

## Original Article

# Set-up accuracy of an external immobilisation system for patients receiving radical radiotherapy for prostate cancer

Ashley d'Aquino<sup>1,\*</sup>, Shalini Harrison<sup>1,\*</sup>, Sarah Helyer<sup>1</sup>, David Dearnaley<sup>1</sup>, Helen McNair<sup>1</sup>

<sup>1</sup>*Department of Radiotherapy, Royal Marsden NHS Foundation Trust and Institute of Cancer Research, Sutton, UK*

*\*Both authors contributed equally as first authors.*

## Abstract

**Purpose:** To evaluate the accuracy of an external immobilisation system in patients receiving radiotherapy for prostate cancer.

**Methods:** Portal Imaging data were audited in 20 patients treated using an in-house immobilisation system and 20 patients treated using an indexed commercial immobilisation system (Combifix™). Individual and group random and systematic errors were calculated to determine the accuracy of set-up using skin marks alone and with a no-action-level protocol.

**Results:** The initial results showed a larger systematic error in the Combifix™ in the anterior-posterior direction (2.7 mm) compared with the in-house system (1.5 mm). The possible source of this was identified as the difficulty in accurately aligning the laser to a curved couch top prior to setting the isocentre height. A change in the process of setting the isocentre was introduced, and comparable baseline set-up accuracy was achieved. This was with a systematic error of  $\leq 2.0$  mm and a random error  $\leq 1.5$  mm of patient position set-up error with skin marks alone, and using the Combifix™. The systematic errors were further reduced to  $< 1$  mm with an off-line no-action-level protocol.

**Conclusion:** Using the Combifix™ system a high level of set-up accuracy was reproduced in routine daily practice.

## Keywords

prostate cancer; radiotherapy; immobilisation

## INTRODUCTION

As radiotherapy treatments have become more complex the need for improved treatment accuracy has increased. The introduction of three dimensional imaging modalities such as

computed tomography (CT), more sophisticated computer planning systems and outlining software have allowed techniques such as three-dimensional conformal radiotherapy (3DCRT) and intensity modulated radiotherapy (IMRT) to be possible<sup>1</sup>. These techniques aim to deliver a homogeneous dose of radiation which is tailored around a tumour volume whilst reducing the 'safety' margins required, thus sparing surrounding healthy tissues.

Correspondence to: Helen A McNair, Radiotherapy Department, Royal Marsden NHS Foundation Trust, Sutton SM2 5PT, UK.  
E-mail: Helen.McNair@rmh.nhs.uk

The use of rigid immobilisation devices has the potential to reduce setup variability. To be effective, the devices must maintain the patient's body in the same reproducible position for all radiotherapy planning and treatment delivery sessions.

It is important to quantify the effectiveness of immobilization, and this can be done by determining the set-up errors, that is, the displacements in patient position from planning and daily treatment. Set-up errors can be divided into either random or systematic errors. Systematic errors are reproducible consistent errors, occurring in the same direction and of similar magnitude over the course of treatment. A random error, however, varies in direction and magnitude for each delivered treatment fraction. Random errors can also arise from changes in target position and shape between fractions and during treatment delivery.

Systematic errors ( $\Sigma$ ) are the mean deviations between the planned patient position and the treated patient position, and random errors ( $\sigma$ ) are the variability around the mean.

There are several studies which compare the benefits of the use of immobilisation devices versus no immobilization for patients receiving radiotherapy for prostate cancer. The use of immobilisation was found to be more effective than no immobilisation in a study comparing 3 simple types of immobilisation<sup>2</sup>. The percentage of patients with a deviation  $>5$  mm was reduced from 17% with no immobilisation to 8% with immobilisation. In another study, two

more complex immobilisation systems were compared for immobilisation of the lower legs only and this appeared to improve the accuracy and reproducibility compared with immobilisation underneath the pelvis only<sup>3</sup>. The percentage of patients with a displacement  $\geq 5$  mm was reduced from 7.0%, 9.6% and 21.6% to 1.7%, 7.1% and 4.4% in the right–left (RL), superior–inferior (SI) and anterior–posterior (AP) directions, respectively<sup>4</sup>. However, in a further study, a leg holder and knee support was compared with a knee support only in 2 groups of 10 patients and no difference was found between the groups.

Studies undertaken at Royal Marsden Hospital (RMH) include the use of a vac-fix immobilisation device<sup>5</sup> and an ultrasound device (NOMOS B-mode acquisition and targeting system [BAT])<sup>6</sup>. Neither of these innovations was found to improve treatment accuracy; however, portal imaging prior to the vac-fix study had shown a favourable result. These findings have led to a culture of assessment of new techniques which is mirrored by national recommendations in the United Kingdom<sup>7</sup>.

In this study, we have audited the set-up accuracy of patients receiving radiotherapy for prostate cancer using a commercially available immobilisation system Combifix™ (CIVCO Medical Solutions, Oncology Systems Ltd., Shrewsbury, United Kingdom) as compared with the standard in-house immobilisation system (Figure 1a). The in-house system had been introduced into our department in the 1990s as part of the Medical Research Council

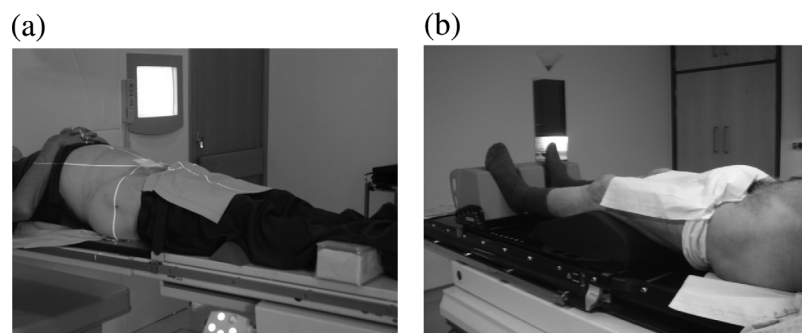


Figure 1. (a) In-house device (b) Combifix™.

(MRC) RT01 study. The system had been evaluated and a tolerance of 3 mm was used for electronic portal imaging (EPI) protocols. However, the in-house system did not interlock onto the couch and with the introduction of new couch tops led to the implementation of the commercial system Combifix™ in 2007 (Figure 1b). The Combifix™ system had the potential advantage of additional foot rests, a larger knee cushion and most importantly being indexed to the couch. However, it was essential that the new system had to provide equivalent if not better set-up accuracy.

## METHODOLOGY

The number of patients required to determine an estimation of the population systematic and random errors has been recommended to be 20<sup>7</sup>. Therefore, the set-up data on 40 patients who had received radical radiotherapy to the prostate was analysed, that is, 2 groups of 20 using each type of immobilisation device. The audit was approved by the Royal Marsden Foundation Trust (RMHFT) audit committee.

### Immobilization devices

Twenty patients were treated supine with a head support cushion and the in-house standard immobilisation device designed by the department's workshop team. This device consisted of two knee support cushions and a Styrofoam ankle support (Figure 1a). This device was not indexed to the couch top and so the superior–inferior position of the immobilisation system, and thus the patient position, on the couch could vary daily. This had the potential of varying the couch sag daily, depending on the position of the patient. Therefore, the departmental procedure was to determine the couch sag daily by aligning the laser to the anterior edge of the bed, note the read out and set the isocentric couch height from that position.

The remaining 20 patients had the same head support cushion but instead of the in-house device had the Combifix™ (Figure 1b). This device consists of an adjustable knee cushion and feet support on a base plate indexed to the couch top. The procedure used to set the isocentric couch height remained unchanged.

### Radiotherapy planning & treatment

The planning and treatment process was similar in both groups. Patients had been scanned in the treatment position with a comfortable full bladder<sup>8</sup> and were positioned on the couch with the sagittal laser aligned along the centre of the Combifix™ and the anterior tattoo. Lateral tattoos were placed mid-plane 12 cm above the couch top and radio-opaque markers placed on the skin for CT scanning. A planning scan was acquired from the top of sacro-iliac joints to 1 cm below the ischial tuberosities using 2.5-mm intervals. The clinical target volume, bladder and rectum were outlined, and a 3 field conformal plan was created (Pinnacle, Philips)<sup>9</sup>.

Anterior and lateral digitally reconstructed radiographs (DRRs) were exported to the iView Imaging System and bony landmarks outlined to provide a template for matching. The displacements were determined using iView software which used manual field-edge detection and template matching. A no-action-level off-line correction protocol was used<sup>10</sup>, that is, EPIs were acquired for the first 3 days of each treatment and the systematic error (mean field displacement) was calculated. If the systematic error was >2 mm in any plane, then the isocentre was adjusted to correct for the error on Day 4. Images were repeated weekly; if >2 mm, the image was repeated the following day, and, if consistent, a new correction was made.

### Analysis

To assess the immobilisation devices, it was necessary to determine the set-up displacements if skin marks only were used. The corrections determined from bony anatomy were therefore subtracted from the data to achieve the set-up as if to skin marks alone. The effectiveness of the imaging protocol could then be established by comparison of the pre-corrected data. The systematic and random errors were calculated for each patient and for the in-house and Combifix™ population groups. The systematic error was calculated as the standard deviation (SD) of the distribution of the average set-up displacements per patient and the random error

is calculated as the SD of the patients' set-up displacements averaged over all the patients in the group<sup>7</sup>.

## RESULTS

The median and range of set-up errors when the patients were aligned to skin marks only is shown in Table 1. The distributions were tested for normality and were normal in the AP direction only. Since the samples were independent, a Mann-Whitney U test was used to test for significant difference in the RL and SI, and an independent samples *t* test was used in the AP direction. The set-up errors were significantly better in the RL direction with the Combifix™ system but poorer in the AP direction. There was no difference in the SI direction.

These differences were reflected when the systematic and random errors were calculated. In both groups of 20 patients, the systematic and random errors were <2 mm in the RL and SI direction. However, in the AP direction, the systematic error was greater in the patients treated with Combifix™ (Table 2). The use of an off-line correction protocol reduced the systematic error to 1 mm in all directions in both groups of patients (Table 3).

## DISCUSSION

Patients set-up accuracy using the Combifix™ and an off-line protocol was <2 mm in all directions which was within published guidelines<sup>7</sup>.

The Combifix™ system had been implemented at RMHFT not only primarily because it

offered indexing but also because of the potential improvement in set-up accuracy due to the more rigid knee and ankle supports. The accuracy of patient repositioning using the Combifix™ was compared with the set-up accuracy using the in-house system which used ankle supports. The importance of evaluating the entire set-up procedure from positioning the patient to setting the isocentre was highlighted. The initial results showed a larger systematic error in the Combifix™ compared with the in-house system when the set-up accuracy was analysed in 20 patients (Tables 1 and 2).

On investigation, it was postulated that this may be due to the method of setting the isocentre which had not changed when the Combifix™ system was introduced. However, the couch top had changed in this period of time to a master couch (Oncology Systems Ltd, Shrewsbury, UK). These tops had a slightly curved anterior edge in the axial plane which made laser alignment to the top of the couch less precise than to a couch top with rectangular edges. The couch height was therefore not always set daily from a consistent baseline, which should have been the case because Combifix™ was interlocked onto the couch and therefore the patient's weight should be distributed in the same way each day. A new process was introduced so that on the 1st day, when the couch sag was checked and height set, this measurement was recorded and used thereafter.

Permission was granted to repeat the audit with a further 20 patients using Combifix™ and the new method of setting the isocentre height. The systematic error in the AP direction was reduced to 1.5 mm using skin marks alone

**Table 1.** Mean and range of set up errors of 20 patients treated using the in-house and Combifix™ aligned to skin marks only

	Mean (range) RL (mm)	Median (range) SI (mm)	Median (range) AP (mm)
In house	-0.7 (-11.3 to 6.3)	0.2 (-5.8 to 7)	-1.0 (-8.5 to 6.0)
Combifix™	0.7 (-6.3 to 5.8)	0.3 (-3.0 to 5.3)	-1.6 (-9 to 8.7)
<i>p</i> value	0.08	0.85	<0.01

Note: RL = right left direction; SI = superior inferior direction; AP = anterior posterior direction and where -ve is left, superior and anterior.

**Table 2.** Random ( $\sigma$ ) and systematic ( $\Sigma$ ) errors of 20 patients treated using the in-house (IH) and Combifix™ (CF) aligned to skin marks only

	RL (mm)	SI (mm)	AP (mm)
$\Sigma_{IH}$	1.8	1.3	1.5
$\sigma_{IH}$	1.8	1.5	2.0
$\Sigma_{CF}$	1.1	1.2	2.7
$\sigma_{CF}$	1.5	1.2	1.5

Note: RL = right left direction; SI = superior inferior direction; AP = anterior posterior direction and where –ve is left, superior and anterior.

**Table 3.** Random ( $\sigma$ ) and systematic ( $\Sigma$ ) errors of 20 patients treated using the in-house (IH) and Combifix™ (CF) after off-line correction protocol

	RL (mm)	SI (mm)	AP (mm)
$\Sigma_{IH}$	1.1	0.9	0.6
$\sigma_{IH}$	1.8	1.5	2.1
$\Sigma_{CF}$	0.9	0.8	0.9
$\sigma_{CF}$	1.6	1.4	2.1

Note: RL = right left direction; SI = superior inferior direction; AP = anterior posterior direction and where –ve is left, superior and anterior.

**Table 4.** Random ( $\sigma$ ) and systematic ( $\Sigma$ ) errors of 20 patients treated using the Combifix™ (CF) and the change in setting isocentre with setting up to skin marks alone and after off-line correction protocol

	RL (mm)	SI (mm)	AP (mm)
$\Sigma_{CF}$ (skin marks)	1.3	1.1	1.5
$\sigma_{CF}$ (skin marks)	1.8	1.4	1.4
$\Sigma_{CF}$ (off line correction)	0.9	0.7	0.8
$\sigma_{CF}$ (off-line correction)	1.8	1.4	1.5

Note: RL = right left direction; SI = superior inferior direction; AP = anterior posterior direction and where –ve is left, superior and anterior.

compared with 2.7 mm using the old method ( $p = 0.05$ ). After couch correction, the  $\Sigma_{CF}$  was 0.8 mm in the AP directions (Table 4).

However, the accuracy of determining the set-up displacements will be limited by the accuracy of the measurement systems used to measure. For example, slice thickness of the CT scans is 2.5 mm, and therefore an accuracy of <2.5 mm in the superior–inferior direction is not realisable. Another limitation of the study is that the groups of patients may not have been representative because this was a cohort study. All staff registering the images would have

undergone the same training programme, and hence any interobserver error in the process should be equivalent in the two groups.

This study has shown that it is essential not only to investigate the immobilisation devices but also to review the complete process of patient set-up, from positioning the patient on the bed to setting the isocentre. This procedure can vary between measuring the isocentre height from the couch top, setting the height to the tattoos and accounting for couch sag due to the patients' weight. The method of setting the AP isocentre has been investigated in previous studies, and it was shown that measuring the isocentre from the couch top was most accurate<sup>11,12</sup>. In addition, the importance of achieving a reproducible baseline set-up prior to any imaging was illustrated when an imaging protocol further improved the systematic error by only 0.8 mm<sup>12</sup>.

The studies above emphasise the importance of verifying the complete process of planning and treatment. The issues that arise are often from basic practice and procedure and are fundamental to the process of improving accuracy but can sometimes be overlooked in the high-technology environment of radiotherapy. This has been illustrated recently when a tomotherapy unit was installed and the overall mean (M) set-up error in prostate cancer patients was 4.7 mm ( $p < 0.001$ )<sup>13</sup>. This was attributed to the difference in procedure when acquiring the CT, when couch sag was taken into account, and delivering the treatment, when the couch sag was not accounted for.

In RMH radiotherapy departments, there have been several studies which have previously evaluated the set-up accuracy in patients receiving radiotherapy to the prostate and the results show how immobilisation has improved patients set-up<sup>14,15,5</sup>. To compare the results of the audit with the previous studies at RMH, the percentage of treatments <5 mm was extrapolated from the papers mentioned above (Table 5). There were 2.9%, 0% and 2.4% of treatments with a displacement >5 mm in the RL, SI and AP directions, respectively. However, these did not occur in the same fraction



**Table 5.** Summary of studies evaluating immobilisation at Royal Marsden NHS Foundation Trust

Author	Immobilisation used	No of patients	% of treatments with >5 mm
Gildersleve (1994)	Not stated	12	69
Huddart (1996)	Foam pads under knees	90	59
Nutting (2000)	Pelvic vac bag	30	3
Audit RMH (2008)	Knee cushion and ankle support (Combifix™)	20	3.8

which resulted in 3.8% of treatments overall with a displacement of >5 mm in any direction. This is very similar to the results in 2000, and at the time it was postulated that the small errors found in Nutting's study was because of the introduction of a radiographer-led portal imaging protocol with accuracy further enhanced by conducting a prospective study<sup>5</sup>. The implication was that because radiographers were evaluating the images and making decisions, this led to greater awareness of the accuracy in set-up and motivation to ensure that patient was set up as accurately as possible prior to imaging. It was also since the routine introduction of EPI in the department which provided the radiographers with greater insight into patient set-up problems<sup>16</sup>. We have shown that the high level of accuracy attained in a prospective randomised trial is now reproduced in routine clinical practice. It might be speculated that the recent implementation of soft tissue imaging would reduce the importance of external immobilisation. However, although it might seem pragmatic to reduce the attention to patient position prior to imaging, patient movement can cause prostate movement which appears to be independent of pelvic bony anatomy. For example, a study which examined repeat CT scan showed that leg motion, which included roll and changing the width of the leg opening, had significant influence on AP and SI prostate motion<sup>17</sup>. Further work could assess if the Combifix™ fixation at the feet and ankle helps maintain prostate position.

## CONCLUSION

An audit of an external immobilisation system for prostate cancer patients demonstrated that an acceptable baseline of set-up accuracy was

achieved. The systematic errors found were <2.5 mm and within U.K. guidelines. The importance of evaluating the entire process of patient set-up when introducing any change was also highlighted.

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