Journal of Radiotherapy in Practice

Journal of Radiotherapy in Practice (2012)
11, 209–216

doi:10.1017/S146039691100029X

Original Article

Assessment of set-up discrepancies using daily portal imaging during radiotherapy treatment for patients with spine and bone metastases

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Abstract

It is well established that patients with bone metastases get good pain relief from radiotherapy. The aim of treatment is to achieve maximum pain relief with minimum morbidity. Accuracy and reproducibility of the patient's position are fundamental to the successful delivery of radiation therapy. It has been recognised for many years, that the accuracy of patient positioning will improve the success of radiation treatment. A previous study carried out in the department showed that the use of only a single tattoo for the set-up of palliative patients resulted in poor accuracy. The aim of this study was to assess if the addition of extra skin marks improved the set-up accuracy of palliative patients being treated for spine and bone metastases. A protocol was implemented detailing the extra skin marks to be used. Daily portal images were acquired and analysed retrospectively using anatomy matching. The results obtained were then compared with those of the previous study. The use of extra skin marks resulted in a total of 45% of images within 5 mm tolerance compared with 36% of images in patients treated with a single centre tattoo. Also, the number of images with deviations greater than 15 mm was reduced by more than 50% with the addition of extra skin marks. This study has shown that extra skin marks do increase the set-up accuracy in palliative patients treated for spine and bone metastases. Therefore, the practice of using extra skin marks has become standard protocol for all palliative patients within the department.

Keywords

Metastases; portal imaging; palliative radiotherapy; set-up accuracy

INTRODUCTION

Palliative radiotherapy accounts for nearly 50% of the workload of radiotherapy departments,[1] of which the management of bone metastases constitutes the most common use.[2]

It is well established that patients with bone metastases experience good pain relief from radiotherapy[3] therefore, it is important that the area of pain is targeted accurately ensuring that the patient receives the full potential benefit. Accuracy and reproducibility of the patient's position are fundamental to the successful delivery of radiation therapy.[4] It has been recognised for many years, that the accuracy of patient positioning will improve the success of radiation treatment.[5–8] To accurately reproduce patient setup, radiographers use skin marks or anatomical landmarks.

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The use of electronic portal imaging has also improved treatment accuracy in radiotherapy.[9] Electronic portal imaging devices (EPIDs) provide a simple and efficient way to obtain daily images of patients over the course of treatment. Portal imaging to measure set-up errors is standard practice in a large number of institutions and has made it possible to detect and reduce set-up errors for a large number of patients.[8]

In our radiotherapy department, palliative patients are not routinely imaged during their treatment. However, because images are not taken during their treatment the accuracy is unknown and therefore, the patient may not receive the full therapeutic benefit of treatment. Also, if the patient needed more treatment and it was required that the fields abutted, it would be advantageous to know if what was planned was exactly what was treated.

Many studies have examined treatment accuracy of various subgroups of radical patients and how it can be improved; however, few studies have involved palliative patients. In a study of on-line portal imaging by De Neve et al.,[10] 566 parallel-opposed pelvic fields were evaluated in 13 patients. They found that using a longitudinal laser line on the superior field border improved accuracy in the cranio-caudal direction. Also, a large study of 4000 patients by Morgan et al.,[11] found that adding lateral tattoos plus marks on the central axis in pelvic patients increased accuracy and reproducibility of these set-ups. Prior to this they had been using only a single centre tattoo.

A study by Easton et al.,[12] looked at the accuracy and reproducibility of the treatment of patients with spine metastases within their department. They carried out daily portal imaging and analysed results using anatomy matching. They found retrospectively that 55% of 60 patients required lateral adjustment prior to treatment. As a result they modified their technique by incorporating lateral tattoos and found that this resulted in improved reproducibility with only 17% of 60 patients requiring adjustment.

A study has previously been carried out within our department to examine the set-up accuracy of palliative patients with spine and bone metastases. The study involved taking daily portal images and analysing them retrospectively using anatomy matching. Image matching was achieved using bony anatomy. Mobile and bed-bound patients were included. Bed-bound patients were transferred onto the treatment couch using an Airpal mattress, which inflates under them enabling a smooth transfer from their bed onto the treatment couch. From the results obtained it was evident that the accuracy of palliative patient set-ups could be improved, 64% of patients had set-up error of greater than 5 mm. In particular Airpal and lower spine patients had least accurate set-ups, while, in contrast, prone patients had the greatest accuracy with all images being within 5 mm. The standard practice in our department was to use a single centre tattoo on palliative patients for set-up.

After analysis of the results of the initial study and a review of relevant literature a protocol was designed and implemented. This protocol detailed the additional skin marks to be used to help improve the set-up accuracy of palliative patients. The aim of the study was to determine if the use of additional skin marks did improve the accuracy of palliative set-ups within our department. The null hypothesis was that the use of additional skin marks provided no improvement in set-up accuracy in neither the cranio-caudal nor the medio-lateral direction.

METHODS

Subjects

Patients of all ages and gender with spine and bone metastases were included. Data was collected for a period of four months. During this time all patients with spine and bone metastases planned for radiotherapy were included for daily imaging, therefore, the subjects were not handpicked and there was no researcher bias. These patients included mobile and bed-bound patients. Ethical approval was also obtained from the NHS Research Ethics Office at Ninewells Hospital.

https://doi.org/10.1017/S146039691100029X Published online by Cambridge University Press

A total of 37 patients were included producing 129 portal images for analysis. The initial study carried out on patients with a single tattoo, resulted in 37 patients with 118 portal images being analysed.

Instruments

A gantry mounted amorphous silicon electronic portal imaging device (EPID) was used to capture the portal images. On completion of data collection the researcher interpreted the images retrospectively using Varian Portal Vision 6.5 anatomy matching software tools. Studies have shown that there is great subjectivity in the interpretation of images,[13–15] and therefore, the researcher contoured all reference images and matched all the portal images produced. The translational displacements in the medio-lateral and cranio-caudal directions were recorded. All set-up information was also recorded, which included skin marks used, patient position and mobility.

Procedure

From the power calculations it was calculated that 35 patients would be required to detect, with 80% power, a 50% reduction in the number of images with a set-up error of greater than 5 mm using a cut-off statistical significance of 0.05, to enable the null hypothesis to be rejected.

During the planning process extra skin marks were applied to patients with spine and bone metastases. These marks consisted of a centre tattoo, superior and inferior central axis pen marks and lateral laser pen marks in line with the isocentre. These pen marks were drawn in red and covered with clear adhesives, enabling the patient to wash without having to worry about losing these marks. It was acknowledged that lateral marks might not be possible in all cases, as this will depend on the position of the patient's arms. To avoid the potential for treatment errors, lateral alignment marks were not used if this would then require a shift to the isocentre position. If lateral marks were not possible at isocentre then the other additional marks only were used.

All patients were irradiated on a Varian Clinac linear accelerator using 6 MV photons. All patients in the study had portal images taken daily. The images were captured within the first few monitor units (MU) of the exposure. The dose delivered to acquire the portal images in this study was part of the therapeutic dose. Single fields and antero-posterior isocentric opposed fields were used; for parallel opposed treatments only the anterior images were used in the study. The Royal College of Radiologists (RCR)[16] state that for parallel opposed treatments, an image is only required on one treatment field.

The Statistical Package for Social Sciences (SPSS) 13.0 was used to input and analyse the collected quantitative data.

RESULTS

The use of extra skin marks produced a total of 45% of images within 5 mm compared with 36% when a single centre tattoo was used (Table 1). Also the number of images with deviations greater than 15 mm was reduced by more than 50% with the addition of extra skin marks (Table 1).

Furthermore, in terms of patients who were bed bound it was found that 22% of treatments were within the 5 mm with the use of extra skin marks compared with only 11% of treatments when only a single tattoo was used for set-up (Table 2). In addition prone patients were found to have the highest accuracy, which is consistent with that found in the initial study with 100% of images being within 5 mm.

To further assess the data each translational deviation was analysed. This analysis showed that set-up deviations greater than 5 mm in the inferior direction were reduced from 38% to 16% (Table 3) with the use of extra skin marks.

Also deviations greater than 5 mm in the right direction were reduced from 19% to 8% (Table 4) with the addition of extra skin marks.

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Table 1. *Percentage of images in each tolerance with and without extra skin marks*

		Tolerances			
		<5 mm	**6–10 mm**	**11–15 mm**	**>15 mm**
Percentage of images	Single tattoo	36%	31%	18%	15%
	Extra skin marks	45%	34%	14%	7%

Table 2. *Percentage of airpal patients in each tolerance with and without extra skin marks*

		Tolerances			
		<5 mm	**6–10 mm**	**11–15 mm**	**>15 mm**
Percentage of images	Single tattoo	11%	22%	28%	39%
	Extra skin marks	22%	43%	24%	11%

Table 3. *Percentage of images in each tolerance in the inferior direction*

Inferior deviation		Tolerances			
		<5 mm	**6–10 mm**	**11–15 mm**	**>15 mm**
Percentage of images	Single tattoo	62%	21%	10%	7%
	Extra skin marks	84%	9%	5%	2%

Table 4. *Percentage of images in each tolerance in the right direction*

Right deviation		Tolerances			
		<5 mm	**6–10 mm**	**11–15 mm**	**>15 mm**
Percentage of images	Single tattoo	81%	10%	7%	2%
	Extra skin marks	92%	7%	1%	0%

However, there was no improvement in the percentage of images greater than 5 mm for the superior and left directions.

The percentage of images greater than 5 mm in the superior direction was actually increased from 8% to 20% (Table 5) in patients with additional skin marks. This was also evident in the left direction where the number of images greater than 5 mm increased from 19% to 24% (Table 6).

The mean set-up deviation, standard deviation of the set-up, range and minimum and maximum values were determined in each direction for both groups of patients (Tables 7 and 8). The mean set-up error represents the systematic error while the standard deviation of the set-up errors represents the random error.[16]

The mean set-up error inferiorly was reduced from 4.97 mm to 2.26 mm by using extra skin marks. It was also reduced in the right direction from 2.42 mm to 1.37 mm with the additional marks. However, the mean set-up error was increased for both superior (1.13 mm to 2.86 mm) and left deviations (2.87 mm to 3.96 mm) with the addition of extra skin marks.

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Table 5. *Percentage of images in each tolerance in the superior direction*

Superior deviation		Tolerances			
		<5 mm	6–10 mm	11–15 mm	>15 mm
Percentage of images	Single tattoo	92%	7%	1%	0%
	Extra skin marks	80%	14%	4%	2%

Table 6. *Percentage of images in each tolerance in the left direction*

Left deviation		Tolerances			
		<5 mm	6–10 mm	11–15 mm	>15 mm
Percentage of images	Single tattoo	81%	10%	3%	6%
	Extra skin marks	76%	14%	4%	6%

Table 7. *Descriptive statistics of patients with a single tattoo*

	Superior (mm)	Inferior (mm)	Right (mm)	Left (mm)
N				
Valid	118	118	118	118
Missing	0	0	0	0
Mean	1.13	−4.97	−2.42	2.87
Standard deviation	2.455	5.892	4.431	5.347
Range	12	28	21	35
Minimum	0	−28	−17	−5
Maximum	12	0	4	30

Table 8. *Descriptive statistics of patients with extra skin marks*

	Superior (mm)	Inferior (mm)	Right (mm)	Left (mm)
N				
Valid	129	129	129	129
Missing	0	0	0	0
Mean	2.86	−2.26	−1.37	3.96
Standard deviation	3.909	3.995	2.427	6.398
Range	17	18	15	36
Minimum	0	−18	−11	−1
Maximum	17	0	4	35

To test the null hypothesis that there would be no statistically significant improvement (at the 5% level) in the accuracy of palliative patient set-ups with the use of extra skin marks a Mann-Whitney U test was carried out.

This showed $p<0.05$ for both the superior and inferior directions, therefore, there is a statistically significant difference between patients with a single tattoo and patients with extra skin marks. However, although this represents

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a significant improvement in deviations in the inferior direction it also indicates a significantly greater set-up deviation in the superior direction. $p>0.05$ for the right and left directions, therefore, no statistically significant difference exists. Therefore the null hypothesis could not be rejected.

DISCUSSION

In the field of radiotherapy the importance of evaluating and correcting set-up errors is well established.[17] Several studies, have looked at setup deviations of radical patients in treatment sites such as the pelvis,[18,19] breast,[20–22] and head and neck.[23,24]However, few studies have examined set-up deviations in palliative patients. The aim of this study was to determine if the use of extra skin marks improved the set-up accuracy of palliative patients being treated for spine and bone metastases.

The use of extra skin marks to improve accuracy and reproducibility of both radical and palliative patient set-up has been recognised by previous authors.[10,11,12,19] This study has also confirmed that the use of extra skin marks in the set-up of palliative patients results in improved overall accuracy and increased set-up accuracy in the inferior and right directions.

The number of images within 5 mm was increased from 36% with a single tattoo to 45% in patients with extra skin marks. Extra skin marks also resulted in a 50% reduction in the number of images with set-up deviations greater than 15 mm. Furthermore the mean set-up error inferiorly was significantly reduced by more than 50% from 4.97 mm to 2.26 mm by using extra skin marks. It was also reduced in the right direction from 2.42 mm to 1.37 mm with the additional marks. However, there was an increase in the mean set-up error in both the superior and left directions. Furthermore, the increase in set-up deviations in the superior direction was shown to be statistically significant.

Analysis of outliers and extreme values showed that they were made up of both bed bound and mobile patients. In terms of the mobile patients it was noted that they were all patients having lower spine treatment with the largest deviation being 27 mm.

In the initial study carried out within our department it was established that patients who were transferred using the Airpal mattress tended to have poorer set-up accuracy. This study showed that the use of extra skin marks in patients who were bed bound resulted in 22% of their images being within 5 mm tolerance compared with only 11% of images when a single tattoo was used. This is a considerable improvement; however, 78% of the images still had a set-up error greater than 5 mm. These patients are generally in a lot of pain and can be quite difficult to manipulate into position. Also because they are transferred using an Airpal mattress plus their bed sheets this could result in the patient lying differently on the treatment couch each day and therefore, resulting in decreased accuracy and reproducibility. It is acknowledged that this group of patients would potentially benefit from on-line imaging during treatment.

The analysis of outliers and extreme values has also indicated that lower spine treatments are less accurate. Set-up marks for these patients are in the abdomen and pelvis region of the body. It has been previously confirmed by positioning studies that supine pelvic treatments have higher set-up displacements than other body sites.[7,25–28] Also the abdomen and pelvis are areas of the body where skin tends to be more mobile and therefore alignment of skin marks relative to patient's anatomy may prove difficult. This might explain why lower spine treatments appear to be less accurate even with additional set-up marks.

On examination of the significant increase in mean set-up deviations in the superior direction, it was noted that 20% of images had a superior deviation of greater than 5 mm. With the exception of two patients, these were all either mobile patients having lower spine treatment or they were bed-bound patients. These are the two groups of patients found to have the least accurate set-ups, therefore, this might

https://doi.org/10.1017/S146039691100029X Published online by Cambridge University Press

explain the increase in set-up deviations even with the additional skin marks. This was also evident on analysis of the increase in mean set-up deviations in the left direction. It was found that 24% of images had a left deviation of greater than 5 mm, 9 of these patients were bed bound and of those that were mobile, the majority were having treatment to the lower spine.

Treatment radiographers highlighted that in some supine patients when lateral marks were present there was a discrepancy in the superior-inferior direction between these lateral marks and the marks on the patients anterior. Standard practice for other pelvic patients within the department is to set to the laterals in the superior-inferior direction. Therefore, it would be of benefit to apply the same practice to lower spine patients to determine if the set-up accuracy in the superior direction could be improved upon. However, before this practice can be changed, further investigation will be required.

This study also confirmed that prone patient set-ups have greater accuracy. Treating patients in the prone position is beneficial as it enables the radiographer to anatomically feel the patient's spine during alignment, hence not just relying on skin marks and therefore, increase accuracy. It is acknowledged that where possible all spine patients should be treated prone.

Clinical implications

The results have shown that extra skin marks do increase the overall set-up accuracy in palliative patients treated for spine and bone metastases. Therefore, it was recommended that the use of these skin marks on this group of patients should become standard practice within the department.

As a result of this study the practice of using extra skin marks has become standard protocol for all palliative patients within the department, not solely those with bone metastases.

CONCLUSION

This study demonstrates the implementation of a protocol using additional skin marks to improve set-up accuracy of palliative patients treated for spine and bone metastases. The results obtained show that the addition of extra skin marks resulted in improved overall accuracy for this group of palliative patients. However, it is acknowledged that there is still room for improvement, patients who were bed bound were still prone to large set-up errors and large deviations were present in some patients having lower spine treatment. The Royal College of Radiologists[16] state that for palliative patients daily portal images should be taken where there is risk of a gross error.

At present, in our department, portal images are not taken on palliative patients unless shielding is used. It is acknowledged that daily on-line imaging and correction may be beneficial for certain sub-groups of patients. However, this can be time consuming and a combination of on-line and off-line protocols may be beneficial for most palliative patients. Also, before routine palliative imaging can be implemented protocols will have to be established. The results obtained from this study will provide evidence for producing these protocols enabling the frequency of imaging and tolerance values to be established and also for the calculation of treatment margins in planning.

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