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Practical Radiation Oncology (2014) **4**, 448-454

practical radiation oncology
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Original Report

Local interfractional setup reproducibility for 2 individual head and neck supports in head and neck cancer patients

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Received 15 August 2013; revised 31 January 2014; accepted 10 February 2014

Abstract

Purpose: In radiation therapy, head and neck (H&N) supports and thermoplastic masks are used to reproduce the setup of patients for H&N treatment. Individualized supports that include the shoulders may improve the immobilization of the upper thorax region. The purpose of this study was to compare the local misalignment of the supraclavicular region using a vacuum cushion H&N support to a more simple in-house modified, clinically standard H&N support.

Methods and materials: Two groups of 15 patients were evaluated: the first group of patients was positioned using a vacuum cushion as an individual head support and the second group with a modified Posifix headrest (MPH). A total of 316 cone beam computed tomography (CBCTs; ~ 10 scans per patient) were evaluated using a multiple region of interest registration protocol. Local setup errors were measured using chamfer matching on the CBCT scan to the planning CT scan for 9 bony structures (cervical vertebrae 1, 3, 5, and 7 [C7], lower jaw, hyoid bone, larynx, skull, and jugular notch). In this study, we compared the local residual misalignments of the bony structures and in particular those of the jugular notch and C7 as surrogates of the shoulders and thorax region. The workload was qualitatively evaluated on the basis of open interviews.

Results: The significant differences in group mean, systematic error, and random error of the local residual misalignments between the 2 groups for jugular notch and C7 were equal or smaller than 0.5 mm and 0.1 degrees, and for the other 7 bony structures were equal to or smaller than 0.6 mm and 1.2 degrees (larynx). There were no large differences in workload.

Conclusions: No clinically relevant differences were found between a modified Posifix headrest and an individual vacuum cushion for H&N cancer patients in local posture change at the level of the clavicle and upper thorax.

Supplementary material for this article (http://dx.doi.org/10.1016/j.prro.2014.02.002) can be found at www.practicalradonc.org.

Conflicts of interest: None.

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http://dx.doi.org/10.1016/j.prro.2014.02.002

Introduction

In the last decades image guidance has increased the accuracy of radiation therapy.[1,2] Analysis of repeat cone beam computed tomography (CBCT) scans regularly taken for setup verification in head and neck (H&N) cancer patients, reveal considerable posture and anatomy changes over the course of radiation therapy (RT).[3-7] We previously developed a multiple region of interest (mROI) registration technique to drive couch corrections.[5] However, residual misalignments remain after a couch correction because the computed couch correction is a compromise between local deformations.[6]

We previously developed a comfort-oriented, in-house modified Posifix headrest (MPH) (Civco Medical Solutions, Coralville, IA) that has been routinely applied together with an Efficast 5-point thermoplastic mask (Orfit Industries, Wijnegem, Belgium). Although this 5-point thermoplastic mask fixates the shoulders, local misalignments of the supraclavicular region were found.[5] This revealed local relevant uncertainties in the supraclavicular region and the lower neck level where conventional margins may be too small.[5] Repositioning the shoulders and thorax could be a part of these uncertainties measured with the abovementioned mROI registration.

With the recent interest in individual head supports,[8,9] individualized head, neck, and shoulder devices that could improve the stability of the shoulders and the thorax became available.

The purpose of this study was to quantify the local interfractional residual misalignments of the MPH compared with an individual head, neck, and shoulder vacuum cushion; in particular for local posture changes in the shoulders and upper thorax. We also discuss the difference in workload for the technicians between the 2 supports during the patient preparation phase.

Methods and materials

Patients

Thirty H&N cancer patients without prior tumor stage selection, who had routinely undergone radical radiation therapy, were selected. Due to the limited field of view of the CBCT scan we did not select patients who presented with nasopharynx tumors (Table 1). In these patients structures like the jugular notch were not visible on the CBCT scan.

An average of 34 fractions (range, 30-35) was delivered to each patient. For all the patients, a planning CT scan (Somatom Sensation Open, Siemens AG, Erlangen, Germany) was acquired with a voxel size of $0.8 \times 0.8 \times 3$ mm^3 from the (whole) cranium to the sternum (upper part). During treatment, the patients underwent CBCT-guided radiation therapy. The CBCT scans (Elekta Synergy 4.2, Elekta Oncology Systems Ltd, Crawley, UK, augmented with in-house developed software) were acquired with an energy of 120 kV and an isocenter dose of about 1 cGy[10] and reconstructed with a voxel size of $1 \times 1 \times 1$ mm^3. A total of 316 CBCT scans were evaluated, with an average of 10 CBCT scans per patient (range, 6-35).

Table 1 Number of patients per tumor site for group 1 (Vac Lok vacuum cushion) and group 2 (modified Posifix headrest)

Tumor sites	Group 1	Group 2
Larynx	6	1
Oropharynx	3	4
Hypopharynx	1	0
Floor of mouth	1	4
Tongue or base of tongue	1	4
Oral cavity	3	2

Patient fixation

The patients were selected consecutively and divided into 2 groups of equal size (Table 1). According to our protocol, the patients in the 2 groups were positioned with the head tilted backward so that the lower jaw was perpendicular to the treatment table (Fig 1A). To maintain this position an appropriate curvature had to be provided. In both groups the selected H&N support was used over the whole course of radiation therapy.

In the first group (group 1) the patients were positioned on the head and neck Vac Lok cushion (Fig 1B). The Vac Lok cushion is a vacuum cushion, filled with tiny polystyrene beads, that supports the head, neck, and shoulders (Fig 1A). The cushion was molded to the shape of the patient's head, neck, and shoulders and subsequently evaluated prior to the thermoplastic mask molding procedure. This headrest was made once and maintained its (individual) shape during the whole treatment. The second group (group 2) of patients were positioned on the MPH (Fig 1C). The MPH is a standard Posifix headrest (available in different curvatures; Fig 1D), in-house extended with 2 extra supporting wedges for the comfortable positioning of the neck. One of the wedges is added to the caudal part of the headrest (Fig 1C, arrows 1) to fill the air gap between the table and the patient's neck and upper thorax. The second wedge is placed at the bottom to rotate the headrest around its own left-right axes (Fig 1C, arrows 2) adjusting for patient's neck curvature. Both glued foam wedges are made of the same material as the standard Posifix headrest. Based on the patient anatomy, the technicians select the MPH that is used for that particular patient during the whole

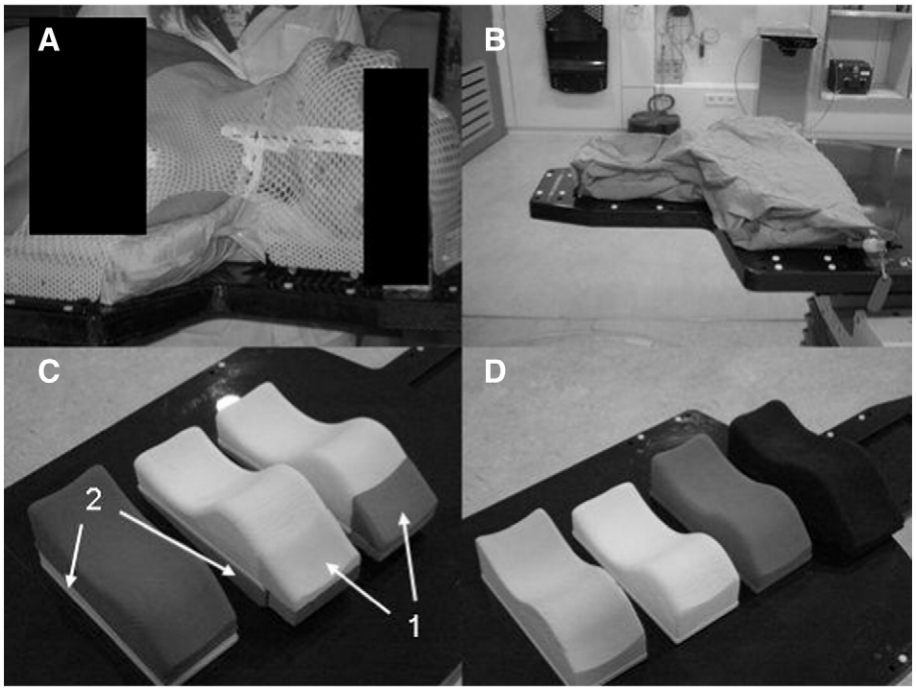

Figure 1 Different head and neck supports: (A) and (B) The Vac Lok vacuum cushion (with patient and without). (C) Modified Posifix headrest; arrows 1 the caudal wedge for the air gap between patient and table, arrows 2 the bottom wedge. (D) Standard Posifix headrest.

course of radiation therapy. If the patient did not fit an already prepared headrest, the technicians modified a standard Posifix headrest by introducing 2 adequate wedges. The patients of both groups were positioned using a 5-point thermoplastic mask (Efficast) and a knee support (Civco Medical Solutions) for stability and comfort.

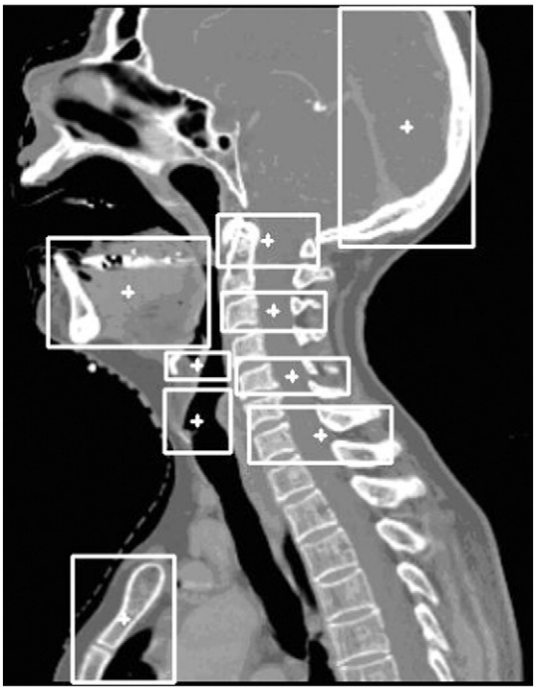

Figure 2 Sagittal view of the planning computed tomograph with 9 regions of interest on bony structures (cervical vertebrae 1, 3, 5, and 7, lower jaw, hyoid bone, larynx, jugular notch, and skull).

Radiation therapy

Patients were set up using localization lines on the mask and skin to align the patient to the isocenter lasers. Subsequently, the table was shifted to align the patient to the planned treatment position. The local setup errors were computed (quantification of the local posture changes) using mROI registration on 9 bony structures (cervical vertebrae 1 [C1], 3 [C3], 5 [C5] and 7 [C7], lower jaw, hyoid bone, larynx, skull, and jugular notch) (Fig 2). Each ROI is local rigidly registered from the CBCT scan to the planning CT scan using Chamfer-Matching.[11] The average of the local setup errors was used to perform the couch shift correction.[5,6,12] In this study we compared the local residual misalignments (simulating an on-line correction protocol) between the 2 groups. By using the bony structures of the jugular notch and C7 as surrogates of the shoulders and upper thorax we quantified the local posture changes in these areas.

Statistical analysis

The analyses were performed by calculating the group mean (GM), systematic error (Σ), and the random error (σ)

Table 2 Group mean (GM) of the residual misalignments for the Vac Lok vacuum cushion (VC) group and the modified Posifix headrest (MPH) group in mm and degrees for cervical vertebra 7 and jugular notch

GM (n = 30)		Translations (mm)			Rotations (degrees)		
ROI	H&N support	LR	CC	AP	LR	CC	AP
C7	VC	−0.6	−0.2	0.2	0.3	1.0	0.2
	MPH	−0.6	−0.1	−0.1	0.1	1.2	−0.3
Jugular notch	VC	0.6	0.0	0.6	0.2	1.2	0.3
	MPH	0.9	0.0	0.1	0.7	1.5	−0.1

AP, anterior-posterior; CC, cranial-caudal; H&N, head and neck; LR, left-right; ROI, region of interest.

Table 4 Random errors (σ) of the residual misalignments for the Vac Lok vacuum cushion (VC) group and the modified Posifix headrest (MPH) group in mm or degree for cervical vertebra 7 and jugular notch

σ (n = 30)		Translations (mm)			Rotations (degrees)		
ROI	H&N support	LR	CC	AP	LR	CC	AP
C7	VC	1.0	0.8	1.1	1.3	1.0	0.9
	MPH	1.2	1.0	1.0	1.7	1.1	0.8
Jugular notch	VC	1.1 [a]	1.5	1.9	2.3	0.9 [a]	1.0
	MPH	1.3 [a]	1.7	1.4	1.5	1.0 [a]	0.9

AP, anterior-posterior; CC, cranial-caudal, GM, group mean; H&N, head and neck; LR, left-right; ROI, regions of interest.
[a] Significant differences ($P < .05$) between the VC group and MPH group.

of the local residual misalignments for each group in left-right (LR), cranial-caudal (CC), and anterior-posterior (AP) directions for translations and rotations. The GM was calculated as the mean of all patients' means, Σ was measured as the standard deviation of the all patients' means, and σ was the root mean square of all patients' standard deviations.[13]

The Mann-Whitney *U* test was performed for both the GM and the random errors as this test is not sensitive to not normally distributed data and outliers. In order to prevent irrelevant differences in GM, of equal magnitude but different signs to become statistically significant, the sign of all samples in a distribution were inverted in case of a negative GM. To evaluate the differences of the systematic errors we used the Levene test.[8] The Levene test evaluates if the standard deviation of 2 distributions are equal; MATLAB 2009a (The MathWorks Inc, Natick, MA) was used for the statistical analysis.

Workload evaluation

The workload was qualitatively evaluated on the basis of open interviews with which we investigated the differences in logistics, patient preparation, and patient positioning-and-comfort during treatment between the 2 supports.

For the patient preparation workload we interviewed 3 experienced technicians who described the preparation of

Table 3 Systematic errors (Σ) of the residual misalignments for the Vac Lok vacuum cushion (VC) group and the modified Posifix headrest (MPH) group in mm or degrees for cervical vertebra 7 and jugular notch

Σ (n = 30)		Translations (mm)			Rotations (degrees)		
ROI	H&N support	LR	CC	AP	LR	CC	AP
C7	VC	1.4	0.5 [a]	1.2	1.5	0.7	0.6
	MPH	0.9	1.0 [a]	1.3	1.8	0.9	0.8
Jugular notch	VC	1.9	2.6	1.7	2.3	1.3	0.8
	MPH	1.1	2.0	1.7	1.3	0.9	0.8

H&N, head and neck; ROI, regions of interest.
[a] Significant differences ($P < .05$) between the VC group and MPH group.

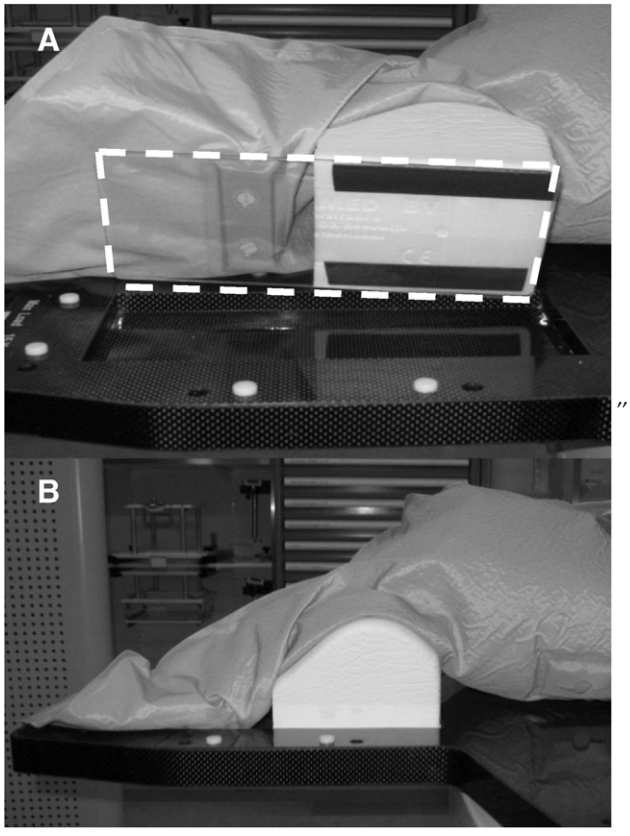

Figure 3 (A) The modified Vac Lok vacuum cushion with a Perspex rectangular plate (dashed line shows outline of plate) on the posterior side of the cushion for fixating the vacuum cushion to the treatment couch. (B) The modified cushion with a piece of Posifix headrest as an extra support for the positioning of the patient in the treatment position.

each patient and if the procedure was able to be successfully completed according to our protocol. The protocol states that 2 technicians complete the whole preparation procedure in a time slot of 45 minutes.

Four technicians were interviewed on logistics and patient positioning comfort.

Results

Quantification of the local posture changes

The GM, Σ, and σ of the local residual misalignments of the 2 groups for the bony structures C7 and jugular notch are given in Tables 2, 3, and 4. The GM, Σ, and σ of the local residual misalignments of the 2 groups for the remaining 7 bony structures are given in Appendices A, B and C (available as supplementary material online only at www.practicalradonc.org). Significant differences ($P < .05$) in the local residual misalignments are underlined. Significant differences larger than 1 mm and 1 degree between the 2 groups are printed in bold. The differences for translation and rotation between the vacuum cushion and modified Posifix headrest for bony structures jugular notch and C7 were smaller than 0.8 mm and 1 degree. Significant differences for the Σ were found for C7 in CC translations (0.5 mm), for the σ for the jugular notch in the LR translations (0.2 mm), and in the CC rotations (0.1 degree). The results demonstrate that the differences in the larynx structure for the random error in the rotational AP direction (Appendix C; available as supplementary material online only at www.practicalradonc.org) are in favor of the vacuum cushion.

Workload evaluation

Logistics

The only logistic difference was in the space necessary to store the supports during the course of the radiation therapy. For the impressed vacuum cushion, an extra shelf was necessary in the treatment room.

Patient preparation

For all patients in the MPH group a single technician was able to select the most comfortable MPH; for the molding procedure of the thermoplastic mask 2 technicians were needed.

The vacuum cushion group required 2 extra technicians to assist (the first technician), making an individual H&N support with tilting the head, folding the cushion around the lateral sides of the head and shoulders, and at the same time operating the vacuum pump. As in the MPH group, the molding procedure of the thermoplastic mask was done with 2 technicians. The 2 procedures (making individual H&N support and mask molding) were completed in the regular time slot.

After the first patient, the vacuum cushion was modified with a Perspex rectangular plate (Fig 3A) for fixating the vacuum cushion to the treatment couch. This Perspex plate was introduced after feedback of the radiation therapy technologists and mold-room technicians. (See Fig 4.)

After the first 9 patients, a part of the standard Posifix headrest (Figs 3B and 4) was attached to the Perspex plate under the patient's neck to obtain the tilted head position. This extra part of the Posifix headrest made it possible to mold the individual H&N support with 2 technicians. This procedure was less time consuming in the folding procedure within the first 9 patients but still took more effort than the MPH.

Patient positioning and comfort

The radiation therapy technologists reported no differences in positioning the patient on the treatment table. No difficulties concerning the repositioning of the shoulders were reported in the vacuum cushion group. Patients mentioned no complaints or discomfort for either support.

Discussion

In this study we quantified the local interfractional setup reproducibility of 2 head and neck supports for 9 bony structures and compared the results for local posture changes in terms of group mean, systematic error, and

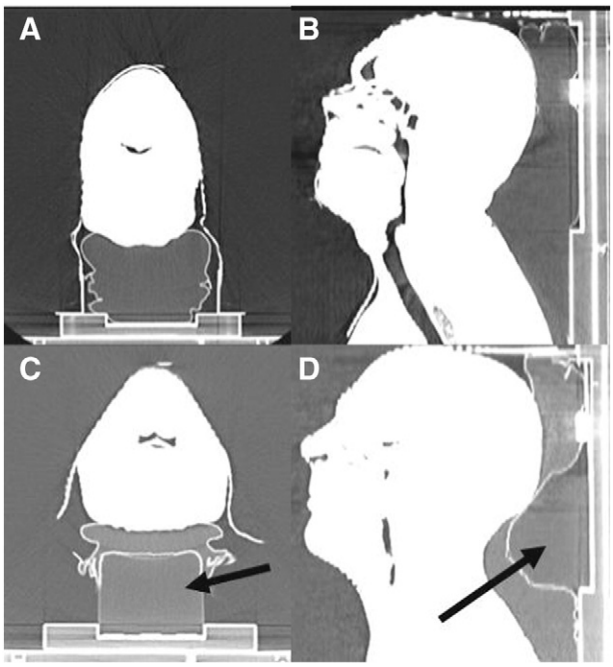

Figure 4 (A) Transversal view and (B) sagittal view of a cone beam computed tomography scan visualizing the standard Vac Lok vacuum cushion. (C) Transversal view and (D) sagittal view of the modified Vac Lok with part of the standard Posifix headrest indicated by the arrows positioned underneath for the correct head position.

random error. All significant differences were in favor of the vacuum cushion; however, they were submillimeter and, except for the larynx, smaller than 1degree, indicating no clinically relevant differences.

Our results were consistent with the findings of Giske et al[4] and van Kranen et al.[5] In their study, Giske et al used an individualized patient fixation device composed of a firm scotch-cast mask and a vacuum mold for the whole body as in a stereotactic setup approach. They concluded that no substantial differences were found in comparison with Aquaplast masks compared with Zhang et al.[7]

In other studies different approaches have been used to customize the patient fixation. For example, McKernan et al[9] used foam bags, sealed packs containing 2 liquids, which activate into expanding polyurethane foam when mixed. Houweling et al[8] used an individual head support that was made of impression foam with a thermoplastic cover on top. Both studies concluded that using a custom-made H&N support with respect to the standard support improved immobilization.

In our case, we compared 2 "individual" head and neck supports; the individual vacuum cushion and the MPH. The MPH was developed in our institute 12 years ago for patients with atypical neck curvatures who did not fit onto the standard Posifix headrest. For the atypical neck curvature the headrest was rotated around its LR axis and the air gap between patient's neck/upper thorax and treatment couch was filled to improve the comfort. Over the years, the use of MPH was extended to all patients. In the molding procedure, special care is taken to fit and select the most comfortable head and neck rest to the patient. Surprisingly, this is as good as making an imprint of the patient's head, neck, and shoulder using the vacuum cushion.

The patients were treated with 1 head rest for the whole treatment course. Another approach could be treating patients with both head rests, alternating them for different fractions. Such an approach would allow for a paired comparison and thus a more sensitive statistical comparison. In practice, however, this approach was not feasible.

The initial workload increment for the vacuum cushion was reduced with the introduction of the Perspex rectangular plate (Fig 3A) and the neck additional support (Fig 3B). A logistical drawback for the vacuum cushions was that much more space was required to store the cushions during the course of the radiation therapy compared with the MPH. We decided to keep the MPH as our clinical standard support due to the fact that no clinically relevant improvements in the patient alignment were found, as well as no workload and logistic benefit were pointed out.

Limits of the study

This study is particularly focused on shoulders and upper thorax; however, due to the limited field of view of the CBCT we could not directly quantify the shoulders and upper thorax alignment. We therefore used the jugular notch and C7 as surrogates. Furthermore, for this reason patients were selected on the basis of tumor location. Nasopharynx tumors were excluded due to the cranial position of the isocenter. In this case the CBCT field of view did not visualize structures as the jugular notch.

Due to our imaging protocol for conventionally fractionated treatment of H&N we acquired only a pretreatment CBCT scan. This limited the analysis to interfractional measurements only, and consequently the study lacks the intrafraction setup reproducibility analysis. It is a topic of future studies, especially for stereotactic cases, where also a posttreatment CBCT scan is required.

We did not apply a correction for multiple comparisons and probably resulting from this an overestimation of the true statistical parameters may have occurred. However, in consideration of the fact that the findings revealed a small number of significant (and not clinically relevant) differences between the 2 groups we preferred not to apply a conservative correction such as the Bonferroni correction.

In this study we did not measure intrafraction motion, delineation uncertainty, and correction accuracy necessary for margin computations.[13] Moreover, published margin recipes are only valid for rigid body displacements, while here differential motion was analyzed. This means that it was not possible to give any margin suggestion.

Conclusions

We found no clinically relevant differences in local posture changes in H&N cancer patients between the modified standard Posifix headrest and the commercially available individual head, neck, and shoulder Vac Lok vacuum cushion. On the basis of these findings and the evaluation of the logistics and the workload drawbacks we decided to continue using the modified Posifix headrest for all our head and neck cancer patients.

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