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Baş-Boyun ve Beyin Tümörü IMRT Uygulamasında Vakumlu Boyun Yastığı (VBY)' nın Set Up Doğruluğuna Katkısı

Efficacy of Thermoformable Vacuum Head Cushion on Set-up Accuracy in IIMRT of Head & Neck and Brain Tumors

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ÖZET

Amaç: Baş-boyun ve beyin tümörlerinde uygulanacak lokal radyoterapi sırasında eşlik eden kritik normal dokulara verilebilecek zararın en aza indirilmesi açısından özel planlama tekniklerine ve ideal sabitleme ekipmanlarına gerek duyulmaktadır. Çalışmamızda baş-boyun ve beyin tümörü tanısı ile radyoterapi uygulanan hastalarda ek sabitleme ekipmanı olarak kullandığımız Vakumlu Boyun Yastığı (VBY)'nın etkinliğinin tedavi süresince alınan haftalık port filmleri ile değerlendirilmesi amaçlandı. Materyal Metod: Kliniğimizde baş-boyun veya beyin tümörü tanısıyla uygulanan küratif/adjuvan radyoterapi sırasında VBY kullanılan ve kullanılmayan 10 hastanın haftalık portları VBY kullanılan (Grup A) ve kullanılmayan (Grup B) olmak üzere iki gruba ayrılarak değerlendirildi. Her hastanın 7 port görüntüsünde longitudinal, lateral ve vertikal eksendeki verisinin set-up değerlerine göre farkları mutlak değer olarak kaydedildi. Her iki gruptaki kaydırma değerleri ve >4mm kaydırma yüzdeleri değerlendirildi. Bulgular: Çalışmaya dahil edilen toplam 20 hastanın tanıları 14 nazofarenks, 2 GBM, 2 dil, 1 larenks, 1 sert damak tümörü şeklinde idi. Her iki grup kaydırma miktarları açısından değerlendirildiğinde vertikal ve longitudinal eksendeki kaydırma düzeylerinin VBY kullanılan hastalarda anlamlı oranda yüksek olduğu saptandı (sırasıyla p:0,039 ve p:0,002). Hastalarda ≥ 4mm düzeyindeki kayma oranları da yine vertikal ve longitudinal eksende VBY kullanılan hastalarda anlamlı oranda yüksek olduğu saptandı (sırasıyla p:0,023 ve p:<0001). Her iki gruptaki fark oranları ve p değerleri Tablo 1 de gösterilmiştir. Sonuç: Hastalarımızda ek sabitleme ekipmanı olarak VBY kullanımının standart yastık kullanımına göre istatistiksel anlamlı oranda daha yüksek kaydırma değerleri ve daha fazla ≥ 4mm kaydırma yüzdesine neden olduğu saptanmıştır. Sonuç olarak baş-boyun ve beyin tümörü radyoterapisinde VBY kullanımının immobilizasyona katkısı gösterilememiştir.

Anahtar Kelimeler: Vakumlu Boyun Yastığı, pozisyonlama güvenilirliği, baş boyun kanseri, IMRT

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ABSTRACT

Objective: An effective immobilization is warranted to minimize set up deviations while treating head & neck (HN) and brain tumors with intensity modulated radiotherapy (IMRT). In this study we evaluated the effectiveness of thermoformable vacuum head cushion (TVHC) on immobilization of these patients via weekly electronic digital port films (EDPF).Material and Method: Twenty patients treated with IMRT for HN and Brain tumors were enrolled in the study. TVHC supporting the head and neck region (n:10) in Group A and thermoplastic mask with additional standard plastic head rest (n:10) in Group B were used for immobilization. Weekly EDPF images were obtained on the linear accelerator. Set-up displacements in latero-medial, anteroposterior and cranio-caudal directions in these images were compared with variation data of first treatment. Results: When each group was analyzed in terms of deviations in all 3 directions, deviations calculated in anteroposterior and craniocaudal directions were significantly higher for TVHC group (p:0.039 and p:0.002 respectively). Deviations ≥4mm in all three directions were also analyzed and similarly, higher rates of ≥4mm deviations were recorded for TVHC group in anteroposterior and craniocaudal directions (p:0.023 and p:<0.001 respectively) which of both were also statistically significant. Conclusion: We found that TVHC utilization in HN and brain IMRT for immobilization leads to significantly higher set-up deviations so future investigations with larger patient populations and evaluating set up accuracy via more sensitive alignments are needed to suggest TVHC for utilization in daily clinical practice.

Keywords: Thermoformable vacuum head cushion, positioning accuracy, head and neck cancer, IMRT

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1.INTRODUCTION

Radiotherapy (RT) is an essential component of the treatment algorithm in Head & Neck (HN) tumors and brain tumors. Intensity-modulated radiation therapy (IMRT) enables delivering highly conformal radiation to the target volumes while minimizing the dose expired to nearby normal tissues and critical organs (1, 2). However, this highly conformal treatment warrants a meticulous immobilization and delicately reproducible positioning for accuracy of each fraction. Especially for HN and brain tumor radiotherapy, this is a major issue of the treatment planning due to sophisticated anatomical allocation of the region and proximity of critical organs and normal tissues to target volume. Therefore, ideal immobilization devices are necessary to keep any possible radiation damage in reasonable levels. Thermoplastic masks are commonly used in clinical practice for immobilization of HN patients (3). Additionally, electronic portal images (EPI) are seen during treatment process for evaluation of positioning accuracy. Plastic head-rest, thermoformable vacuum head cushion (TVHC) or bite blocks may also be added according to the patient's anatomical needs, location of primary tumor and treatment intent. During classical set up alignment procedure, the lasers are aligned to laser marks on the mask which is drawn in simulation CT and a portal image is taken to evaluate treatment field accuracy. For portal imaging megavolt (MV) X-rays (4-8); or (kV) X-rays (9) can be used. With the presentation of complex and effective immobilization devices and accessories each radiation oncology clinic developed specified immobilization strategies and RT techniques individualized for specific patients based on their availabilities (10-12).

The necessity of imaging for satisfactory immobilization even in image guided treatment is reported in a study by Zeidan et al. (13) which they found three-dimensional (3D) setup errors of at least 5mm in 11% of H&N patients. Poor contrast resolution is the major handicap of MV portal imaging while it is two-dimensional (2D) projection technique (14). When compared to MV images kV radiographs were found more qualitative (9).

In many clinics, in-room systems, capable of both 2DkV radiographic imaging and 3DkV cone beam CT (CBCT) are in utilization. In daily routine, 2DkV images are easily acquired and gives much less dose compared to CBCT. However, as volumetric CT images provide a more delicate vision allowing to identify both bony structures and soft tissues, and provides a more accurate evaluation of (3D) and rotational set up errors it becomes a better practice for IGRT especially for prostate and lung cancer (15,16). Superiority of 3D approach with CBCT also in set up verification of HN patients is shown by previous literature (17,18).

Three main causes of set up errors are defined as (1) the systematic difference in the immobilization device between the simulation and treatment; (2) the random setup errors between treatment fractions (3) progressing variations as tumor shrinkage or weight loss during treatment (14,17,19).

All these above mentioned set up error causes, especially while performing highly conformal radiation such as IMRT, creating steep dose gradients in the treatment field boundaries, even in case of minimal deviation in dose distribution dramatic dosimetric changes may occur. Consequentially, this will eventuate with a geometric miss of the target leading to treatment failure or unacceptable complications due to high dose expired to critical organs (20).

In this study we evaluated the effectiveness of thermoformable vacuum head cushion we used as an additional immobilization device in these patients via weekly electronic digital port films (EDPF) in patients who underwent radiotherapy for HN or brain tumors.

2.MATERIALS and METHOD

The study was approved by the Scientific Research Ethics Committee of Medical Faculty of University (protocol code, 2020/40). All procedures performed in terms of the ethical standards of the institutional research committee in alliance with the 1964 Helsinki declaration and its later amendments. Informed consent was waived owing to the retrospective nature of the study.

Table 1. Comparison of groups in terms of RT treatment characteristics, gender and primer cancer site

		Group A (TVHC†)	Group B (SHR‡)	p value
Gender	Female Male	3 7	6 4	0.370
Primary	Nasopharynx Brain Tongue Larynx Hard palate	3 2 2 2 1	7 0 1 2 0	0.079
PTV§ high risk		70Gy(60-70Gy)	70Gy (all)	**0.030**
PTV low risk		54Gy(46-60Gy)	54Gy (50-60Gy)	0.625
SIB¶	Yes No	7 3	10 0	0.211
IMRT fields	5-field 7-field 9-field	1 9 0	0 8 2	0.217
Number of Fractions	30 frx 33 frx 35 frx	2 7 1	0 2 8	**0.006**
Set-up time (min)		12.5 (7-29)	10.5 (7-37)	0.290
Treatment time (min)		3.22 (1.79-4.13)	2.81 (2.40-3.66)	0.761

†TVHC: Thermoformable Vacuum Head Cushion,
‡SHR: Standard head rest
§PTV: planning target volume,
¶SIB: Simultaneous Integrated Boost, frx: fraction.
Statistically significant p-values are in bold.
†, ‡, §, ¶

Twenty patients treated with curative or adjuvant RT for HN and brain tumors from December 2018 to October 2019 were enrolled in the study. Two types of immobilization systems we used for IMRT of HN and brain tumor treatment in our department are: (1) patient supine positioned lying with TVHC under head and neck with thermoplastic mask (The implementation of TVHC on standard head rest and a set up view are shown in Figures 1-3); (2) patient supine positioned lying on plastic standard head rest (SHR) and base plate with thermoplastic mask immobilizing the skull (Fig. 4). Ten patients were treated with TVHC supporting the head and neck region (TVHC/Group A), and SHR (SHR/ Group B) was used in treatment of remaining 10 patients for immobilization.

Treatment Planning

All patients were scanned in a supine position with radiotherapy head & neck thermoplastic mask, which is used for immobilization equipment. CT images were obtained with a 2.5-mm slice thickness for head & neck region, which covers the total cranium and neck of the body, using CT scanner (General Electric Medical Systems, Brightspeed). Treatment plans were created using the Eclipse treatment planning system on Varian DBX linear accelerator. Anisotropic Analytical Algorithm (AAA) dose calculation algorithm was used in the radiotherapy treatment planning process. Sliding Window Intensity Modulated Radiation Therapy (SW-IMRT) treatment plans for all patients were performed with equal-spaced multiple fields using 6 MV x-rays.

All the treatment plans were performed by the same two medical physicist. In each fraction of the treatment, the patients of each group were positioned in the treatment couch using their respective immobilization equipment. Megavoltage electronic portal imaging device (EPID, Varian Medical Systems, Palo Alto) were used to determine the position accuracy of patients with the help of matching anatomical bony structures. At least one anterior-posterior (AP PORT) and lateral sided (LAT PORT) portal images taken for each patient in order to verify the accurateness of geometric position before treatment. During each imaging session, the patients were scanned with 6 MV x-rays with a field size of 20x20 cm^2. After each imaging process, the acquired images were registered and matched with reference image which is originated from simulation CT. The registration and matching the fused images were carried out by physician and medical physicist.

Table 2. Comparions of the deviations in ports for the groups with and without TVHC

	Group A (TVHC†)	Group B (SHR‡)	p value
Vertical deviation (median, range)	1 mm (0-6)	1 mm (0-3)	**0,039**
Longitudinal deviation (median, range)	2,5mm (0-8)	2 mm (0-6)	**0,002**
Lateral deviation (median, range)	2mm (0-7)	2 mm (0-5)	0,568
Number of ports with vertical deviation >4 mm	5 (7,1%)	0	**0,023**
Number of ports with longitudinal deviation >4 mm	28(40%)	9 (12,9%)	**<0,001**
Number of ports with lateral deviation >4 mm	11 (15,7%)	7 (10%)	0,313

†TVHC: Thermoformable Vacuum Head Cushion,
‡SHR: Standard head rest

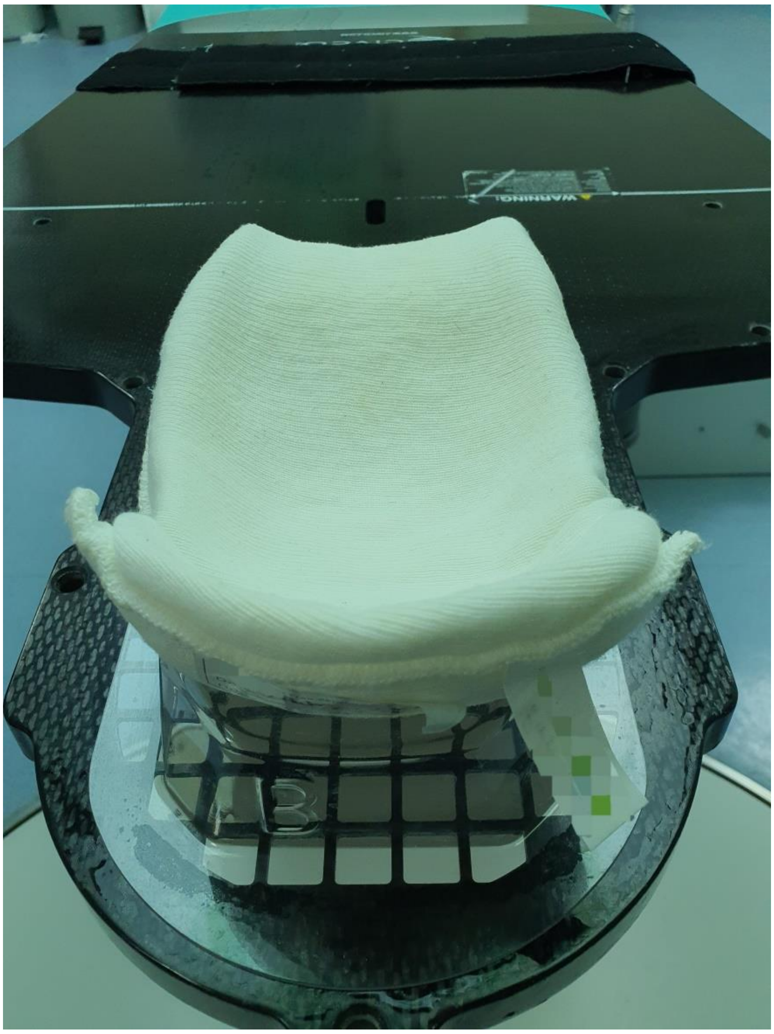
Statistical Analysis

Set-up displacements in latero-medial, anteroposterior and cranio-caudal directions in all these 7 weekly images of each patient taken during whole treatment course were recorded and compared with variation data of first treatment which were accepted as basal absolute values.
Differences between the variation data in each group were compared with Mann-Whitney U test. The percent of variation > 4mm in each group was compared with chi-square analysis. All the statistical analysis were performed by the Statistical Package for the Social Sciences software program version 21.0 (SPSS Inc., Chicago, IL, USA) and a p-value of less than 0.05 was considered to show a statistically significant result.

3.RESULTS

Among the 20 patients enrolled, 10, 2, 4 and 4 were treated for nasopharynx, high grade glioma, oral cavity and larynx, respectively. All patients were treated with IMRT, however simultaneous integrated boost (SIB) was used for 17 of the patients where dose was escalated with a phase II boost in remaining 3 patients.
The median fraction number of patients was 33 (30-35); the median setup time was recorded as 11 minutes (7-37 minutes), and the median treatment time was 2.98 minutes (1.79-4.13 minutes). The median set up and treatment times for both groups with comparison are shown in table 2. The gender, diagnosis, and RT treatment characteristics of the patients with and without TVHC are compared in Table 1. The differences between group A and B were not statistically significant except PTV high-risk dose and fraction number (p=0.030 and 0.006 respectively).
A total of 140 port images were collected from the 20 patients. 7 port images of each patient were recorded in terms of axis deviations. When both groups were evaluated in terms of the deviations in the vertical, longitudinal and lateral axis, it was found that the deviations in the vertical and longitudinal axis were significantly higher in patients using TVHC (p:0.039 and p: 0.002 respectively). When the number of ports that had deviation more than 4 mm in the vertical, longitudinal and lateral axes were compared between two groups, it was found that the deviations > 4mm in vertical and longitudinal axes were more common in patients using TVHC which of both were statistically significant (p:0.023 and p:<0.001 respectively). Median values of deviation in both groups and p-values are shown in Table 2.

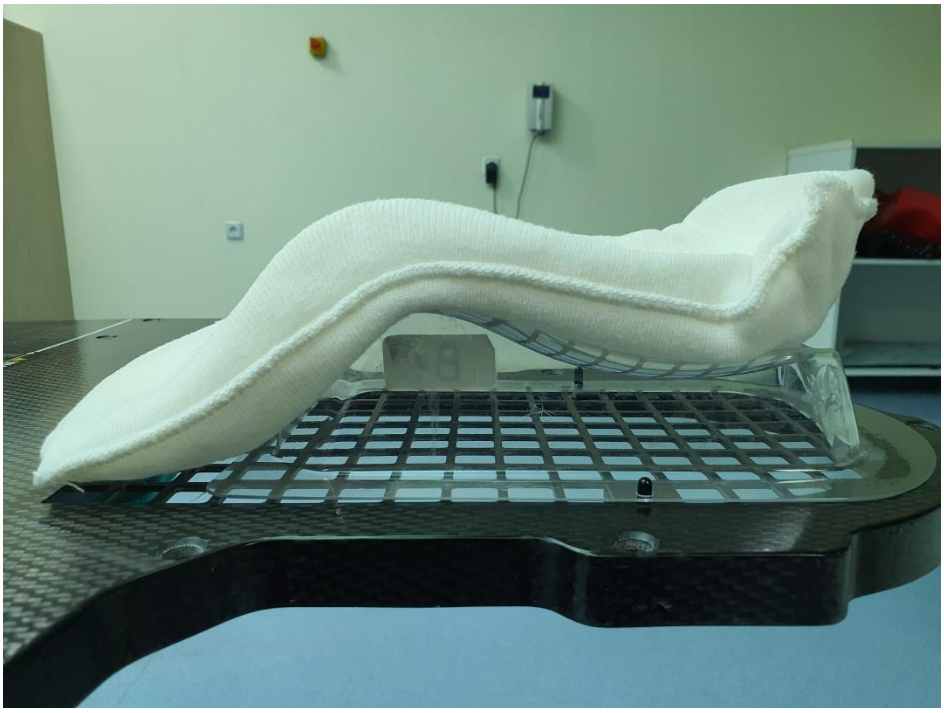
Figure 1. The frontal view of implemented thermoformable vacuum head cushion



4.DISCUSSION

Advanced RT techniques evolved in the past three decades such as IMRT, ensures more conformal target dose and steeper dose cut off in the field edges. Correspondingly; even a small deviation in set up position may end up in unexpected dosimetric changes both in the target and OARs. Consequentially; an immobilization strategy with a multifaceted technique is needed to avoid any positional displacement. The SHR with base plate is the conventional immobilization device in our department. Although there are head rests with different sizes and shapes, they mostly cannot fit the scalp curvature and cervical lordosis which is individual for all patients. This may lead to gaps between patient's head and the head rest and cause an unstable set up position with a low reproducibility. TVHC came into use 3 years ago in our department. TVHC becomes reformable in hot water and it is placed at the nape covering from the lower part of the head to upper chest and tailored according to patient's anatomy individually while cooling. When the reference points are matched, set up deviation in lateral axis was not significant. This was in accordance with the study by Lin et al. which the authors did not determine any significant difference in set up deviation along the x-axis in their nasopharynx patients (20). This can be attributed to strong immobilization effect of thermoplastic mask while it tightly covers the anterior and lateral contour of the head which restrains the mediolateral shift. The deviations in craniocaudal, and anteroposterior directions were both significantly higher in TVHC system. In order to interpret this unexpected result, we discussed on any problematic set up issue with RT technicians. Two possible causes emerged to comment on: 1)

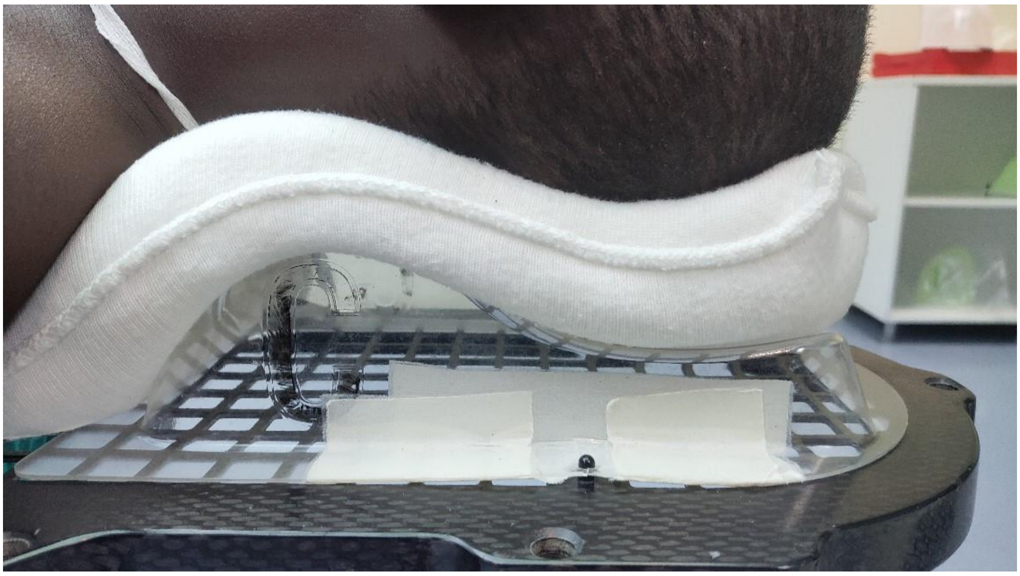
Figure 2. The lateral view of implemented thermoformable vacuum head cushion



The additional height formed due to TVHC material leads to an extra force to stretch the thermoplastic mask. Consequentially, a loosening in the mask becomes inevitable especially after 4th week of the treatment. 2) the patients positioned with TVHC were mostly the cases which we were unable to obtain a convenient reproducible position due to anatomical issues. Another aspect to mention is the shoulder stabilization. Nuebauer et al. reported about shoulder motion in head and neck RT which even causes dosimetric changes on IMRT (21). If the lack of any support at the back of shoulders with TVHC is taken into consideration, the higher set up deviation we detected in our study may be explained by shoulder motion. In the radiation treatment of neck region therapy of the neck region, deviations in the antero-posterior direction is important for the dose to the spinal cord, while medio-lateral deviations may cause geometric miss in terms of lymphatic targets. However; difficulty and less effectiveness of cervical immobilization compared to other regions is reported via different immobilization systems (20, 22). Cheng et al. (23) compared two immobilization systems in head and neck patients and concluded that the Orfit system (Orfit Industries NV, Wijnegem, Belgium) provided better immobilization than the standard head rest system. Another explanation for our results which shows a better set up immobilization with standard headrest may be analyzing them via two-dimensional kilovoltage (2DkV) imaging. This issue is reported by Li et al. who investigated the positioning accuracy of patient-specific TVHC headrest and standard clear plastic headrests using 2DkV imaging and three-dimensional CBCT in HN cancer patients.

Statistically significant difference was found on AP direction in favor of patient-specific TVHC headrest with the CBCT evaluation only. The authors speculated that the region which includes the most visible bony landmark for each projection in 2DkV may not be the same on different radiographs. Additionally, it is not possible to identify out-of-plane rotations in 2DkV images. Last but not least, it may be difficult to distinguish the bony anatomic landmarks in 2D projection images if they were obscured by other anatomic features such as superposing bony structures. So, it is indicated that CBCT is more sensitive in detecting setup errors than 2DkV image techniques. However, as TVHC was found more convenient in CBCT images in AP direction, the authors concluded that patient-specific TVHC headrests reduced the individual variations in neck curvature on AP direction. (17).

Figure 3. The view and implementation of thermoformable vacuum head cushion



We also couldn't find any difference between the median set up and treatment times of the groups. And, to our concern this is the first study to compare the different immobilization systems in terms of set up time or treatment time. It can be inferred from the study that the efficiency of treatment hasn't been affected significantly by the usage of TVHC in the positioning of patients during radiotherapy in terms of tumor coverage and normal tissue irradiation.

These findings may guide radiation oncologists when deciding treatment margins for cervical lymphatics and may be individualizing it according to immobilization system used. Although similar studies on comparing different set up systems can be seen in the literature (20,22,24), to our concern, this is the first one investigating the effect of TVHC on set up accuracy via comparing it with standard head rest.

Figure 4. The view of patient in supine position lying on plastic standard head rest

5.CONCLUSION

In conclusion, we found that the deviations in the vertical and longitudinal axis were significantly higher in patients with TVHC. Deviations > 4 mm in vertical and longitudinal axes were also more common in TVHC group. According to our study TVHC system showed less satisfying results compared to standard head rest which leads to inconvenience for daily routine. Besides, as HN region is not a rigid body, and identification of rotation is compelling with 2D alignments such as in our study, it can be deduced as a last word that not only better and clear localization but also better immobilization is warranted to reduce the individual variations in neck curvature. And further larger investigations with 3D alignment are needed to recommend TVHC as an immobilization system in HN IMRT treatments.

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