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A pelvic positioning study comparing the set-up reproducibility of prone pelvic treatments for obese patients, with and without the use of a thermoplastic immobilisation shell

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Abstract

Background and purpose. The objective of this study was to assess set-up reproducibility of pelvic treatments for obese patients in the prone position, with and without the use of an immobilisation shell.

Method and materials. The patients were treated using a posterior open field and opposed lateral wedged fields for 20 fractions over four weeks. Ten fractions were set-up using a pelvic shell and ten fractions without. The patients were randomised into two groups, whose initial set-up was either with or without a shell. Portal images were obtained on 14 treatment fractions (7 for each set-up) and compared against initial simulator images to assess movement. For each fraction when portal imaging was scheduled the treatment radiographers also assessed the ease at which the patient could be positioned. The aim was to determine the correlation between good visual positioning to surface marks and accurate location of bony landmarks in portal imaging.

Results. Early results from this study highlighted large random positioning errors in the superior/inferior plane when patients were positioned in the pelvic shell. The study was therefore abandoned at patient number four.

Conclusion. The use of the pelvic shell was found to increase positioning errors in the longitudinal (superior-inferior) direction. Reasons for this observation are discussed and modifications to the shell design suggested. The study also highlighted that ease of patient positioning using surface marks is not a good guide to positional accuracy and emphasises the importance of regular on-set verification.

Keywords

Pelvic radiotherapy; prone positioning; immobilisation shells; patient positioning

INTRODUCTION

A common problem with all radiotherapy planning is that of accounting for patient movement during treatment. Small changes in tissue dose can create wide variations in the effectiveness of treatment and complications may ensue,[1] because of the steepness and separation of the dose effect curves for tumour control and normal tissue damage. Conformal therapy may reduce the dose delivered to adjacent normal structures whilst escalating the dose to the treatment region,[2] but the uncertainty created by variable patient positioning is a major limiting factor.[3]

Dose errors during a course of treatment can result from both systematic and random errors. Systematic positioning errors can be undetected inconsistencies with equipment, such as laser misalignment; random errors can occur with patient positioning and movement.[4,5] Movement inaccuracies may be greatly reduced by careful positioning, ensuring that patients are as comfortable as practicable and utilising immobilisation devices or support systems.[6] Clinical evidence is accumulating which indicates that procedures must be in place to quantify and reduce patient set-up errors.[7–9]

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The accuracy and consistency of patient positioning may be assessed by frequent portal imaging which is an important part of routine normal clinical practice. Patients receiving treatment to the pelvic areas such as the rectum and gynaecological sites may be the most difficult category to immobilise and the results of previous studies which have utilised immobilisation devices are unfortunately inconclusive.[2,10–17] The obese patient positioned prone for treatment provides yet more challenges for reproducible set-up as they tend to 'roll' and the abdominal apron is moveable, a phenomenon also described by Thilmann et al.[17] At this centre, a prone position is preferred for obese patients as there is less irradiation of the small intestine and the bladder.[18–20] This study was proposed to see if accuracy could be improved by the use of a pelvic shell.

Various other studies have assessed pelvic immobilisation devices. Bentel et al.[10] evaluated the effect of a hemibody cradle for the treatment of patients with prostate cancer. Forty-four patients were positioned in the cradle and thirty without. Results indicated field placement errors in the anterior-posterior plane greater than 5 mm to be 17% in the non-immobilised group and 8% in the cradle group. The study concluded no significant improvement in cranio-caudal and left-right planes.

Catton et al.[11] compared the positioning of 31 patients treated with a soft immobilisation device supporting the lower legs to 30 patients without the same. This was an inexpensive in-house device and results indicated an improvement of errors larger than 5mm from 17% in the non-immobilised group to 8% in those immobilised.

Fiorino et al.[12] compared the set-up accuracy of 21 patients without immobilisation to 25 patients with pelvic immobilisation (Group A) and 27 patients with lower leg support (Group B). Greatest errors over 5mm in the anterior-posterior plane occurred in group A, whilst movements in other directions were highest in the non-immobilised group.

Mitine et al.[13] determined set-up errors in 10 patients with no device, 10 patients in an Alpha-cradle and 10 patients in an Orfit thermoplastic shell. Both immobilisation devices appeared to improve reproducibility of set-up but the magnitude of this improvement was small.

Other studies[2,15,16] are similar, concentrating on the set-up ability of pelvic patients. However, there are a variety of positioning devices available, both commercially and 'in-house' products, making comparative analysis difficult. Also many of the previous studies have focused on the supine position which is inherently more stable when 'setting -up' a patient.

METHOD AND MATERIALS

The entry criteria for this study were that patients must be considered as obese (according to Body Mass Index of 30 or more) by the prescribing consultant, who would then specify prone positioning with a standard 3-field technique. The treatment would be given in two phases, ten fractions with a pelvic shell and ten fractions without.

All patients underwent an initial localisation and simulator session on the Varian Ximatron®, prone without any positioning device. The target volume was identified by screening and then posterior and lateral reference images were obtained. Cross-sectional outlines were measured using the Osiris® system and the treatment plan calculated on a Varian Cadplan® treatment planning system using a posterior 6 MV X-ray beam and two opposed lateral 10 MV X-ray wedged beams, with multileaf collimation as required.

Within a few days, a thermoplastic shell was moulded using standard pre-cut material and the simulation session repeated. The pelvic shell was attached to a base-plate which may then be locked to the simulator or treatment couch-top using a Med-Tec® bar. The target volume was again identified, reference images and outlines obtained and plans calculated as before, but with the patient positioned within the pelvic shell.

All patients were to be treated with two phases, with and without the pelvic shell, on the same Varian Clinac 2100C linac. Patients were randomised into two groups and a cross-over trial design employed, so that each patient acted as their own control: group 1 no shell to shell; group 2 shell to no shell.

For each phase, posterior and lateral images were obtained on treatment fractions 1–5, 7 and 9 using the Varian Mark 2 electronic portal imaging

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system (Figs 1 & 2). Thus for each patient, a total of 28 treatment portal images were to be assessed for movement against 4 simulator images (posterior-anterior and lateral images of plan 1 and plan 2).

The simulator and treatment images were compared using the fully integrated Varis Vision system. This was done retrospectively and independently by two separate readers who estimated movements in the posterior-anterior, lateral and longitudinal directions for each fraction (Figs 3 & 4).

For each fraction in which portal imaging was scheduled, the radiographers also assessed the ease at which the patient could be positioned, classified as (based on Nutting et al.[14]):

1. Good set-up, rapidly achieved;
2. Good set-up, requiring time to achieve;
3. Adequate set-up, requiring time to achieve.

This was done to see if good rapid visual positioning to surface marks could be correlated to accurate positioning to bony landmarks in portal images.

RESULTS

The trial was abandoned after only four patients had been treated (two within each group) as an interim analysis appeared to indicate that the use of this particular pelvic shell *reduced* positional accuracy in the longitudinal direction. There was possibly some improved accuracy in the posterior-

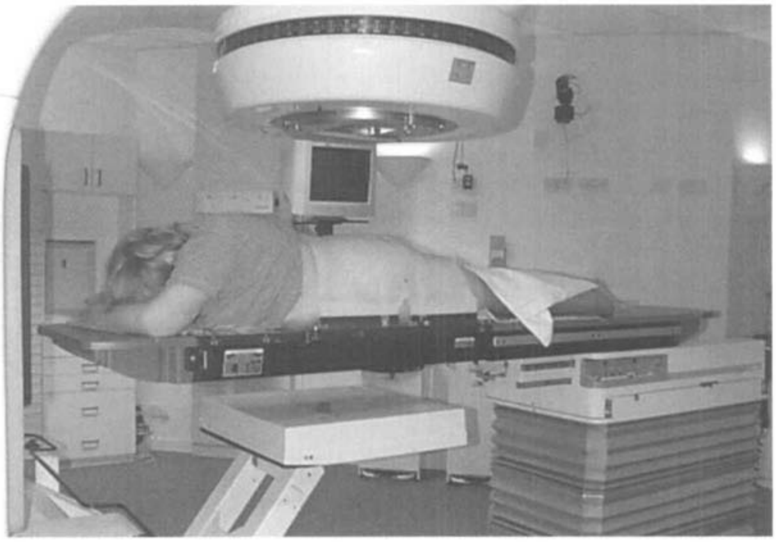

Figure 1. Patient positioned in thermoplastic shell on treatment couch, EPID prepared for acquisition of posterior-anterior image.

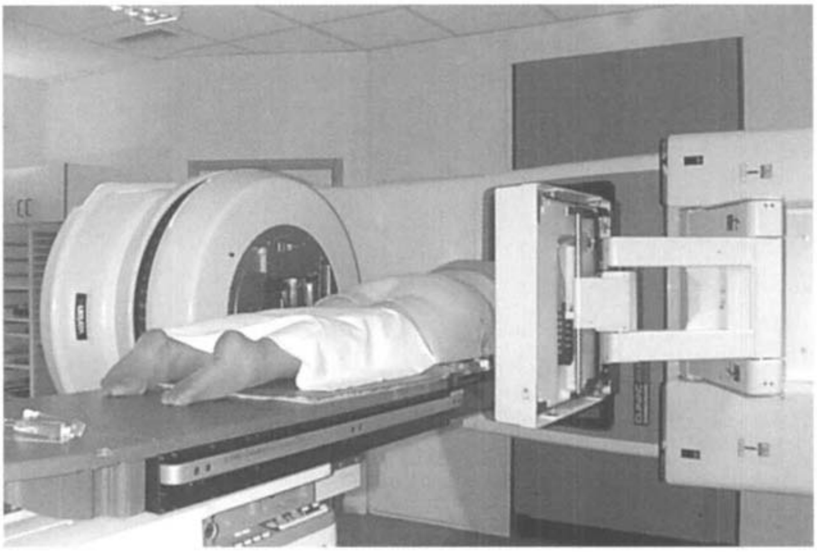

Figure 2. Patient positioned in thermoplastic shell on treatment couch, EPID prepared for acquisition of lateral image.

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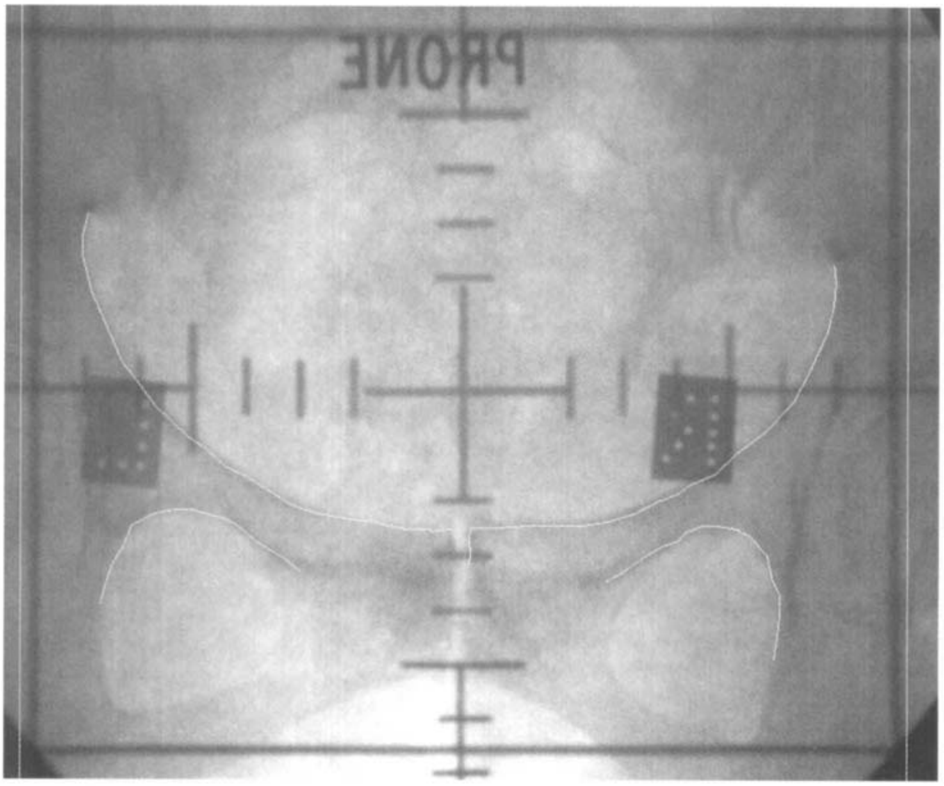


Figure 3. Original simulator image of posterior-anterior field.

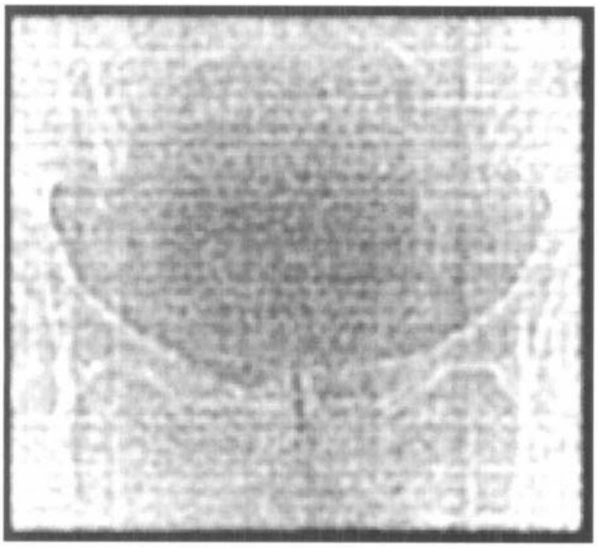
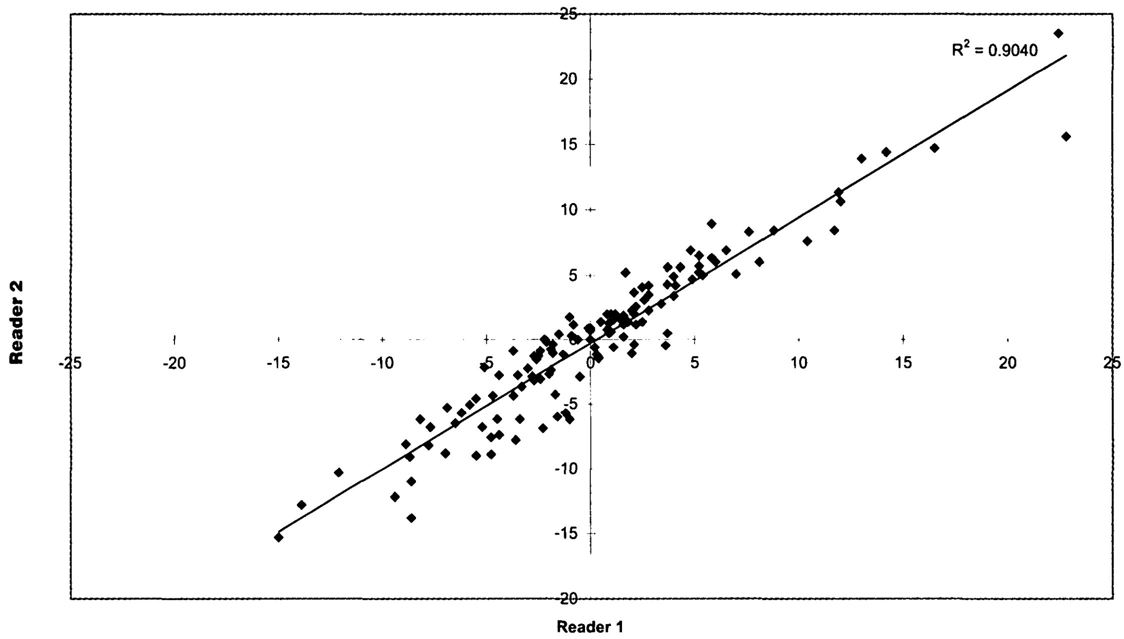


Figure 4. Verification EPID image of posterior-anterior field.

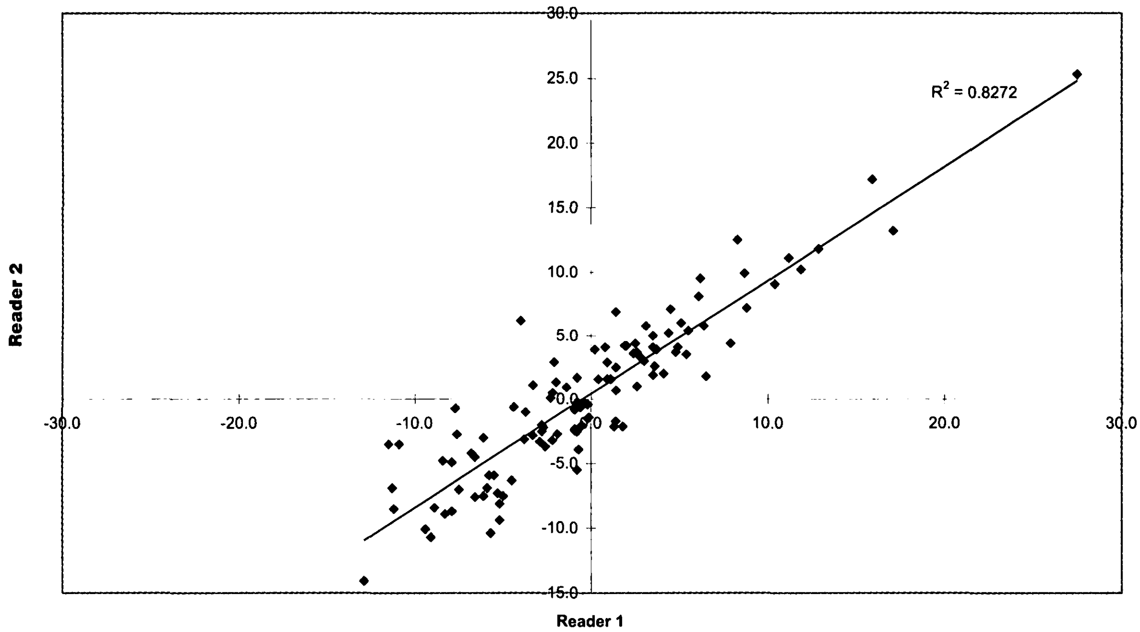
anterior and lateral directions, but it was decided that modifications to the shell design in the longitudinal direction should be considered before continuing with the study.

For these four patients, 106 portal images were obtained instead of the intended 112 due to intermittent malfunctioning of the imager. Of these images, 51 were posterior-anterior images and 55 were lateral images. Each image was read by the two persons, as described, and the correlation of their measurements is shown in Graphs 1 and 2. This illustrates the good agreement between the readers, hence the individual measurements for each image were averaged.

Table 1 gives some summarising statistics for the four patients grouped together, highlighting the number of images taken and the overall movement errors. Systematic positioning errors would be manifested by large mean values in patient movement, random errors by large values of standard deviation. The standard deviation of positioning errors was about 5 mm without the pelvic shell and this increased to 9 mm for longitudinal movement with the shell (1SD).



Graph 1. Movement in lateral & longitudinal directions on posterior portal field from shell and no shell.



Graph 2. Movement in lateral & longitudinal directions on lateral portal field from shell and no shell.

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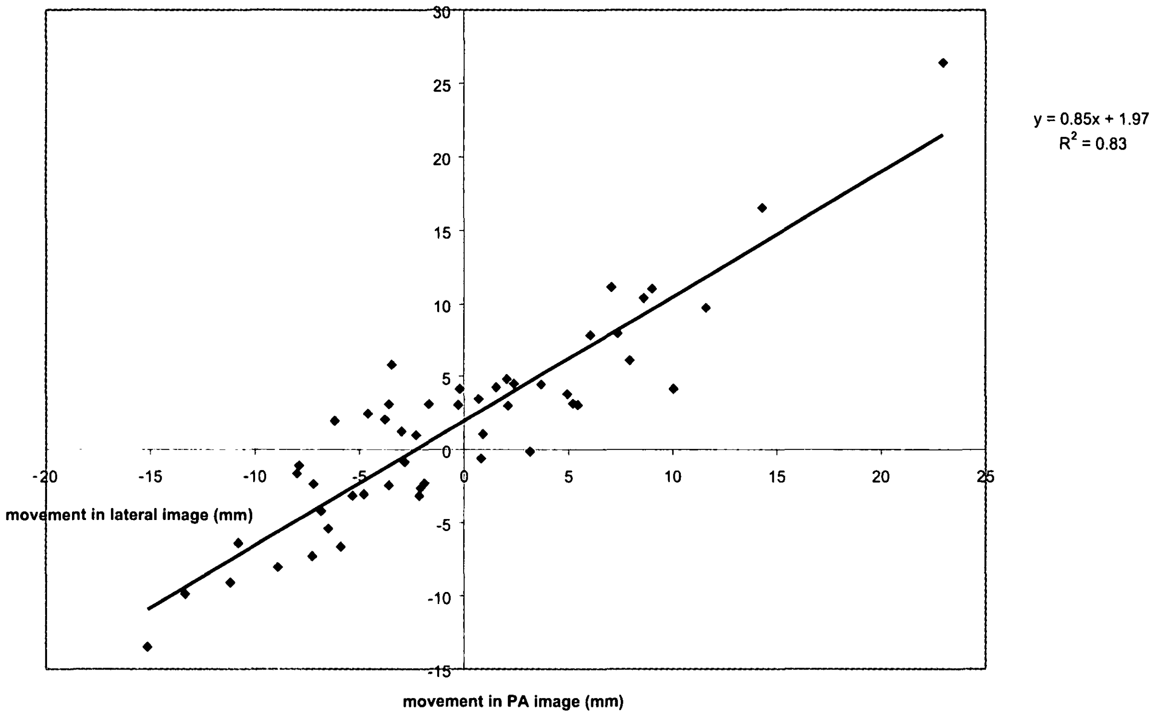

Graph 3. Comparison of longitudinal patient movements, measured in both PA and lateral portal images.

Table 1. *Summarising statistics of patient movement errors (mm) for the 4 patients combined.*

Movement direction	Image	Shell	No. of images	Max	Min	Mean	Std. dev
P/A	Lateral	With	27	4	−9	−2.2	3.7
		Without	28	15	−10	−0.9	6.2
Lateral	P/A	With	25	6	−6	1.2	2.5
		Without	26	11	−7	0.4	4.4
Longitudinal	i) Lateral	With	27	26	−14	0.5	9.0
		Without	28	12	−4	2.7	3.9
	ii) P/A	With	25	23	−15	−1.3	9.3
		Without	26	12	−8	0.3	5.0

The longitudinal movement in any given fraction was measured in both the posterior-anterior and lateral portal image. Graph 3 is a scatter diagram of these values which shows a reasonable correlation but that the measurement in the lateral image is only about 85% of that in the posterior-anterior image. For obese patients the lateral images are frequently of poorer quality so that the derived measurements are thought to be less accurate than those for the posterior-anterior image.

A comparison of movement errors was made using the chi-squared test. Images were classified into three groups for each direction, with movements of 0–4 mm, 5–9 mm and > 9 mm. The results given in Table 2 are testing the distribution of errors and the null hypothesis that there is no difference between the two set-ups. For the posterior-anterior and lateral movements the p-values are ≥ 0.05 and therefore the null hypothesis is not disproved. In the longitudinal direction the p-values are ≤ 0.05, the null hypothesis may therefore be disproved as there is a significant difference in the observed distribution of errors between the two set-ups.

Longitudinal movements were then analysed separately for each patient, in case a particular patient was difficult to set-up or if the order of

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treatment (group 1 or 2) was significant. This data is presented in Table 3 which shows that for each of the four patients, the standard deviation was significantly larger for the 'with shell' treatments. The quoted p-values were calculated using the F-test. All p-values are $\leqslant 0.05$ and may, therefore, be considered as statistically significant differences.

These results, therefore, indicate that use of the shell had in some way *decreased* the set-up accuracy in the longitudinal direction for these patients and that the trial should therefore be halted.

DISCUSSION AND CONCLUSION

The study was abandoned after only four of the proposed twenty patients had been treated. However, 106 portal images had been obtained and their analysis indicated that use of the shell had in some way *decreased* the set-up accuracy in the longitudinal direction for these patients. This was surprising, as the treatment radiographers had felt that the pelvic shell was useful in obtaining rapid and accurate set-ups. In fact the worst longitudinal positioning errors on portal image occurred using the shell where good rapid set-ups were recorded by the treatment staff. Table 4 illustrates how the ease of set-ups correlates with use of the pelvic shell. It is apparent that the shell does indeed increase the numbers of visually good and rapid set-ups (category 1), but that these do not correspond to accurate longitudinal positioning assessed by portal imaging.

The principal conclusion of this limited study is that the prone pelvic shell in its current format is not adequate for accurate positioning in the longitudinal direction.

Several other observations can be drawn.

Patient movements in the other directions (posterior-anterior and lateral) were not significantly affected by the use of the shell.

The ease at which a patient may be positioned using surface marks is not a good guide to positional accuracy, as determined by bony landmarks in portal images (Table 4).

Table 2. Chi-squared analysis of movement errors (mm) for the 4 patients combined.

Movement direction	Image	Shell	No. of images	No. of images with movement errors of: 0–4 mm	5–9 mm	> 9 mm	(χ^2) P
P/A	Lateral	With	27	18	9	0	(4.9)
		Without	28	12	13	3	NS
Lateral	P/A	With	25	21	4	0	(2.7)
		Without	26	17	8	1	NS
Longitudinal	i) Lateral	With	27	11	10	6	(8.4)
		Without	28	22	3	3	0.02
	ii) P/A	With	25	6	12	7	(9.5)
		Without	26	16	9	1	0.01

Table 3. F-test comparison of standard deviations for longitudinal movement errors (mm) for individual patients, with and without the pelvic shell.

Group	Pt. no.	Image	Std. dev (mm) Shell	Std. dev (mm) No shell	No. of images Shell	No. of images No shell	P
1	04	P/A	6.6	1.4	7	7	0.001
		lateral	6.5	1.5	7	7	0.01
1	06	P/A	7.7	3.1	5	7	0.05
		lateral	4.7	1.7	6	7	0.05
2	02	P/A	10.7	3.0	7	6	0.01
		lateral	11.2	4.3	7	7	0.05
2	03	P/A	9.7	2.8	6	6	0.01
		lateral	9.8	2.9	7	7	0.01

Table 4. Numbers of treatment fractions categorised according to ease of set-up and longitudinal movement errors (mm), with and without the pelvic shell.

Shell	Longitudinal movement (mm)	Ease of set-up: (1) Good set-up rapidly achieved	(2) Good set-up requiring time	(3) Adequate set-up requiring time	Total no. of fractions
With	0–4	5	2	0	7
	5–9	9	2	0	11
	10– ...	7	0	0	7
	Total no. of fractions	21	4	0	25
Without	0–4	10	4	3	17
	5–9	5	2	1	8
	10– ...	0	1	0	1
	Total no. of fractions	15	7	4	26

Portal imaging should therefore be undertaken throughout the treatment period, not only at the first few fractions.[21]

For obese patients, the lateral portal images are often of poor quality hence longitudinal positional accuracy should if possible be derived from the posterior-anterior images.

The thermoplastic shell was shown to be inadequate in its initial format and this was thought to be due to insufficient inferior location points for the shell. The manufacturers were notified of these results and have modified the shell design. The study will be re-started when the shell design has been finalised.

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