The Radiographer 2006: 53 (3) 18–22 *Review*

Online corrections – evidence-based practice utilising electronic portal imaging to improve the accuracy of field placement for locally advanced prostate cancer

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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 examines the role of online corrections (OC) to increase the accuracy of field placement. This study explores the role of radiation therapists in the process of achieving an online correction.

Method Field placement data were collected on patients receiving radical radiotherapy to the prostate. Both intra- and inter field data was collected with OC being carried out within the confines of the Ballarat Austin Radiation Oncology Centre (BAROC) prostate Electronic Portal Imaging (EPI) policy.

Results Statistical analysis of 740 portal images from 10 patients was carried out, illustrating that without OC field placement will fall at ± 7 mm on a daily basis. This evidence was further supported by a case study of computer dosimetry presenting the worst-case possible impact upon a patient's total course of treatment if OC were not performed.

Discussion The use of OC can prove to be of enormous benefit to both patient and practitioner. For centres with the available technology, it places the responsibility of field placement upon the radiation therapist. This responsibility, and the development of relevant protocols, in turn impacts on the education, training and empowerment of the radiation therapy group. These are issues of the utmost importance to centres considering the use of OC.

Conclusions Without the use of OC there is a serious risk of underdosing both CTV and PTV. In this instance the CTV received only 60% of the prescribed dose, while the PTV received only 80% of the expected dose. OC are an important consideration for those looking to dose escalate.

Keywords: electronic portal imaging field placement, online corrections, prostate cancer

Introduction

Radiotherapy has an established role in the management of prostate cancer. A typical course of radiotherapy spans 37 daily treatments over 7 weeks.

An important factor associated with treatment delivery is consistent and accurate targeting of the prostate and avoidance of surrounding critical structures.

Traditional radiotherapy involves setting up the radiotherapy machine to treat a consistent volume of pelvic tissue referenced to defined bony landmarks. Nederveen *et al.*[1] reported that the use of internal bony structures decreased geometric uncertainties, though margins to account for organ motion are still needed. Given that the prostate is subject to considerable internal movement and also that it is not possible to directly visualise the prostate on EPI images, it is usual for the oncologist to treat a volume of tissue larger than the actual prostate itself. This is done to ensure that there is a high statistical likelihood that the prostate will be entirely covered by the radiation beams during each of the prescribed daily treatments. Van Herk *et al.*[2] proposed that to ensure a minimum dose to the clinical target volume (CTV) of 95% for 90% of the patients, the margin around the CTV should be 2.5 multiplied by the SD of the overall systematic error and 0.7 times the SD of the overall random error. Stroom *et al.*[3] calculated a similar relationship. It is important to note that in order to calculate these margin recipes, it is necessary to collect data pertaining to a department's set-up error, and electronic portal imaging provides this vital component.[2,3]

With the onset of dose escalation and greater planning target volume (PTV) conformity, the need for accuracy in field placement has never been higher. The emergence of amorphous silicon electronic portal imaging (EPI) and associated streamlined analytical software has given us the opportunity to place treatment fields in the correct position each day.

At the Ballarat-Austin Radiation Oncology Centre (BAROC), a radical treatment plan for locally advanced prostate cancer consists of delivering 74 Gy over 37 fractions. Conformal radiation therapy, where the shape of the treatment fields closely conform to the shape of the target volume is the method of administering the radiation therapy at BAROC.[3] The technique utilised at BAROC to treat prostate patients is a five-field conformal radiation beam arrangement.

During the initial treatment anterior and right lateral images are taken pre treatment.

The location of the treatment field is compared to a reference image, known as a digitally reconstructed radiograph (DRR). A comparison is then performed between these two images using

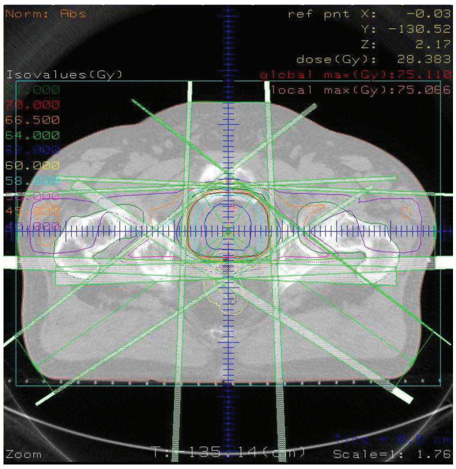

Figure 1a Theoretical Plan.

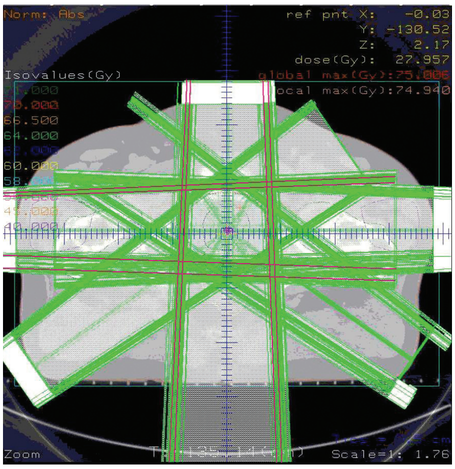

Figure 1b Actual treatment under protocol conditions.

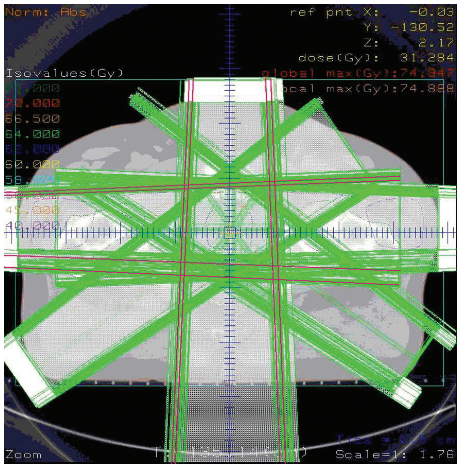

Figure 1c Hypothetical treatment without any form of OC.

the inherent bony anatomy of each image. Should the acquired pre-treatment portal image reveal that the field centre varies from the intended position by more than 5 mm, the radiation therapists re-enter the treatment room and adjust the patient's position accordingly. This move is known as an online correction (OC). If a shift in field placement is made during the initial treatment it is documented and verified the next fraction with pre treatment images. After two fractions of field placement being verified correct as a pre-treatment procedure, single images are then taken on the anterior and right lateral fields during treatment on a daily basis. Each image is then analysed on a daily basis after treatment or offline by one radiation therapist (RT) and one senior RT. If this analysis identifies field placement outside a 5 mm action threshold on any of the orthogonal axes pre treatment images are required before the next fraction. Analysis of this field position is then performed with the patient on the bed. If required, an OC will then be performed. It is considered the RT's responsibility to ensure accurate field placement and required moves in field placement are at the RT's discretion. This is a move away from the traditional approach of field shifts being the responsibility of the radiation oncologist (RO). Traditionally, the practicalities of performing and developing megavoltage port films meant verification of field position was traditionally done on a once weekly basis and any corrections made offline. It is, however, important to note that a field shift carried out by RTs occurs within the confines of a geometrical, not clinical, consideration.

Once weekly, the RO reviews the acquired images as a movie loop with an RT present. This exercise facilitates discussion, analysis of trends and provides a teamwork approach towards field placement. It eliminates the problem of delays in image analysis and subsequent action needed which can be a significant factor in the efficiency of image management. This study aimed to introduce to the radiation therapy team that OC were a valuable and vital tool in the quest for accurate field placement, and the radiation therapist was the logical and appropriate member of the team to carry these out. The study hoped to illustrate that by introducing RT led OC, we could increase the accuracy of our treatment and potentially look to reduce margins and dose escalate.

Method

Ten radical prostate patients were selected on a random basis to provide field placement data for this study. Ethics approval was not required as the treatment delivered was within departmental policy and results analysis was retrospective.

Anterior and right lateral images were taken daily for 37 fractions, within the confines of the BAROC EPI field placement policy. Bony anatomy matches were performed on each of these images. From these data the field position along each of the orthogonal axes can be exported directly into a spreadsheet and analysed. Statistical analysis of field placement was then undertaken with data broken down into pre- and post-intervention, incorporating both systematic and random components of set-up error. Correlation analysis was also carried out on each of the orthogonal axes.

A case study was then carried out on a randomly selected 67-year-old man with clinically localised prostate cancer from our patient population. Seventy four Gy in 37 fractions was prescribed with a CTV outlined that consisted of the prostate. The PTV was a three dimensional expansion. This incorporated an expansion 1 cm superiorly, inferiorly, anteriorly and right and left. The posterior expansion was 0.6 cm. It is policy at BAROC that the PTV be surrounded by the 95% isodose line, which in this case was 70.3 Gy. This treatment was to be delivered by anterior, right lateral, left lateral, right posterior oblique and left posterior oblique fields.

Using this data, it was then possible to enter every isocentre position for 37 fractions into the treatment planning system (TPS). Three sets of dosimetry were then analysed;

1 The original plan with expected isocentre maintained for 37 fractions (Figure 1a);
2 What was actually treated on a daily basis, utilising field placement data, incorporating OC (Figure 1b); and
3 What could have been treated if we did not use OC, in other words the worst case scenario (Figure 1c).

Dose volume histrograms (DVH) were prepared and analysed for each of the above scenarios, allowing detailed plan comparison and analysis. This allowed direct comparisons to be made between plans and also to move forward and compare tumour control probabilities (TCP).

Results

Analysis of isocentre set-up

The Faculty of Radiation Oncology Genito-Urinary Group (FROGG)[4] has presented *Consensus Guidelines for 3-D Conformal Radiotherapy in Prostate Cancer.* It has been recommended that to escalate doses to 74 Gy, 90% of treatment isocentres must be within 5 mm of the planned isocentre. The presented data indicates that utilising online corrections (within the confines of the

MM	PRE CORRECTION				PST CORRECTION		
SYSTEMATIC	x	y	z		x	y	z
MEAN	-0.63	0.3	0.95	MEAN	-0.008	0.36	1.13
SD	1.98	1.41	0.96	SD	0.84	1.43	1
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

Figure 2.

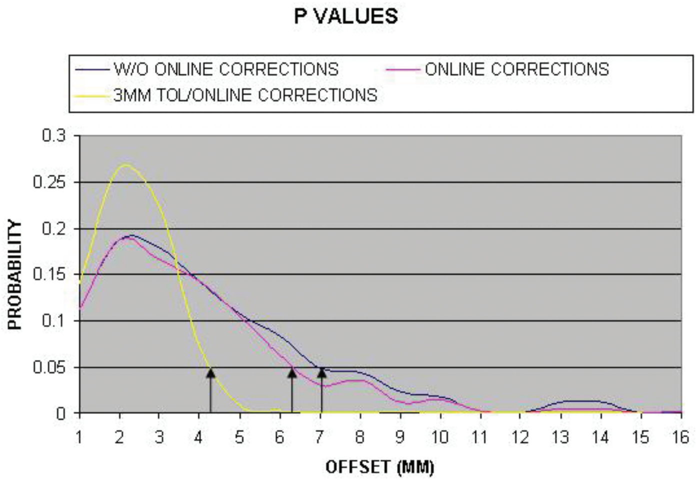

Figure 3.

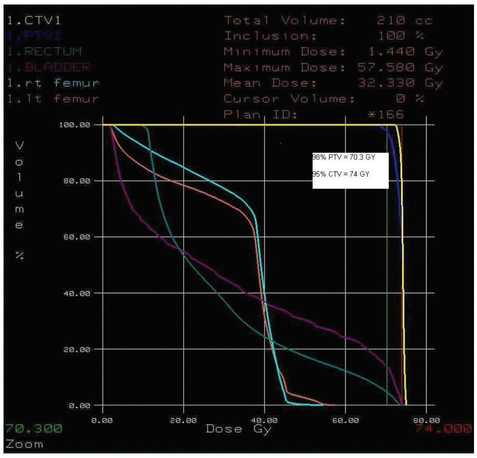

Figure 4a DVH 1.

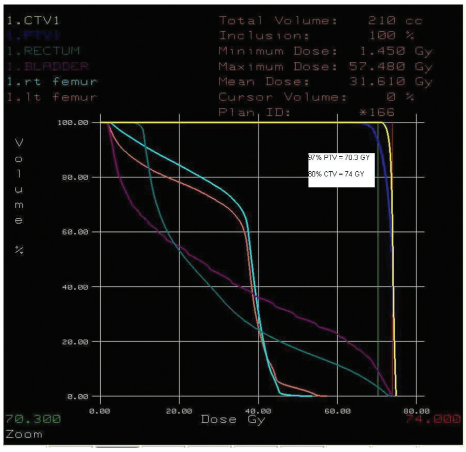

Figure 4b DVH 2.

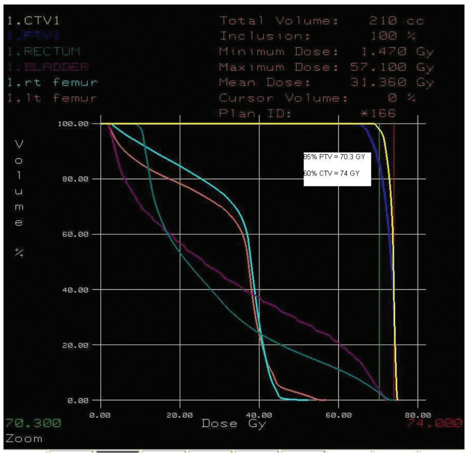

Figure 4c DVH 2.

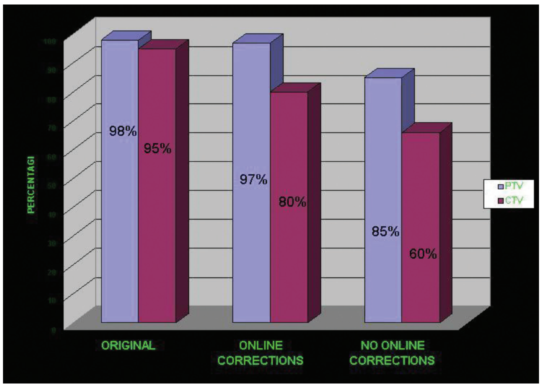

Figure 4c Comparison.

BAROC EPI policy) we were able to achieve a figure of 86%, while without OC this figure dropped substantially to 75%.

Analysis of isocentre set-up errors on a daily basis revealed that there were relatively constant set-up errors along each of the orthogonal axes throughout the course of treatment. Of the total number of fractions, 11% delivered required corrective action and these were located randomly throughout both individual courses and as a whole.

Analysis of data using the outlined protocol supports previous research[5,6,7,8] that a combination online/offline correction policy is very effective in managing the systematic component of set-up error but has little impact on the random component. This is illustrated in Figure 2. Statistical analysis of these 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 this data has been achieved with a combination online/offline approach,[9,10] but there has been negligible impact on random positional errors.

Probability distributions were calculated for offsets on the X- and Y-axis and then calculated as a total. Statistical analysis of the data without OC showed that a 95% CI was located at ± 7 mm on each of the orthogonal axes. It can be concluded from this that we can be 95% certain that field placements are going to fall within ± 7 mm along each of the orthogonal axes and that this is a real event, it is not happening by chance.

Utilising OC within the confines of the outlined protocol a 95% confidence interval of ± 6 mm was achieved, and for the hypothetical situation of a 3 mm tolerance utilising OC a 95% confidence interval value of ± 4 mm could be achieved (Figure 3).

Case study

Dose volume histograms (DVH) for each of the three aforementioned scenarios are represented in Figures 4a, b, c and d. These findings indicated that there was a substantial difference in dose delivered to both CTV and PTV between the three plans. Dose delivered to the PTV ranged from 98% receiving 70.3 Gy for the original plan, 97% received 70.3 Gy using OC, while without OC only 85% of the PTV reached that figure.

In terms of the CTV, 95% received 74 Gy for the original plan,

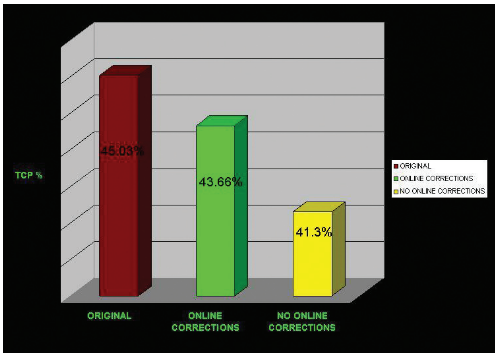

Figure 5 TCP.

80% using OC and a reduction to 60% without using OC.

These outcomes in turn also impact on tumour control probability (TCP) (Figure 5). For the original plan a TCP of 45.03% was recorded, for OC a value of 43.66% and without OC a value of 41.3%.

Discussion

Analysis of isocentre set-up

These data indicated that there were no preferences within the orthogonal axes with displacements in the anterior direction occurring as often as the posterior direction, with the same relationship holding true for both superior-inferior and right to left displacements. Correlation analysis supported these findings showing a negligible Pearson's co-efficient for each of the related displacements (Figures 6a, b).

As supported by Alasti *et al.*[11] the presented data indicates that set-up errors are a random phenomenon. This is due in effect to a combination online/offline correction protocol being only an indirect and incomplete determination of the target volume at the time of treatment.[8]

This contrasts with the findings of Mubata *et al.*[9] who reported a decrease in the magnitude of set-up errors in all directions after the initial few treatments.

FROGG also recommends that, as a minimum, an anterior and right lateral port film should be taken at least weekly during treatment, ideally daily during the first week of treatment. This approach supports the findings of several studies[9,10] that isocentre verification is only needed for the first few fractions, after which the frequency of isocentre verification can be reduced, typically, by weekly checks. However, the results of this study indicate that daily imaging and isocentre verification throughout the course of treatment[8, 9] is a vital and necessary tool to improve the accuracy of field placement. Herman *et al.*[6] noted that EPIs can readily identify systematic and random variations for individual patients, and their analysis provides the means to achieve rapid pre-treatment correction of radiotherapy field positioning.

Case study

Using OC within the confines of the BAROC EPI policy enabled the treatment to come close to the expected outcome, yet still fell short in terms of expected accuracy, while not utilising OC had a significant impact on dose delivered both to CTV and PTV.

Nahum *et al.*[12,13] reported that dose deficit to volumes inside the tumour may have dramatic consequences (5% of the volume irradiated to 80% of the prescribed dose makes the TCP decrease by 18%). The results indicate that inaccuracies in field placement can cause the introduction of cold spots, as evidenced in a reduction in dose to the CTV.

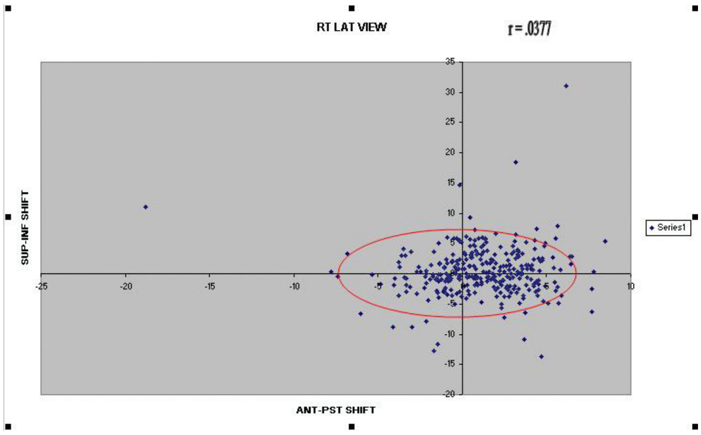

Figure 6a RT lateral view.

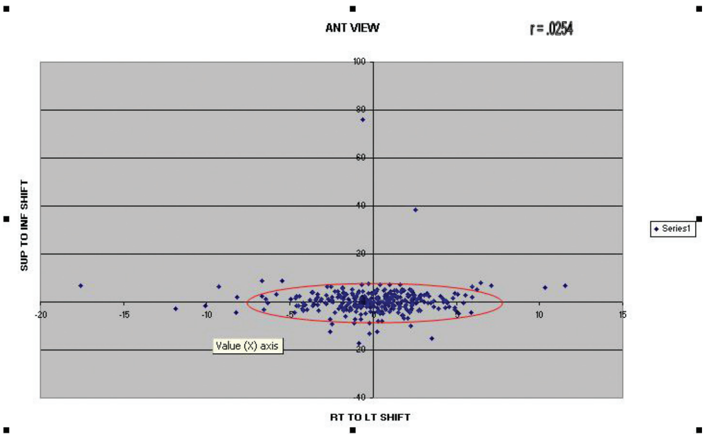

Figure 6b Anterior view.

In this particular case study, 5% of the volume irradiated to 59 Gy would decrease the TCP by 18%. The minimum dose received without the use of OC was 68 Gy but theoretically this extreme situation could arise. The TCP results should be seen as a research tool to estimate the effects of different dose distributions and as an aid to evaluate treatment plans, but it seems clear that with dose escalation TCP values will increase. However, in order to escalate dose safely, greater accuracy in field placement is required. These results indicate that OC pave the way for further dose escalation and thus an increase in TCP.

Conclusions

As demonstrated by the presented results, the introduction of OC can and does make a significant difference to the accuracy of a treatment course when considering bony anatomy referencing as the method for correct field placement. It is important to note that a combination online/offline approach as used in this study is very effective in managing the systematic component of set-up error, but has little impact on the random component. However, our case study illustrated that the dosimetric effects on both DVH and TCP are improved with the introduction of OC into clinical practice. These results indicate outcomes for the patient can be improved when incorporating generational change to treatment philosophies, such as the introduction of OC.

In order to achieve the FROGG recommendation of 90%[4] of treatment isocentres to be within 5 mm of the planned isocentre, several factors need to be considered. An action threshold of less than 5 mm, the presented results indicate 3 mm combined with imaging and field verification on a daily basis are vital for accurate field placement and safe dose escalation.

This study has formed the foundation for continuing work at BAROC that has resulted in the introduction of a complete OC protocol and a move from bony anatomy to implanted prostate gold seed fiducials. As a result of this work, CTV-PTV margins have been reduced and dose escalated to 78 Gy. This has occurred due to the dedication and motivation of the RT group, and a recognition that accurate field placement at BAROC is the radiation therapist's responsibility. This level of responsibility is considered appropriate, as the RT group is the only group feasibly in the position to perform an online correction on a daily basis. This extra responsibility has been welcomed by the RT group, and by radiation oncology specialists. OC are an area that RTs can embrace, and that can only serve to enhance the skills, professionalism, empowerment and growth as a profession. They are an extension of the RT role that can 'increase job satisfaction, professional standing and respect amongst others in the health care field'.[14,15]

This study has indicated the benefits of utilising both new technologies for correct field placement and importantly the development of roles and responsibilities amongst professional groups within the radiation oncology treatment environment. It has indicated that change in policy and procedure from one professional group to another can be achieved harmoniously among team members, and significantly provide a great improvement for patient treatment outcomes.

References

1 Nederveen AJ, Dehnad H, Uulke A, van der Heide A, van Moorselaar A, Hofman P, Lagendijk J. Comparison of megavoltage position verification for prostate irradiation based on bony anatomy and implanted fiducials. *Int J Radiat Oncol Biol Phys* 2003; 68: 81–8.

2 Van Herk M, Remeijer P, Rasch C, Lebesque JV. The probability of correct target dosage: dose population histograms for deriving treatment margins in radiotherapy. *Int J Radiat Oncol Biol Phys* 2000; 47: 1121–35.

3 Stroom JC, de Boer JCJ, Huizenga H, Visser AG. Inclusion of geometrical uncertainties in radiotherapy treatment planning by means of coverage probability. *Int J Radiat Oncol Biol Phys* 1999; 43: 905–19.

4 Skala, M, Berry, M, Duchesne, G, Gogna, K, Kneebone, A, Tai KH, Turner, S. Consensus guidelines ofr 3D conformal radiation therapy (3DCRT) in prostate cancer. Faculty of Radiation Oncology Genito-urinary Group 3DCRT workshop May 2002.

5 Balter J, Sandler H, Kwok L, Bree R, Lichter A, Ten Haken R. Measurement of prostate movement over the course of routine radiotherapy using implanted markers. *Int J Radiation Oncology Biol Phys* 1995; 31 (1): 113–18.

6 Herman M, Pisansky T, Kruse J, Prisciandaro J, Davis B, King B. Technical Aspects of daily online positioning for three-dimensional conformal radiotherapy using an electronic portal imaging device. *Int J Radiation Oncology Biol Phys* 2003; 57 (4); 1131–40.

7 Michalski J, Graham M, Bosch W, Wong J, Gerber R, Cheng A, Tinger A, Valicenti R. Prospective clinical evaluation of an electronic portal imaging device. *Int J Radiation Oncology Biol Phys* 1996; 34 (4): 941–51.

8 Bergstrom P, Lofroth P, Widmark A. High-precision conformal radiotherapy (HPCRT) of prostate cancer – a new technique for exact positioning of the prostate at the time of treatment. *Int J Radiation Oncol Biol Phys* 1998; 42 (2): 305–11.

9 Mubata CD, Bidmead AM, Ellingham LM, Thompson V, Dearnaley DP. Portal Imaging protocol for radical dose-escalated radiotherapy treatment of prostate cancer. *Int J Radiat Oncol Biol Phys* 1998; 40: 221–31.

10 van Lin E, van der Vight L, Witjes J, Huisman J, leer J, Visser A. The effect of an endorectal balloon and off-line correction on the interfraction systematic and random prostate position variations. A comparative study. *Int J Rad Oncol Biol Phys* 2005; 61 (1): 278–88.

11 Alasti H, Petric P, Catton C, Warde P. Portal imaging for evaluation of daily on-line setup errors and off-line organ motion during conformal irradiation of carcinoma of the prostate. *Int J Radiat Oncol Biol Phys* 2001; 49: 869–84.

12 Nahum A. Modelling Tumour Control Probability and Consequences for Treatment Planning. In: Estro Teaching Course on 'Conformal Radiotherapy in Practice'; 2000 June 4–8 Amsterdam.

13 Webb S, Nahum AE. A model for calculating tumor control probability in radiotherapy, including the effects of dose and clonogenic cell density. *Phys Med Biol* 1993; 38.

14 Hall R, Kleemann S, Egan I. The Red Dot System: The outback experience. *The Radiographer* 1999; 46 (2): 83–7.

15 Field-Boden QC. The Red Dot System, what is it and where is it going? *The Radiographer* 1997; 44 (2): 126–29.