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# Online versus offline corrections: opposition or evolution? A comparison of two electronic portal imaging approaches for locally advanced prostate cancer

*Mark Middleton,[1] Aldo Rolfo,[2] Steve Medwell,[1] Andrew See,[3] Jacky Wong,[1] Michael Lim Joon,[3] Mary Lynton-Moll[1]*

[1] Radiation Therapy Staff Ballarat-Austin Radiation Oncology Centre, Austin Health, Ballarat, Victoria 3350, Australia
[2] Radiation Therapy Staff Radiation Oncology Centre, Austin Health, Melbourne, Victoria 3350, Australia
[3] Medical Staff Ballarat-Austin Radiation Oncology Centre, Austin Health, Ballarat, Victoria 3350, Australia
[4] Correspondence email mark.middleton@baroc.austin.org.au

**Abstract** Given the onset of dose escalation and increased planning target volume (PTV) conformity, the requirement of accurate field placement has also increased. This study compares and contrasts a combination offline/online electronic portal imaging (EPI) device correction with a complete online correction protocol and assesses their relative effectiveness in managing set-up error. Field placement data was collected on patients receiving radical radiotherapy to the prostate. Ten patients were on an initial combination offline/online correction protocol, followed by another 10 patients on a complete online correction protocol. Analysis of 1480 portal images from 20 patients was carried out, illustrating that a combination offline/online approach can be very effective in dealing with the systematic component of set-up error, but it is only when a complete online correction protocol is employed that both systematic and random set-up errors can be managed. Now, EPI protocols have evolved considerably and online corrections are a highly effective tool in the quest for more accurate field placement. This study discusses the clinical workload impact issues that need to be addressed in order for an online correction protocol to be employed, and addresses many of the practical issues that need to be resolved. Management of set-up error is paramount when seeking to dose escalate and only an online correction protocol can manage both components of set-up error. Both systematic and random errors are important and can be effectively and efficiently managed.

*Key words:* Electronic portal imaging field placement, online corrections, offline corrections, set-up error, systematic error, random error.

## Introduction

Electronic portal imaging protocols have evolved considerably over the last decade.[1,2,3,4,5] This study discusses the experiences at the Ballarat-Austin Radiation Oncology Centre and compares and contrasts the relative advantages and disadvantages of a combination offline/online correction policy with that of a complete online correction policy. Both policies involved daily electronic portal imaging (EPI) and thus a comprehensive analysis of set-up error could be performed. Anatomy matching software was utilised to assess field placement accuracy, with bony anatomy used as the primary matching mechanism (Figure 1). By this method the set-up error for each fraction could be assessed. Thorough analysis of set-up error is vital when considering dose escalation.

For the purposes of this study, an offline correction indicates that EPIs were evaluated after treatment has been delivered. However, an online correction protocol indicates that images were taken pre treatment, assessed and field placement intervention made if required.

The aims of both protocols are identical, that is to minimise and manage set-up error. There are two components to set-up error, those being systematic and random. A systematic error can be defined as an error that is introduced at planning stage and, if unaddressed, would occur for each treatment fraction. A random error however occurs only once and as the name implies is unpredictable.[2]

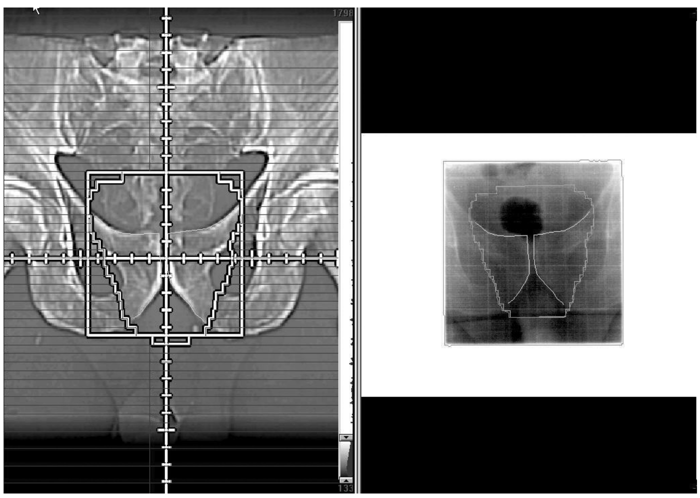

Figure 1

**Table 1**

| Treatment preparation CT Room | Treatment execution Treatment Room |
|---|---|
| Lasers | Lasers |
| Skin marks | Skin marks |
| Images | Bone |
| Bone | Tumour |
| Contouring | Beam |
| Delineation | Accelerator |
| Margin | Treatment beam |
| Planned beam | |

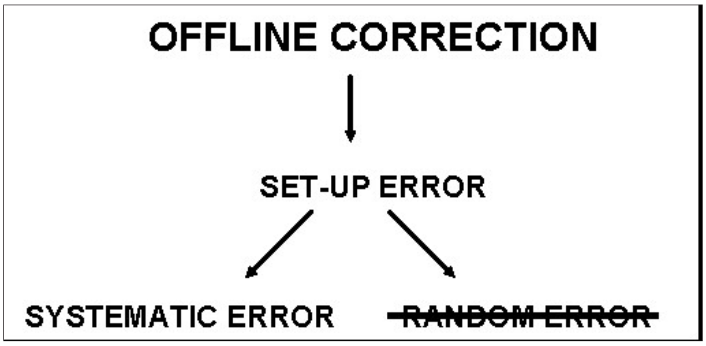


**Figure 2a**

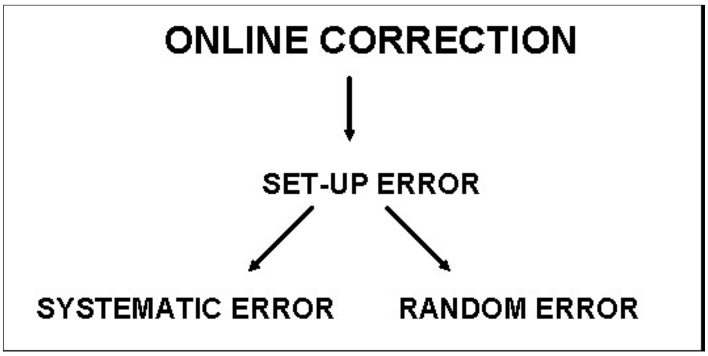


**Figure 2b**

For the purposes of this study, systematic error is a treatment preparation error, while a random error is a treatment execution error.[1]

It has been noted previously that there are 17 potential sources of error in the treatment preparation and treatment execution of a course of radiotherapy[2] (Table 1). Of these 17 sources of error, EPI can address 13, with tumour delineation and margin being radiation oncologist dependent. With the advent of Gold Seed fiducials and other similar approaches, tumour motion can now also be addressed by EPI on a daily basis. However, this study utilises only bony anatomy. With so many possible sources of error, EPI protocols need to be designed to manage and minimise set-up error, and a thorough understanding of the components of set-up error assist in this process. An offline correction protocol addresses only the systematic component of set-up error, while an online correction protocol is able to manage both systematic and random components of set-up error. These relationships are illustrated in Figures 2a and 2b.

## Method

### Offline/online correction protocol

On the first day of treatment, an anterior and right lateral EPI was taken pre-treatment and, if outside a defined action threshold of 5 mm on any of the orthogonal axes, an online correction was performed. Treatment was then delivered with the treatment fields in the correct position. All corrections were carried out via Varian's Vision® software anatomy match. If intervention was made, then the patient would require pre-treatment images again for the subsequent fraction. Once this correction had been verified correct for two fractions, anterior and right lateral EPI were taken daily during treatment. These images were then assessed in the offline environment and, if outside the action threshold, pre-treatment images were required the following fraction. Data for 10 patients were collected using this protocol, resulting in daily anterior and right lateral images or 740 data points. Daily field placement data, both pre-intervention and post-intervention, were then exported to a spreadsheet for further analysis.

Commencement time of set-up was recorded for each patient on a daily basis and beam on/beam off time was extracted directly from Varian's Varis Version 6.1® database for further analysis.

The stabilisation utilised for this offline/online protocol consisted of an un-indexed kneefix and feetfix arrangement with two 5 cm sponges under the head unindexed (Figure 3).

### Online correction protocol

Pre-treatment images were taken daily on the anterior and right lateral fields. A defined action threshold of 4 mm was used and, if field placement exceeded this on any orthogonal axes, an online correction was performed. Again, all required interventions were diagnosed by Varian's Vision® software anatomy match. An additional 10 patients provided data for this protocol, providing 740 data points (anterior and right lateral EPI daily). Again, daily field placement data, both pre-intervention and post-intervention, were exported to a spreadsheet for further analysis. Daily time taken to set up and treat each patient was also extracted directly from the information management system.

This online correction protocol had stabilisation consisting of an indexed pelvic board and personalised Vacfix bag with two 5 cm sponges under the head unindexed (Figure 4).

## Results

### Offline/online correction protocol

Analysis of data using this protocol supports previous research[3,4,5,6] that an offline correction policy is very effective in managing the systematic component of set-up error but has little effect on the random component, this is illustrated in Table 2. Statistical analysis of this data indicated that there were larger, more frequent systematic errors in the right to left plane, while random errors were much more prevalent in the sup-inf direction. The mean absolute displacement was greater in the sup-inf plane, indicating that there were larger and much more frequent set-up errors in this direction. The reduction in systematic positional errors evident in these data has been achieved with a mainly offline approach,[7,8] but there has been negligible impact on random positional errors. This is due in effect to an offline correction protocol being only an indirect and incomplete determination of the target volume at the time of treatment.[9]

Figure 5 illustrates an individual treatment course from the entire population, with the ellipses representing 95 per cent confidence intervals for both pre-intervention and post-intervention data. The distance from the centre of the ellipse to the origin of the graph presents the systematic error while the size of the ellipse represents the random error. Within the confines of a combination offline/online correction protocol, it is evident that there has been an impact on the systematic component of set-up error but there

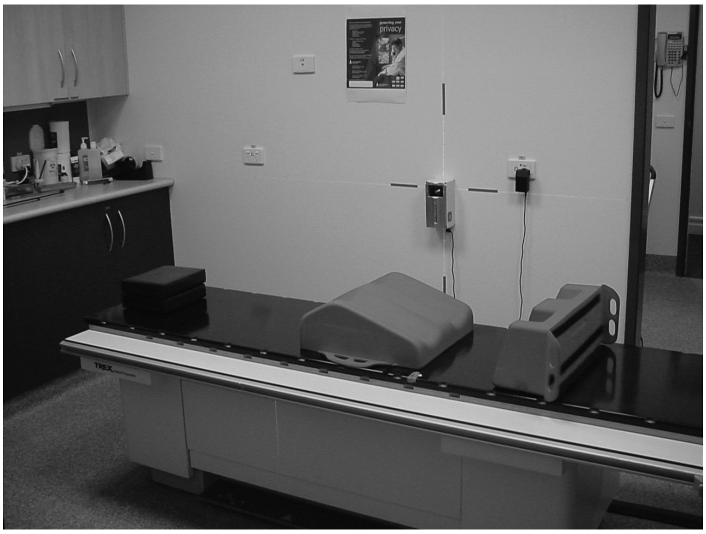

**Figure 3**

**Figure 4**

**Table 2**

| MM | Pre-correction | | | | Post-correction | | |
|---|---|---|---|---|---|---|---|
| **Systemic** | x | y | z | | x | y | z |
| Mean | -0.63 | 0.30 | 0.95 | Mean | -0.008 | 0.36 | 1.13 |
| SD | 1.98 | 1.41 | 0.96 | SD | 0.84 | 1.43 | 1.00 |
| **Random** | x | y | z | | x | y | z |
| Mean | 1.19 | 3.46 | 0.64 | Mean | 0.85 | 3.46 | 0.64 |
| SD | 3.19 | 5.91 | 2.79 | SD | 2.74 | 4.93 | 2.71 |

**Table 3**

| MM | Pre-correction | | | | Post-correction | | |
|---|---|---|---|---|---|---|---|
| **Systemic** | x | y | z | | x | y | z |
| Mean | -0.90 | 0.27 | 0.99 | Mean | 0.11 | -0.33 | -0.45 |
| SD | 2.68 | 2.36 | 1.64 | SD | 1.19 | 0.72 | 0.88 |
| **Random** | x | y | z | | x | y | z |
| Mean | -1.38 | -0.23 | -1.47 | Mean | -0.22 | -0.09 | -0.87 |
| SD | 4.08 | 3.96 | 2.96 | SD | 1.94 | 2.26 | 2.52 |

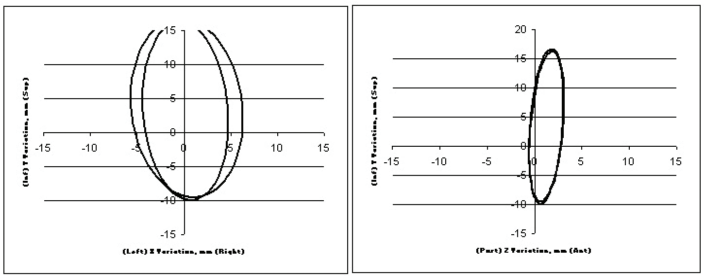

**Figure 5**

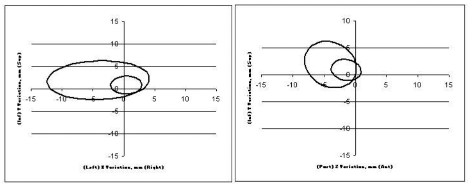

**Figure 6**

has been no impact on the random component.

The average time taken to set-up and treat a patient under the conditions of this protocol was 10.06 min.

### Online correction protocol

Data provided by the complete online correction protocol illustrate that by using daily EPI and possible intervention, there has been significant reductions in both the systematic and random components of set-up error (Table 3). Such an approach can simply identify both systematic and random variations and analysis of treatment field position can provide the means to achieve rapid pre-treatment corrections.[3,5,6] Both systematic and random components were greater in magnitude in the right to left direction, while the mean absolute displacement was greatest in the ant-post direction. The management and subsequent reduction of both the systematic and random errors evident in these data highlight the advantages of a truly online approach.

The ellipses in Figure 6 again show an individual treatment course extracted from the total population and highlight the impact on both systematic and random errors that are achievable with an online correction protocol.

Utilising the extracted time data it was found that the average daily time taken to set-up and treat using a full online correction protocol was 10.54 min.

## Discussion

For both studies, there were relatively small treatment preparation (systematic) errors, however, there was a large range of treatment execution (random) errors. This contrasts with previous studies that suggest that there is little benefit in implementing a protocol to correct for random errors.[10] However, there is only one way to effectively manage random errors, and that is to utilise daily imaging and online corrections.

A frequently posed question has been: Are random errors important? An often used approach is to address them with your stabilisation. The results obtained from the offline/online correction data led to a change in set-up for prostate patients. This in turn resulted immediately in a reduced 95 per cent confidence interval for field placement. The original patient set-up provided a 95 per cent confidence interval of ± 7 mm, while the revised and improved set-up reduced this to ± 5.3 mm (Figures 7a and 7b).

However, there is only so much that can be achieved purely with a change in set-up. There must be an acceptance that both systematic and random errors will occur, they cannot be eliminated but they can be managed. Current technology has given the capacity to accurately and efficiently manage all components of set-up error.

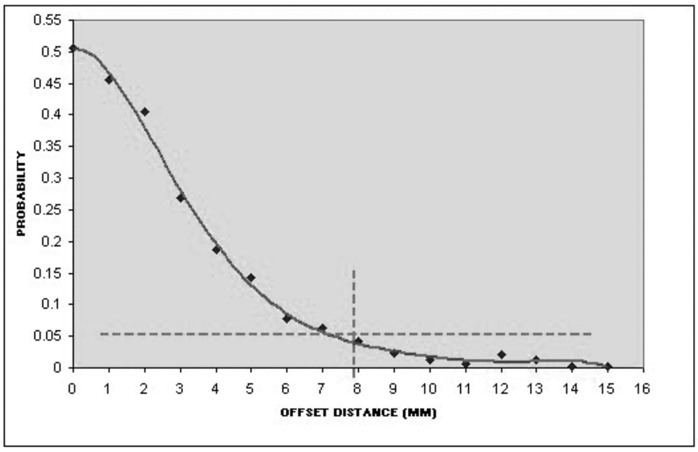


**Figure 7a**

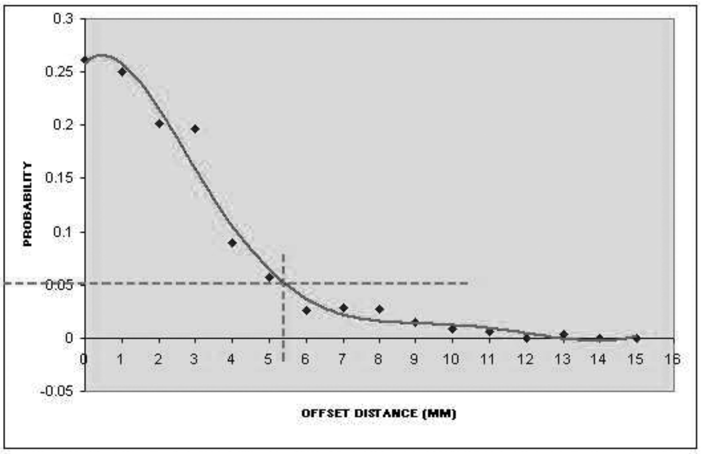


**Figure 7b**

Implementing an online correction protocol requires thorough planning and preparation and an understanding of any clinical workload issues that may arise.[10,11]

The results of this study indicated an average time for daily treatment of 10.06 min for the offline/online protocol while the online protocol took 10.54 min. Thus, there was little impact on workload and a significant reduction in set-up error, indicating that online corrections are indeed clinically viable.

Of direct relationship to clinical workload issues, is the choice of an action threshold, which is closely related to the magnitude of a study's random deviations.[1] For the offline/online correction protocol an action threshold of 5 mm was used, purely because of its recognition as a starting point. The magnitude of the random deviations of this protocol was 3.96 mm, which allowed the subsequent online correction protocol to utilise an action threshold of 4 mm. With the incorporation of a new patient set-up the magnitude of the random deviations was reduced to 3.36 mm, thus indicating that a further reduction in action threshold to 3 mm is possible. It has been noted that too tight an action threshold can result in unnecessary corrections and if it is too wide it may not yield the required set-up accuracy.[12] For example, with a 4 mm action threshold using an online correction policy, corrections were carried out 32 per cent of the time, however, if the action threshold was reduced to 3 mm, corrections would have been required 55 per cent of the time.

In order to successfully implement an online correction protocol several issues need to be addressed;

1 Equipment – An amorphous silicon EPID gives the required image clarity to accurately assess and intervene, while streamlined analytical software provides powerful image processing. Of enormous benefit is the capacity to export image mismatch results directly to a spreadsheet, making data collection and analysis very straightforward;
2 Support of radiation oncologists – Get radiation oncologists' support to take daily images, present the magnitude of the systematic and random errors and ask the question; 'Can they be ignored?' 'Who are the only group of people logistically capable of performing online corrections?' Getting support for this should be the radiation therapist' role;
3 Champion/champions – There must be members of the team who believe in the benefits of online corrections, and will pursue their implementation;
4 Training – Intensive training as a team, with all Radiation therapists capable of performing an online correction and;
5 Culture/change – Online corrections present a major challenge and change for most radiation therapists. Empower the team with evidence based knowledge, knowing that when given the power, management of set-up error will occur.

## Conclusion

Complete removal of both systematic and random interfraction set-up error can only be achieved by on-line position verification.[13,14] Online corrections are an effective and efficient tool in the quest for greater accuracy in field placement for locally advanced prostate cancer. Electronic portal imaging protocols have evolved significantly over the past decade, and this study indicates an evidence based evolution. Imaging protocols have moved from weekly portal imaging, to more frequent imaging and an analysis of systematic error, to daily imaging with offline analysis, to daily imaging with online intervention. This in turn has resulted in total management of set-up error, both systematic and random.

Online corrections are a logical and feasible extension of all EPI protocols, giving significant advantages that far outweigh the disadvantages.

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