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Original Article

The dosimetric impact of supplementing pre-planned prostate implants with discretionary ^{125}I seeds

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Abstract

Introduction: Prostate implants at the British Columbia Cancer Agency are performed using a pre-planned technique. Physicians can augment the dose distribution using one to five non-planned 'extra' seeds and this option is determined without intraoperative feedback. The purpose of this research is to quantify the dosimetric impact of extra seeds and to assess the circumstances under which they are considered necessary.

Materials and methods: Implanting physicians used a questionnaire to record the three-dimensional location and their rationale for using extra seeds. A plan reconstruction algorithm was used to distinguish the extra seeds from the planned seeds. Distributions with and without extra seeds were calculated to quantify the dosimetric impact to the prostate, urethra and rectum.

Results: Extra seeds resulted in mean relative increases to V_{100}, V_{150} and V_{200} of 3·7%, 13% and 19·1%, respectively. Mean prostate D_{90} increased from 147 to 156 Gy. Improvements in post-implant quality assurance codes were recorded in 30% of the implants with minimal dose increase to the rectum and urethra. Extra seeds were mainly deposited in the prostate anterior–superior quadrant.

Conclusions: The use of two to five extra seeds can result in improvements to pre-planned prostate implants, whereas the costs in terms of increased rectal and prostatic urethral dose are relatively minor.

Keywords: prostate cancer; low dose rate brachytherapy; non-planned seeds

INTRODUCTION

Permanent implant (LDR) prostate brachytherapy is a standard and effective treatment for localised prostate cancer. The British Columbia Cancer Agency (BCCA) Prostate brachytherapy programme was established in 1998, and to date more than 3,250 patients have received LDR permanent ^{125}I seed implantation. Recently published BCCA results demonstrate a 5-year freedom from biochemical recurrence rate of 95·6% for low-risk [prostate-specific-antigen (PSA) ≤10, Gleason score (GS) ≤6, clinical stage T1c–T2b] and low-tier intermediate risk (PSA 10–15 and GS ≤ 6 or

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PSA ≤ 10 and GS = 7) patients.[1] Excellent outcomes following permanent brachytherapy have widely been reported in both academic and community settings internationally.[2–5]

All implants performed by the BCCA group use a pre-planned, 'real-time', ultrasound-guided transperineal technique that was pioneered by physicians at the Seattle Prostate Institute.[6] Detailed descriptions of the BCCA prostate brachytherapy treatment planning process have been previously published.[7,8] In summary, transrectal ultrasound (TRUS) volume study images are transferred to the VariSeed planning system (Varian Medical Systems, Palo Alto, CA, USA) and the planning target volume (PTV) is outlined. A modified peripheral seed placement system is used for treatment planning to deliver a minimum peripheral dose (mPD) of 144 Gy to ≥98% of the PTV with 2–5 mm margins in all directions, except posteriorly where no margin is added. The planning strategy ensures excellent PTV coverage by constraining the 150% horse-shoe-shaped isodose coverage to the peripheral prostate zone and therefore limiting dose to the urethra (Figure 1). Stranded ^{125}I seeds (RAPIDStrand, Oncura, Arlington Heights, IL, USA) are utilised at a fairly low activity (0·424 U). At the completion of the implant, an additional one to five non-planned (extra) seeds may be deposited under fluoroscopic guidance to augment the dose distribution. As we use a pre-planned technique, potential need for extra seeds is determined without the aid of intraoperative feedback; however, instead, the decision to use extra seeds is an empirical one based on the experience of the implanting physician and is accomplished using fluoroscopy and US images.

Post-implant analysis of the implant is performed as recommended by the American Brachytherapy Society,[9] immediately following the procedure (day 0). The CT images are transferred to the VariSeed treatment planning system and the seeds are identified using a combination of automatic and manual methods. The radiation oncologist contours the prostate, urethra and rectal volume on each CT data set, and the following dosimetric parameters are calculated by the VariSeed software: post-operative D_{90} (dose covering 90% of the prostate volume), V_{100}, V_{150} and V_{200} (fractional volume of the prostate covered by 100%, 150% and 200% of the prescription dose respectively), VR_{100} (volume of the rectum receiving 100% of the prescribed dose) and mean urethral dose. This reflects the dose deposited from both the planned and extra seeds.

Although extra seeds are used by BCCA brachytherapy physicians, their dosimetric impact and biological effectiveness has remained unclear because until recently they could not be reliably distinguished in the post-implant dose distribution. The purpose of this study was to quantify the dosimetric impact of extra seeds and to assess the circumstances under which extra seeds are considered to be potentially necessary.

MATERIALS AND METHODS

The study consisted of a convenience sample of 73 consecutive patients implanted between January and May 2010 by five radiation oncologists practicing brachytherapy at the Vancouver Cancer Center (VCC). A peer-reviewed questionnaire regarding use of the extra seeds was completed on each patient by the implanting radiation oncologist. The questionnaire was used to record the location of deposited extra seeds, along with the rationale for using the extra seeds. University of British Columbia-BCCA research ethics board approved the study.

All study patients received a day 0 post implant CT scan as per the standard BCCA brachytherapy programme quality assurance (QA) process. The scan limits were 20 mm cranial and caudal to the visible implanted seeds (slice interval 2·5 mm). The CT images were transferred to VariSeed and the prostate, prostatic urethra and rectum were contoured by the radiation oncologist who performed the implant.

To distinguish the extra seeds from the pre-plan, an in-house plan reconstruction algorithm[10] was used to determine the correspondence between planned and post-implant source positions. This implies connectivity between stranded sources in the CT data set, which is displayed for visual verification (Figure 2). All reconstructions were initially completed by the principal investigator (N.M.P.) and these were subsequently

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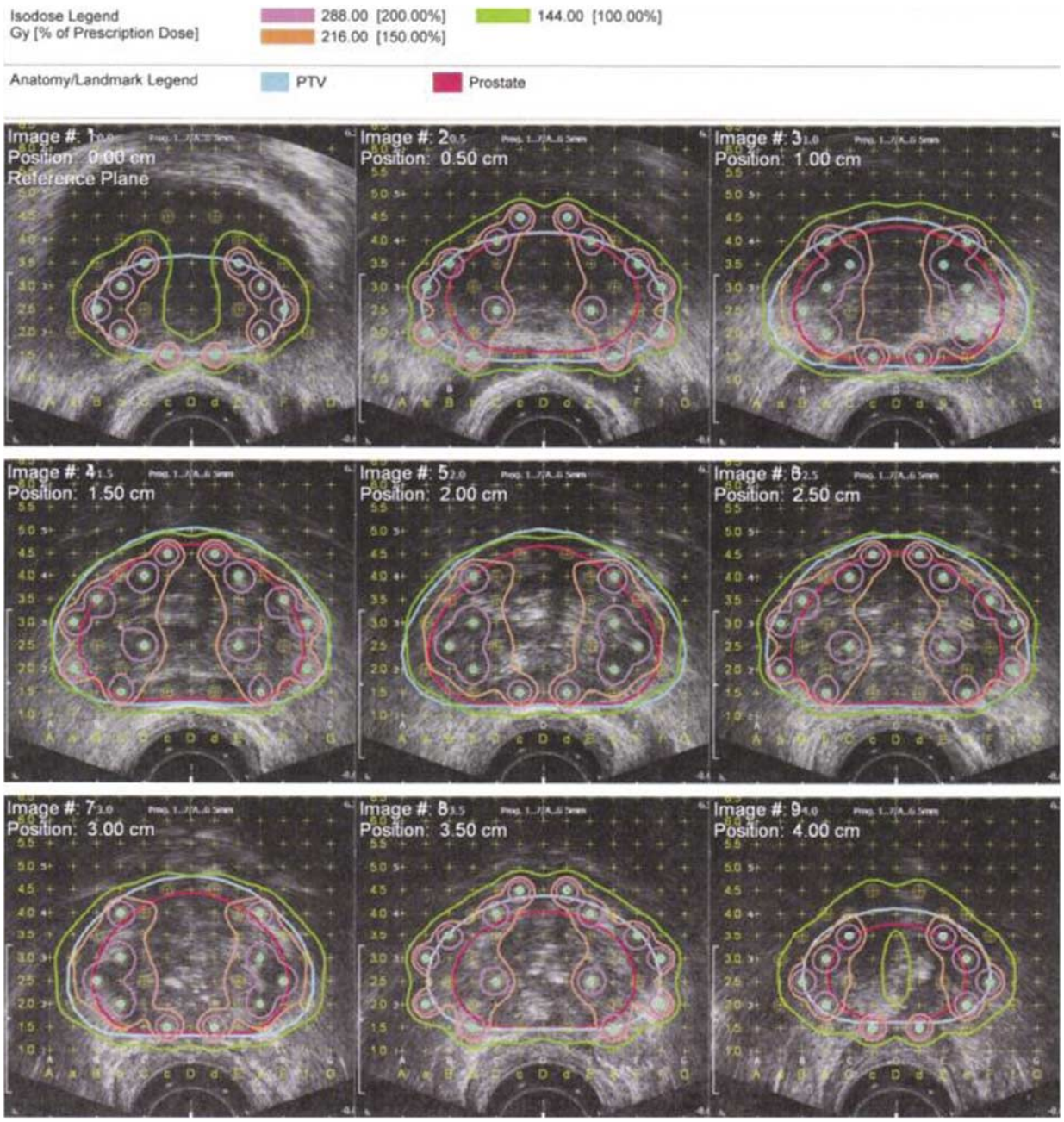

Figure 1. An example of a typical British Columbia Cancer Agency treatment plan. The PTV is encompassed by the 100% isodose line and the 150% horse-shoe-shaped isodose encompasses the peripheral prostate while sparing the urethra. Reproduced in colour in the online version.

independently reviewed (N.C.) to ensure consensus on all reconstructions. Once the positions of the extra seeds were determined, two sets of seed coordinates were exported to VariSeed. The first contained the entire implant (pre-plan + extra) and the second only the planned seeds (pre-plan only). Plan reconstruction was performed on all implants regardless of whether extra seeds were used to verify the accuracy of the localised seeds by requiring that they be sensibly organised into strands at the strand-constrained spacing. For each patient, post-implant dose distributions and dosimetrics were calculated for both seed distributions in VariSeed.

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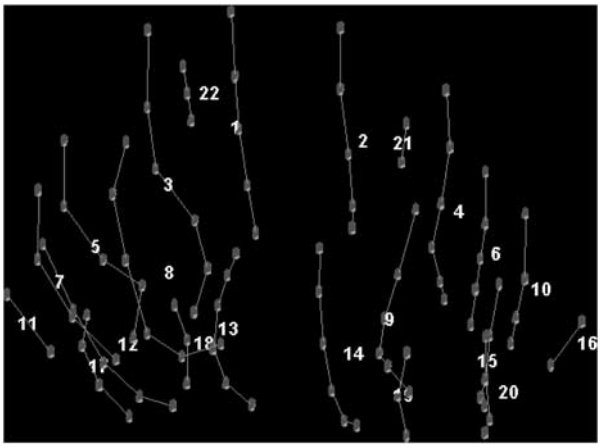

Figure 2. An example of the post-implant reconstruction of stranded seeds using in-house MATLAB® software. Strands #22 (three seeds) and #21 (two seeds) have been identified as the extra seeds. All other strands represent the planned seeds. The extra seeds can be deleted from the reconstruction so that two sets of seed coordinates are available for the same implant.

For the whole prostate, D_{90}, V_{100}, V_{150} and V_{200} were compared between the distributions with and without the extra seeds. In addition, the prostate was segmented into four quadrants and dosimetry recorded separately for D_{90} and V_{100} in anterior–superior (ASQ), anterior–inferior (AIQ), posterior–superior (PSQ) and posterior–inferior (PIQ) quadrants. These quadrants are created by bisecting the prostate along the mid-transverse and mid-coronal planes. The dose to the rectum was recorded as the VR_{100} and VR_{150}, the volume of rectum in cubic centimeters receiving 100% and 150% of the prescription dose, respectively. For the urethra, the following parameters were recorded: Ur150, the volume of the urethra in cubic centimeters receiving 150% of the prescription dose, the mean urethra dose, and UrD5 and UrD30, the dose in Gy to 5% and 30% of urethra, respectively.

The statistical package for the social sciences (SPSS, version 14·0, SPSS Inc., Chicago, IL, USA) was used to calculate the descriptive statistics for this project.

Quality thresholds

The BCCA brachytherapy provincial programme uses an in-house planning algorithm, which aims for a planned $V_{100} \geq 99\%$ and a D_{90} of 166–187 Gy. Post-implant analysis is performed and the implants are classified using the following QA standards for implant quality[11]: Excellent = $V_{100} \geq 90\%$, $D_{90} \geq 144$ and <180 Gy; Good = V_{100} 85–90%, $D_{90} = 130$–144 or 181–200 Gy; Sub-optimal = $V_{100} < 85\%$, $D_{90} < 129$ or >200 Gy, The percentage of implants that changed in QA code as a result of using extra seeds was calculated.

Table 1. *Summary of study cohort characteristics*

Age (years)	64 (51–77)
iPSA (ng/ml)	7 (2·2–18·0)
Clinical stage	
T1c	28/70 (40%)
T2a	22/70 (31%)
T2b	15/70 (21·5%)
T2c	4/70 (6%)
T3a	1/70 (1·5%)
Gleason score	
6	15/70 (21%)
7 = 3 + 4	37/70 (53%)
7 = 4 + 3	16/70 (23%)
8 = 3 + 5	1/70 (1·5%)
8 = 4 + 4	1/70 (1·5%)
Percent positive cores	
≤50	41/70 (59%)
≥50	29/70 (41%)
Total cores biopsied	8 (2–12)
Risk category	
Low	12/70 (17%)
Low-tier intermediate	40/70 (57%)
High-tier intermediate	18/70 (26%)
ADT used	
Yes	16/70 (23%)
No	54/70 (77%)

Note: Values expressed as median (range), number (%).
Abbreviations: ADT, androgen deprivation therapy; iPSA, initial prostate-specific antigen.

RESULTS

Frequency and distribution of extra seed use

A total of 73 prostate implants were completed at VCC during the 4-month data collection phase of this study. Three implants were excluded because the questionnaires were not completed. The characteristics of the 70 patients who make up this study cohort are summarised in Table 1.

The median number of pre-planned seeds was 105. Extra seeds were used in 58/70 (83%) of the implants. All oncologists used extra seeds in the majority of their cases, with all five

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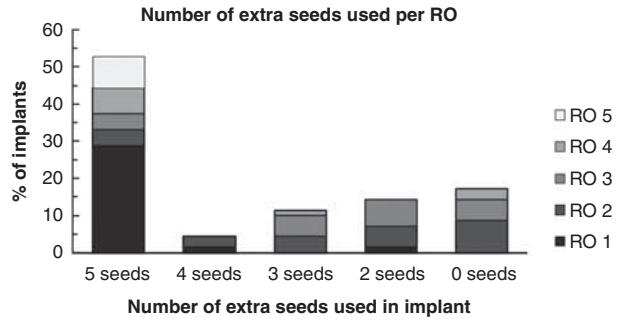

Figure 3. Seventy patients were implanted by five radiation oncologists (RO). In 58 implants, extra seeds were used, with a mean of 4·15 extra seeds used per implant (median 5, range 2–5).

extra seeds used in 53% of implants (Figure 3). The tendency to use all five extra seeds was strongly correlated with the implanting oncologist [RO 1 (20/22 implants) and RO 5 (6/6) implants]. The location of the extra seeds was recorded according to the quadrant in which they were found during post-implant analysis. The majority of the extra seeds were deposited in the ASQ (64%) and less frequently in other quadrants; PSQ (24%), AIQ (7%) and PIQ (5%).

As part of the post-implant questionnaire, data were collected to establish the rationale for using (or not using) extra seeds. The most common reasons that extra seeds were considered unnecessary were when the intraoperative estimated dose distribution from the ultrasound and/or fluoroscopic image was good (45%), and when there was sufficient confidence that the planned seeds were placed correctly (25%). Less popular reasons were the avoidance of a 'hot' distribution (12%) and patients with low bulk of tumour (13%). The most commonly reported reasons justifying the use of extra seeds were to improve coverage of the anterior base (43%), and target regions of biopsy confirmed cancer (26%). Perceived 'cold areas' (22%), seed misplacement (8%) and changes in the prostate shape (1%) were also noted as reasons as to why extra seeds are used.

Target coverage

The use of extra seeds resulted in increases to whole prostate V_{100}, V_{150} and V_{200} (Table 2). The mean cohort V_{100} increased from 90·5% to 93·8%,

Table 2. *Whole prostate V_{100}, V_{150} and V_{200} values calculated with and without extra seeds*

	V_{100} (%)			V_{150} (%)			V_{200} (%)		
	(+) extra seeds	(−) extra seeds	% ↑	(+) extra seeds	(−) extra seeds	% ↑	(+) extra seeds	(−) extra seeds	% ↑
Mean ± SD	93·83 ± 3·69	90·5 ± 4·53	3·74 ± 2·53	50·57 ± 8·91	44·99 ± 8·70	12·95 ± 6·9	15·92 ± 5·13	13·46 ± 4·58	19·08 ± 11·54
Median	94·57	91·60	3·24	51·44	45·74	12·60	15·21	13·45	15·39
Minimum	73·12	70·81	0·47	21·02	20·36	3·24	5·67	5·42	2·48
Maximum	98·11	96·92	12·74	67·12	64·73	35·70	25·82	24·53	50·10

Notes: (+) is calculation with extra seeds included in the post-implant distribution and (−) is the calculation excluding the extra seeds. The percentage increase (% ↑) that results from the extra seeds use is also shown.
Abbreviation: SD, standard deviation.

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a mean improvement of 3·3% (95% CI, 2·8–3·9%). The case with the most improvement had an increase in V_{100} from 83·3% to 93·9%, whereas in the case with the least improvement the change was minor, increasing from 94·4% to 94·8%. With respect to D_{90}, the use of extra seeds resulted in a mean absolute increase of 9·1 Gy (95% CI, 8·1–10·2 Gy) resulting in an increase in the mean of the cohort from 146·8 to 155·9 Gy.

Implant V_{150} rose for the cohort by a mean of 5·6% (95% CI, 4·9–6·2%). The V_{200} increased by a relatively larger extent compared with the V_{100} and V_{150}, with a mean relative percentage increase of 19·1% versus 3·7% and 13·0%, respectively. However, in absolute terms, this only increased the mean V_{200} by 2·5% (95% CI, 2·1–2·9%).

Quadrant analysis

The quadrant analysis found that extra seeds had the most impact on the ASQ coverage, in line with the stated goals of their use. The mean cohort ASQ V_{100} increased from 74% to 83% with a mean increase in absolute terms of 9·2% (95% CI, 7·6–10·7%). In addition, the maximum relative increase in V_{100} (60·5%) was recorded in the ASQ (ASQ V_{100} 51·2% increased to 82·2%). In comparison, the effect of extra seeds on V_{100} for the other three quadrants were small (Figure 4) as they were less typically implanted in these regions. The mean increases in absolute V_{100} for the PIQ, PSQ and AIQ were 0·31% (95% CI, 0·2–0·4%), 0·9% (95% CI, 0·7–1·1%) and 1·75% (95% CI, 1·3–2·2%), respectively.

The largest increases in D_{90} values were also recorded in the ASQ with the cohort mean rising from 123·4 to 134·3 Gy, an improvement of 10·9 Gy (95% CI, 9·3–10·9 Gy). Relative increases in D_{90} for the remaining quadrants were more moderate at 4·3 Gy (95% CI, 3·5–5·1 Gy) for the PIQ, 6·6 Gy (95% CI, 5·1–8·0 Gy) for the PSQ and 6·5 Gy (95% CI, 5·3–7·8 Gy) for the AIQ.

Dose to the rectum and urethra

The dosimetric impact of extra seeds on the prostatic urethra and the rectum are summarised

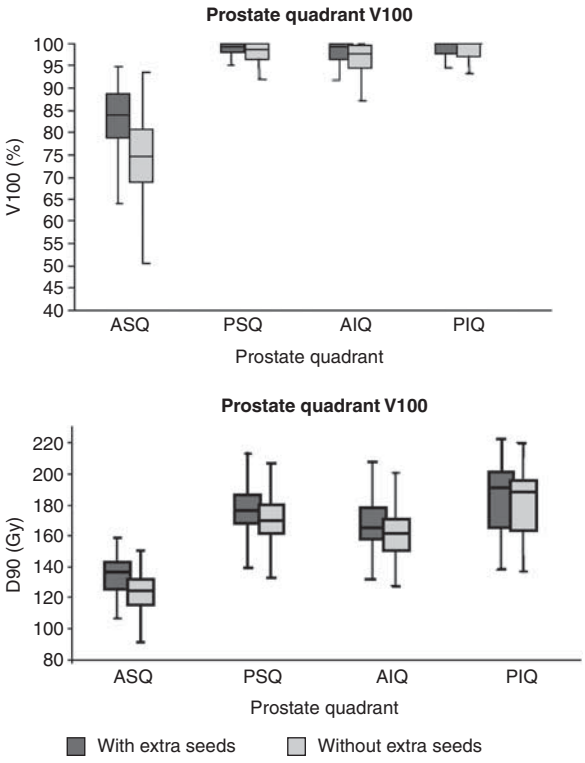

Figure 4. Box plot shows median, range and inter-quartile range for the prostate quadrant V_{100} and prostate quadrant D_{90}. Post-implant quadrant analysis of the prostate demonstrated that the anterior–superior quadrant (ASQ) contained lower D_{90} and lower V_{100} values than the other three quadrants. However, the use of extra seeds did result in a relatively larger increase in the V_{100} and D_{90} values for the ASQ compared with the increases recorded in the other quadrants.

in Table 3. The mean urethra dose increased by a mean of 5·8 Gy (95% CI, 5·0–6·6 Gy) resulting in an increase in cohort mean from 134·8 to 140·6 Gy. The minimum increase was 1·2 Gy and the maximum was 15·8 Gy. The UrD30 increased by a mean of 6·1 Gy (95% CI, 5·2–7·0 Gy) with the cohort mean increasing from 166·8 to 172·9 Gy. The UrD5 increased by a mean of 5·8 Gy (95% CI, 5·0–6·6 Gy) resulting in an increase in the cohort mean from 188·5 to 194·3 Gy. The increase in the urethra as measured by Ur150 was negligible (mean Ur150 of 0·04 cc increased to 0·05 cc), and there was no recorded increase in Ur150 for 50/58 (86%) of the patients.

The dose to the rectum as measured by VR_{100} increased from a cohort mean of 0·54–0·58 cc, a mean difference of 0·04 cc (95% CI, 0·02–0·05 cc). In 22/58 (38%) of patients, there was

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Table 3. The dosimetric impact of extra seeds on the prostatic urethra and the rectum

Dose metric	With extra seeds	Without extra seeds	Increase (%)
Mean urethra dose	140·7 (140·6 ± 19·3)	135·0 (134·8 ± 18·7)	4·4 (0·9–11·4)
UrD30 (Gy)	171·0 (172·9 ± 15·8)	167·0 (166·8 ± 16·5)	3·8 (0·0–9·9)
UrD5 (Gy)	194·0 (194·3 ± 21·0)	188·0 (188·5 ± 22·0)	3·24 (0·0–18·5)
Ur150 (cc)	0·00 (0·05 ± 0·12)	0·00 (0·04 ± 0·10)	2·40 (0·0–32·0)
VR_{100} (cc)	0·365 (0·579 ± 0·675)	0·345 (0·543 ± 0·647)	5·90 (0·0–29·0)
VR_{150} (cc)	0·01 (0·036 ± 0·066)	0·01 (0·035 ± 0·063)	0·005 (0·0–0·125)

Note: Values expressed as median (mean ± SD), mean (range).

no change in the VR_{100} measurement, whereas the maximum relative increase (29%) occurred when extra seeds increased the VR_{100} from 0·41 to 0·53 cc. In 55/58 (95%) of the implants, there was no recorded change in the VR_{150}.

Implant quality

An analysis of the V_{100} and D_{90} values after extra seeds were used demonstrated that improvements resulting in changes to the QA codes occurred routinely (Figure 5). The use of extra seeds increased the V_{100} over the 90% threshold in 15/58 (26%) of patients. Five patients (9%) who received dose supplementation would otherwise have been classified as having suboptimal coverage. In 15/58 (26%) patients, dose supplementation increased the D_{90} beyond the 144 Gy threshold for an excellent implant, while shifting the QA code from suboptimal to good in 3/58 (5%) patients.

In the 12 implants where extra seeds were not utilised, the mean whole prostate V_{100} was 92·4% (range 85–99·1%). In terms of V_{100} QA codes, 10/12 (83%) of these implants were excellent and 2/12 (17%) were good. The whole prostate mean D_{90} for these implants was 149 Gy (range 134–174 Gy), with 7/12 (58%) of the implants classified as having an excellent D_{90} and 5/12 (42%) classified as good.

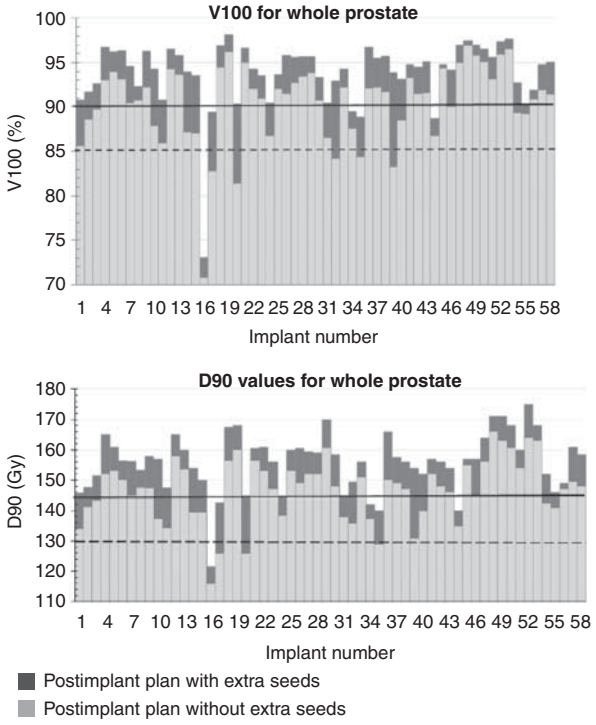

Figure 5. The effect of extra seeds on post-implant dosimetry quality assurance codes. In respect to the whole prostate V_{100} and the whole prostate D_{90} values, the implant is graded as: Excellent, if the V_{100}/D_{90} is above the solid line; Good, if the V_{100}/D_{90} is between the solid and dashed line; and Suboptimal, if the V_{100}/D_{90} is below the dashed line. In the case of implant #16, the patient had a very large prostate and low-risk disease. The radiation oncologists therefore decided a priori to plan a non-standard implant (130 Gy versus 144 Gy with a pre-plan V_{100} of 86%).

DISCUSSION

The predominant rationale for using extra seeds was to optimise coverage to the anterior base of the prostate; 64% of the extra seeds were found to be deposited in the prostate ASQ in post-implant analysis. Previous research at VCC has indicated that the ASQ (as contoured on CT) is disproportionately underdosed relative to other quadrants,[12] and therefore it is not surprising that this region is the principal recipient of dose

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supplementation. This pattern of underdose can be partially attributed to the BCCA planning algorithm, which is designed to avoid excessive dose to the bladder neck and urethra. Anterior source density is significantly lower than that in the posterior, resulting in greater sensitivity to source misplacement, especially in the base where needle deflection and the risk of transgressing the bladder wall are concerns.

The second most common reason to use extra seeds is to optimise dose coverage relative to a biopsy positive region. However, this was mainly favoured by one individual who accounted for 78% of such responses. It is a reasonable expectation that an increase in seed density will yield greater certainty that an ablative dose at the known tumour site has been achieved. However, a subset analysis of the 23 implants in which the seeds were used to optimise biopsy site dose revealed no difference in the mean V_{150} or mean V_{200} compared with the other 35 implants (V_{150}: 50·58% versus 50·57% and V_{200}: 15·54% versus 16·16%). The mean D_{90} for this subset was 157·8 Gy (95% CI; 153·8–161·7 Gy) compared with 154·8 Gy (95% CI; 151·8–157·9 Gy) that was recorded for the other implants. Unfortunately, a more detailed investigation of the accuracy with which the 'boost' was targeted could not be conducted because no delineation of the 'region of boost' was recorded.

Stock et al.[13] completed the first dose–response study for contemporary ^{125}I prostate implants. This study demonstrated a statistically significant improvement in freedom from biochemical recurrence (FFBR) for patients with a post-implant $D_{90} \geq 140$ Gy. The utility of D_{90} as a parameter to predict clinical outcome has been further validated[14,15] with the finding that a significant dose response occurs with $D_{90} \geq 90\%$ of the prescription dose ($\geq$130 Gy). The dosimetric parameter V_{100} has also been reported as a statistically significant predictor of biochemical outcome. Papagikos et al.[16] demonstrated that a $V_{100} \geq 80\%$ had a 5-year FFBR of 91% versus 76% for patients with a $V_{100} \leq 80\%$, whereas others suggest that a higher V_{100} ($\geq$90%) is required to produce a statistically significant dose response.[17] Contrary to these findings, the BCCA brachytherapy group[1] and other institutions[3] with very small numbers of failures in the cohort and excellent dosimetry did not find an association between dosimetric parameters and disease response.

Other large institutions that use a similar pre-plan technique to ours have stated that, although extra seeds are available, they are very rarely used by the implanting physician.[6] However, the results from this study indicate that, in our institution, extra seeds are frequently used and two to five extra seeds can result in a meaningful improvement in implant quality in 30% of the cohort, and ensured that all implants achieved a minimum D_{90} of 140 Gy and a minimum V_{100} of 88·7%. The one exception to this was the implant #16, where a V_{100} of 86% was specified in planning. In the 12 implants in which only planned seeds were used, none of the implants were suboptimal and the mean V_{100} and D_{90} were 92·4% and 149 Gy, respectively.

Prostate quadrant analysis confirms that the ASQ continues to be susceptible to under dosage. Despite the use of extra seeds, the mean ASQ V_{100} remained below the mean V_{100} recorded for all other quadrants. However, extra seeds did result in a substantial improvement to coverage in this quadrant by increasing the mean ASQ V_{100} from 74% to 83% and D_{90} from 123·4 to 134·25 Gy. These V_{100} and D_{90} values compare favourably with previous BCCA quadrant analysis where the ASQ V_{100} and D_{90} were 78·5% and 130·6 Gy, respectively.[12] The extra seeds clearly have the desired effect of increasing the ASQ dose, but the clinical impact of augmenting dose in this quadrant is uncertain. Our recent study examined the correlation between quadrant dosimetry and biochemical relapse in patients.[18] The only quadrant that predicted for disease recurrence was the AIQ, despite the recurring finding that the ASQ received considerably less dose than the other quadrants. This lack of correlation between ASQ dose and biochemical control may be related to the absence of the disease in this region for low risk patients,[19] and/or reflect the difficulties in contouring and typically over contouring ASQ on post-implant CT.[20] Patients with 'high-tier' intermediate risk prostate cancer[21] are eligible for

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prostate brachytherapy at BCCA and our cohort includes 26% of such patients. It is therefore conceivable that these patients might benefit from dose augmentation in this quadrant, as they may have a greater probability of harbouring higher cancer burden in the ASQ. The use of extra seeds can clearly improve coverage to the whole and region-specific zones of the prostate. Overall, the benefit of using extra seeds with respect to biochemical outcome would be difficult to translate into clinically meaningful and measurable outcome. Our in-house treatment algorithm dosimetricaly favours peripheral prostatic zones, which together with wide peripheral margins is most likely a reason for our very high institutional biochemical control rate.[1] The addition of extra seeds to the ASQ is mostly guided by desire to correct misplacement of anterior strands, prone to needle splay and lateral deflection.

In this study, we assessed the effects of using extra seeds in terms of increased dose to the rectum and the prostatic urethra. The association between rectal toxicity and higher rectal dose has been reported by others[22,23] and research from our group would also validate this.[24] We report grade $\geq$2 late rectal toxicity rates of 4·8%, 7·1%, 10%, 8·8% and 12·6% for patients with $VR_{100} < 0{\cdot}6$, 0·6–1, 1–2, 2–3 and >3 cc, respectively. Extra seeds had a very minor impact on the rectum with a median absolute increase in VR_{100} of 0·02 cc. The limited clinical significance is also supported by the fact that, despite the use of extra seeds, the VR_{100} remained below 1 cc for 54/58 (93%) of the implants.

We demonstrated that extra seeds had a minor effect on prostatic urethral dose with a mean and median increase below 5% for all of the urethral dose parameters. The largest absolute dose increase was 31·5 Gy (UrD5 = 170–201·5 Gy), which remains below the 150% of prescription dose (216 Gy) threshold set by the BCCA prostate brachytherapy programme. In 7/58 (12%) of the implants, the UrD5 was above the 216 Gy threshold (maximum UrD5 = 258·5 Gy), but this would have occurred regardless of the addition of extra seeds. Allen et al.[25] concluded that a dose of 145–203 Gy is well tolerated by all segments of the urethra and that urinary morbidity is not correlated with mean or maximum urethral doses. However, segmental urethral dosimetry analysis at our institution has demonstrated very significant dose variation in urethral segment of ASQ, whereas other urethral segments have essentially no dose variation. More so, the higher radiation dose to the urethral base segment was predictive for increased urinary toxicity.[26] Although we did not report segmented urethral doses in this study, it is important to consider that the implantation of extra seeds in the prostate ASQ may result in increased urinary toxicity.

To the best of our knowledge, this is the first study that has examined the dosimetric effect of additional seed in pre-pan LDR brachytherapy. This paper highlights the limitations of the pre-plan technique, where intraoperative modifications of the perceived dose distribution are carried in the absence of intraoperative dosimetric feedback. Intraoperative planning and real-time dynamic dosimetry as recommended by the American Brachytherapy Society[27] allows the physician to make intraoperative adjustments on the basis of instantaneous dosimetric feedback. To date, the implementation of intraoperative planning that is compatible with the constraints of a large public provider like the BCCA has not been realised. However, the results of this study do suggest that in an established programme, and in the context of robust pre-plan and generous margins, the implanting physician is able to make a mental assessment of the seed distribution to determine the need for dose augmentation. The use of non-planned supplemental seeds can result in categorical improvements in implant quality with minimal increase in dose delivered to the rectum and prostatic urethra.

CONCLUSION

Non-planned 'extra' seeds are routinely used at the Vancouver Cancer Centre to augment the dose distribution after the delivery of the planned seeds. With development of our new in house algorithm,[10] we are for the first time able to quantify the dosimetric impact of this approach. These extra seeds are mostly used to increase dose coverage in the ASQ and increase the dose to the known biopsy-positive segments of prostate. The clinical benefit for this

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approach is unknown; however, our biochemical and toxicity results continues to support this approach.[1,18,21,24,26] Increased experience with pre-planned, real-time prostate brachytherapy can result in improvements in whole prostate D_{90} and V_{100} with the use of two to five extra seeds, whereas the costs in terms of increased rectal and prostatic urethral dose are relatively minor.

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