Evaluation of Silverman® and Posifix® headrests for head and neck immobilisation

Abstract ***Purpose****:* The accurate delivery of intensity modulated radiotherapy (IMRT), volumetric-modulated arc therapy (VMAT) and conformal head and neck (H&N) radiotherapy (RT) relies on patient stabilisation. With the multitude of products and variations available, it is imperative to investigate which product or combination of products offer the most optimal immobilisation. This quality improvement paper investigates the feasibility of using Posifix® (Civco Medical Solutions, Iowa, USA) headrests compared with Silverman® (Civco Medical Solutions, Iowa, USA) headrests in H&N RT stabilisation. This investigation is based on the hypothesis that foam Posifix® headrests may improve stabilisation and reproducibility as compared with the rigid plastic cast moulds of Silverman® headrests. ***Methods***: A retrospective group of 12 consecutive patients (six Silverman® and six Posifix®) were used to evaluate the accuracy of positioning from planning to treatment. In the assessment, 204 treatment portal images were matched to planning digitally reconstructed radiographs (DRR). The resultant shifts were documented for anterior/posterior and lateral films. For all three directions; left/right, anterior/posterior and superior/inferior (x, y and z) set-up deviations from the planning DRR were measured and averaged. A change in patient position by removal or addition of plastic spacers (shims) was collated from the treatment set-up sheet. ***Results****:* A total of 33 shifts of ≥ 3 mm were required for Silverman® headrests compared with 11 for Posifix® headrests. Total shim adjustments made were 10 and 0 for Silverman® and Posifix® headrests respectively. ***Conclusion****:* Using Posifix® headrests reduced shifts of ≥ 3 mm and patient set-up adjustments. As a result, Posifix® headrests have been implemented as part of the department's protocol for head and neck patient positioning.

Keywords: head and neck, immobilisation, radiation therapy.

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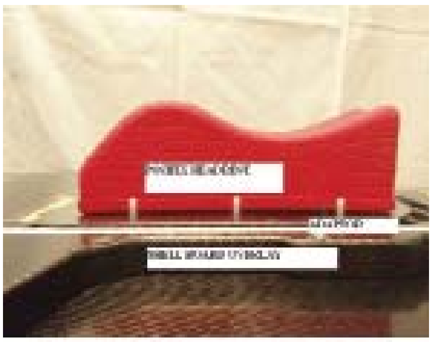


Figure 1: Posifix® headrest side view.

Figure 2: Silverman® headrest side view.

Introduction

Accurate and reproducible positioning throughout a treatment course is critical in head and neck (H&N) cancer patients receiving fractionated radiotherapy (RT).[1,2] Radiation therapists are exposed to a variety of stabilisation devices, standard and custom, that purport to provide accurate and reproducible stabilisation. Standard and custom headrests provide accurate and reproducible stabilisation, although quantifying their actual benefits, however insignificant, is not always at the forefront of a busy RT department. As treatment approaches for H&N cancer become increasingly conformal, precise localisation and immobilisation is imperative and any improvement, although slight, may be justified.

Position and fixation of the patient is important to reduce variation and thus ensures that the treatment is accurate and consistent.[3] Adjusting the patient's original planning set-up position during treatment introduces a further variable, potentially affecting accuracy and treatment reproducibility. Adjusting plastic spacers (shims) during treatment to account for patient swelling or weight loss can affect patient positioning and consequently potentially alter the dose distribution. Spatial error, whether random or systematic, will alter the dose-volume relationship for organs at risk.[4]

This retrospective quality improvement evaluation compares the use of Posifix® (Civco Medical Solutions, Iowa, USA) headrest supports (Figure 1) with Silverman® (Civco Medical Solutions, Iowa, USA) headrest supports (Figure 2). The department originally acquired and used Posifix® headrests, however with the expansion and acquisition of new equipment, Silverman® headrests were purchased. No formalised documentation to reflect which headrest or why it was used was recorded. From

Table 1: Number of displacements ≥ 3 mm between planning DRRs and treatment EPIs.

Direction	Silverman® headrest	Posifix® headrest
Superior/Inferior	20	5
Left/Right	4	5
Anterior/Posterior	9	1
Total	33	11

Table 2: Number of permanent shifts throughout treatment.

Headrest	Number of shifts
Silverman® headrest	4
Posifix® headrest	2

clinical observation and patient comments regarding comfort, it has been hypothesised that foam Posifix® headrests offer more stability, accuracy and reproducibility as compared with the rigid plastic cast moulds of Silverman® headrests. Therefore this quality improvement evaluation was conducted.

Materials and methods

From June to July 2010, 12 H&N RT patients were selected, six consecutive patients each using Posifix® and Silverman® headrest supports. Patients were representative of the normal case mix within the department and ranged in age from 24 to 72 years. Patients were assigned to a specific headrest that provided the best fit to the individual patient's head and neck contour. Patients were excluded from this assessment if their treatment was ≤ 20 fractions, was not a conformal multifield approach, their thermoplastic mask was adjusted after the planning scan or if the patient had a mouth bite. Since a small sample group was evaluated, this exclusion criteria was set to minimise potential skewing of the results when measuring the isocentre displacement.

The accuracy of positioning was determined by comparing the planning digitally reconstructed radiographs (DRR) to treatment electronic portal images (EPI) using iViewGT™ (version 3.4, Elekta Ltd, Stockholm, Sweden) anatomy matching tools. Anterior/posterior and lateral treatment images were assessed. It is noted that the measured results will contain systematic and random error components. Set-up error can only be accurately assessed when results are attained using daily image guided radiation therapy (IGRT). Currently within the department daily IGRT is not performed on conformal H&N patients. Using this method enabled the set-up error to be assessed.

In addition, changes to patient positioning as a result of adjusting shims throughout treatment was collated, to determine the consistency between planning and treatment for each headrest type. Low risk ethical approval was granted on 16th July 2010 from the Human Research Ethics Committee at the Princess Alexandra Hospital.

Simulation and planning

All patients were immobilised in thermoplastic masks on the CT couch, encompassing the head, neck and shoulders. A suitable contoured headrest was selected (Posifix® or Silverman®) from the manufacturer's standard products, to achieve appropriate head tilt support and placed on the shell board overlay (Civco Medical Solutions, Iowa, USA). To alleviate patient discomfort throughout treatment if the shell became too tight as a result of shell shrinkage, weight gain or fluid retention, 5 mm of plastic shims were fitted under the manufacturer's headrest. An adaptor was required to attach the Posifix® headrest to the shell board and can not be removed. A knee bolster for patient comfort and feet immobilisation stocks were used with hand grips to reproduce shoulder position from planning to treatment. All patient stabilisation documentation was recorded electronically at the planning session.

Once planned, evaluated and approved, all plans included treatment fields or isocentre verification fields within 10° of the horizontal or vertical axis. This was to ensure that the isocentre localisation could be verified in three planes.

Treatment

Each patient had anterior/posterior (AP/PA) and lateral verification DRRs matched to treatment EPIs. The departmental EPI action point for H&N patients is 3 mm. Action thresholds are in place to ensure the planned dose given to target volumes and organs at risk are maintained through treatment and may be dependant on the sensitivity of the treatment technique.[5] Departmental EPI action threshold is determined in consultation with the radiation oncologist and is reviewed in accordance with hospital policies and procedures. Departmental protocol determines that treatment EPIs are taken on the first three fractions of a patient's treatment. If the displacement is < 3 mm, EPIs are then taken weekly. This protocol is in place for conformal H&N patients only and excludes IMRT patients. When a displacement is ≥ 3 mm, EPIs are required for the next two days to assess set-up errors. In total, 204 treatment EPIs were assessed retrospectively, comprising of 102 orthogonal image sets. The number of orthogonal image sets per patient ranged from six to 11 using this protocol. This resulted in only 50% of the measured set-up error being assessed.

To maintain consistency in data collection, one staff radiation therapist reviewed all treatment images. The review of EPI images was not blinded. Treatment EPIs were matched to planning DRRs using iViewGT™ template matching tools. Treatment images were matched to planning DRRs using the skull, mandible, cervical vertebrae 1–3 and 4–6.[6] Treatment EPI shifts for AP/PA films in the superior/inferior and left/right direction were recorded in millimetres in a basic Microsoft Excel document (Microsoft, Washington USA). Treatment image shifts for lateral films were also recorded in the superior/inferior and anterior/posterior direction on the same treatment day. The total number of shifts in each direction of ≥ 3 mm was recorded.

Consecutive AP/PA and lateral treatment EPIs taken on the first three days were assessed retrospectively for shifts and the results averaged. The methodology of using the first three-day EPIs was to assess systematic shifts. Systematic errors, unlike random errors, occur in the same direction and of similar magnitude for consecutive treatments. A systematic error can be defined as an error that is introduced at planning stage and, if unaddressed, would occur for each treatment fraction.[7] To assess the systematic and random component of errors after the first three days, it would require daily IGRT.

Areas of interest used in assessing the two support systems included; head tilt, patient straightness, permanent moves and shim adjustments. Head tilt and patient straightness was assessed and recorded when treatment EPI discrepancies from planning DRRs exceeded 3 mm. Permanent moves were taken directly from the treatment sheet where staff documented and adjusted for systematic moves throughout the patients' treatment. Shim adjustments throughout treatment were recorded by treatment staff.

Results

Analysis of the recorded shifts in AP/PA and lateral treatment EPIs demonstrated patients using Silverman® headrests required 22 more shifts of ≥ 3 mm compared with using Posifix® headrest supports (Table 1). Permanent shifts throughout the course of treatment for Silverman® headrests were made on four occasions compared with two permanent shifts using Posifix® headrests (Table 2).

In the first three days, the average number of shifts ≥ 3 mm required in

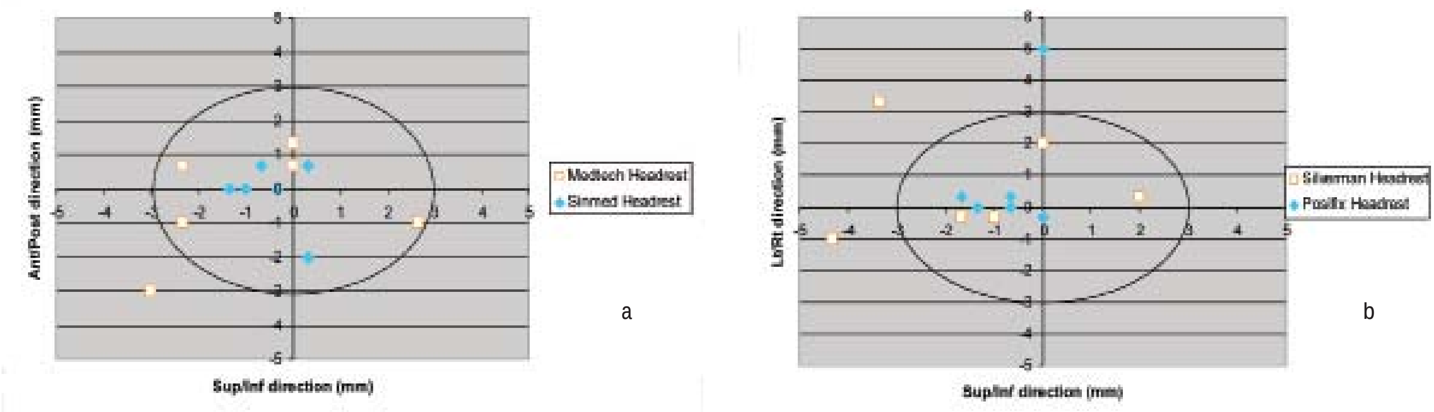
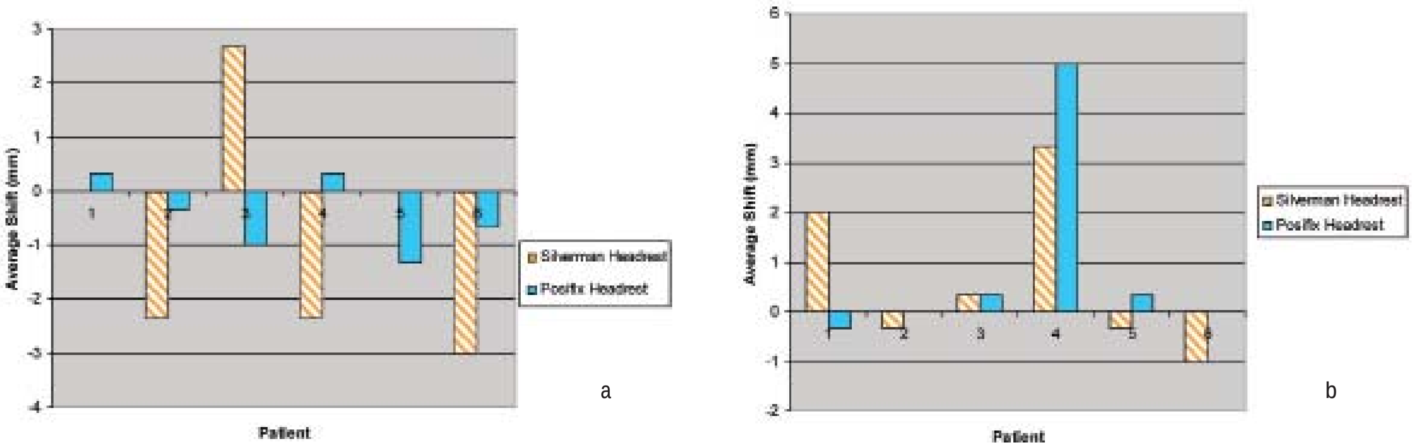


Figure 3: Scatter plot graph demonstrating average three-day EPI isocentre displacement shifts. Oval indicates 3 mm action threshold for isocentre displacement shifts, a) demonstrates average three-day anterior/posterior EPI isocentre displacement indicating 1 Silverman® headrest patient > 3 mm action threshold, b) demonstrates average three-day lateral EPI isocentre displacement indicating two Silverman® headrest patients and one Posifix headrest patient > 3 mm action threshold.



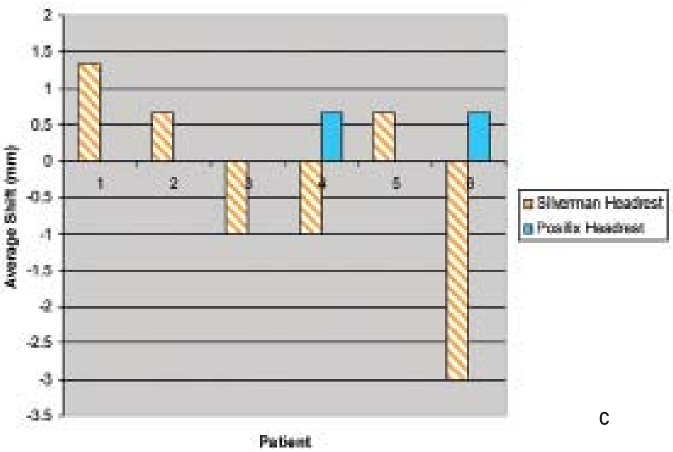


Figure 4: Column graph demonstrating individual patient average three-day EPI isocentre displacement shifts in the (a) superior/inferior direction (b) right/left direction (c) anterior/posterior direction.

each direction for AP/PA and lateral treatment EPIs was measured for both headrests (Figures 3a and 3b). These measurements were then separated into individual patient data to determine if isocentre displacement shifts were consistent across all patients or if results were skewed by one patient. The measured isocentre displacement showed Silverman® headrests had an average of three shifts in two patients of ≥ 3 mm in comparison to one shift with Posifix® headrests when assessing moves in three planes (Figures 4a, 4b, 4c). Figure 4a data is taken from the lateral treatment EPI. Treatment staff principally uses this image when deciding on the magnitude of the shift in the superior/inferior direction.

Table 3 demonstrates the number of instances where head tilt and patient straightness were assessed as ≥ 3 mm difference to the planning DRR. On eight occasions Silverman® patients recorded head tilt variations, compared with three occurrences in Posifix® patients. Similarly four more patient straightness issues were identified on Silverman® patients compared with Posifix® patients.

Total shim adjustments made during treatment documented 10 shim adjustments were made to the set-up sheet on Silverman® patients (Table 4). This compared with no changes being made to Posifix® patients throughout the course of treatment.

Table 3: Number of patient straightness and chin tilt discrepancies ≥ 3 mm between planning DRRs and treatment EPIs.

Position variation	Silverman® headrest	Posifix® headrest
Patient straightness	7	3
Chin tilt	8	3

Table 4: Number of shim adjustments throughout treatment.

Headrest	Number of shims adjusted
Silverman® headrest	10
Posifix® headrest	0

Discussion

This quality improvement paper assessed the frequency and magnitude of shifts between patients positioned on Silverman® headrests and those positioned on Posifix® headrests. Patients assessed were conformal H&N patients who did not have daily IGRT. To truly assess the systematic and random error components of a shift it is necessary for daily IGRT. This evaluation can only measure the isocentre displacement of the field and is unable to determine the systematic and random components of these displacements.

It has been reported in the literature that inadequate stabilisation of the H&N region will affect isocentre positioning for patients undergoing RT.[1,8,9] Departmental protocol (excluding IMRT patients) requires that orthogonal treatment EPIs are taken on the first three days of a patient's treatment, to assess field isocentre displacement. The average shift for the first three days and overall permanent shifts for the two systems were similar. Analysing systematic shifts showed slight trends toward decreased set-up accuracy when using Silverman® headrests. This was demonstrated when assessing the number of permanent shifts of ≥ 3 mm.

This assessment demonstrated that Posifix® patients had fewer measured isocentre displacement shifts of ≥ 3 mm compared to Silverman® patients. Although the number of shifts ≥ 3 mm recorded for Silverman® headrests amounted to 33, this represented AP/PA and lateral films. The effect of the large number of shifts of ≥ 3 mm compared with Posifix® patients can be profound, impacting on several immediate stakeholders.

First, the outcome for the patient is longer treatment times, experienced when correcting for shifts online and increased radiation dose. Any recorded shifts of ≥ 3 mm are required to have repeat treatment EPIs on the subsequent two fractions, determined by departmental protocol. This increases patient dose, which is not taken into account in the treatment plan. Dose to critical structures such as the spinal cord may also be increased as a result of random errors. Departmental protocol requires planning fields arranged to miss the spinal cord have a 5 mm clearance. This allows for a 3 mm tolerance on field placement and 2 mm for machine specific parameters such as shielding. Therefore, on days that random errors occur and no weekly or repeat EPIs are taken, the dose to critical structures and potentially the tumour volume may not meet the approved plan. It has been reported in literature that average random errors of 4 mm may result in up to 5% discrepancy in the plan dosimetry.[9] Managing the random component of set-up error by improving stabilisation is important, however to accurately assess random errors requires daily IGRT.

Second the radiation therapist is potentially exposed to delays on the treatment machine, as EPIs are not accounted for in patient appointment times. Departmental protocol requires repeat treatment EPIs to be assessed by the charge radiation therapist to determine possible effects (systematic or random errors), increasing their workload. If random errors of > 3 mm continue, patient stabilisation and positioning may be reassessed by the planning radiation therapist. The outcome of these scenarios is increased staff workload and hence affecting workflow to maintain the department's priority to patient outcomes. The flow on effect is extended to the radiation oncologist, whose workload is increased by viewing more treatment EPIs. Departmental protocol requires online EPI correction by treatment staff radiation therapists who are responsible for accurate field placement. Any treatment EPIs shifted by ≥ 3 mm must be sent to, reviewed and approved by the consultant radiation oncologist.

Close investigation of the first three-day orthogonal films demonstrates only three instead of five systematic shifts were required using the Silverman® headrests. The reason for this discrepancy was due to one patient using the Silverman® system recording an average systematic shift of ≥ 3 mm in the superior/inferior direction on the AP/PA treatment EPI but not the lateral treatment EPI. The discrepancy in results from Figures 3a and 3b and Figures 4a, 4b, 4c showed that other factors were affecting the anatomical matching of planning DRRs to treatment EPIs. Although the clinical significance of one patient is questioned, further discussion is generated as to why this discrepancy occurred and whether it is shown in other orthogonal films to lesser degree.

A potential reason for discrepancies in the superior/inferior direction between AP/PA and lateral treatment EPIs was assessed in this quality improvement evaluation. Head tilt measured on all lateral images demonstrated that on eight occasions, head tilt was ≥ 3 mm from the planing DRRs using Silverman® headrest systems. Posifix® systems recorded three instances of ≥ 3 mm indicating this may potentially be one source of increased isocentre displacement errors. Head tilt may be a result of incorrect superior/inferior positioning of the patient on the headrest or inappropriate shell contact, not measured in this assessment. Superior/inferior positioning of a patient on the headrest is recorded as a measurement on the headboard taken at the inferior tragal notch. This measurement is recorded in the treatment set-up sheet at planning and staff members refer to this when fitting the shell. Eliminating this as a cause would indicate that inappropriate shell contact/fitting is a contributing factor.

In addition to head tilt assessments, patient straightness was assessed from the treatment EPIs. This demonstrated seven occurrences where patients on Silverman® headrests were measured as ≥ 3 mm from the planning DRR, compared with three patients on Posifix® headrests. Although not quantified, a source of differential patient straightness may be attributed to incorrect lateral placement in the thermoplastic mask due to loose shell fit. A problem with both systems is the lack of lateral stability in the headrests that may potentially minimise patient straightening issues. Van Lin[8] and his colleagues undertook a study demonstrating that a customised headrest conforming around the head provides extra comfort and support, reducing systematic and random errors.

Shim adjustment as a result of shell contact being too tight/loose is a decision taken by treatment staff when fitting the shell. At planning, 5 mm of shims are used to potentially account for shell shrinkage after moulding, as well as patient fluid retention/weight gain on treatment. Additional shims are not added if weight loss is significant. The decision to adjust shims is open to interpretation/opinion and was not measured in this assessment. Films were not routinely taken on every occasion that shims were adjusted. Isocentre verification using IGRT should be made when any adjustment of patient stabilisation or positioning from the planning set-up is performed.

Therefore the effects of removing/adding shims could not be assessed. In total 10 shim adjustments were made on Silverman® patients compared with no shim adjustments for Posifix® patients. Subjectively this may be a result of the comfort of a soft foam headrest, although this qualitative assessment was not measured in this retrospective evaluation. The direct link between the increased number of shim adjustments and isocentre displacement errors shown in Silverman® compared with Posifix® patients cannot be confirmed however it is an area of investigation. This quality improvement paper did not investigate the impact of shim adjustment on chin tilt and isocentre displacement as treatment EPIs were not taken on every day a shim was adjusted.

It is important to note the limitations and bias in this evaluation. It is acknowledged that a small patient sample was used in this evaluation. Although it was felt the patients were representative of the normal case mix, far reaching conclusions can not be made. This assessment was a non-blinded retrospective evaluation and bias could have been introduced from the assessor who had knowledge of which head rest was used for each patient. In addition only one radiation therapist assessed the treatment verification images. Furthermore, systematic and random components of the set-up error could not be truly assessed in this evaluation without daily IGRT. Daily IGRT was not performed in this evaluation.

Conclusion

This evaluation showed H&N immobilisation using Posifix® headrest indicates reduced isocentre displacement errors as compared with Silverman® headrest supports. With further investigation, the clinical benefit in reducing isocentre displacement errors to the patient and staff indicates that continued use of the Posifix® headrest supports is justified and beneficial to these stakeholders. Furthermore, trends indicated Silverman® headrest support patients required more interventions to limit incorrect shell fit as compared with Posifix® headrest support patients.

This evaluation contained a small patient sample size and without daily IGRT to quantify the component of systematic and random errors the evaluation cannot be conclusive. However using daily IGRT as a basis, a larger sample size would be worthy of investigation. Another area of interest warranting further investigation is the effect of shim removal on chin tilt and patient straightness, and furthermore the effect that shim removal has on random errors.

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