur, and a breast board is not needed. An automated beam-off, instead of manual, would improve the reliability of the system. However, the accuracy will be the same.

Irradiation without a thermoplastic head mask for palliative whole-brain treatment is a new method that uses optical surface scanning to position and monitor the patient. It is concluded that the method is clinically feasible for a radiation treatment consisting of two lateral fields with a CTV-PTV margin of 5 mm. In the future, new technologies are expected to improve the use of optical surface scanning, such as intra-fractional couch movements and MLC-tracking based on intra-fractional motion monitoring. These developments will result in smaller margins, and other treatments may become eligible for radiation therapy without a thermoplastic mask.

Declaration of Competing Interest

None.

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