Journal of Radiotherapy in Practice

Journal of Radiotherapy in Practice (2013)
12, 180–186

doi:10.1017/S1460396912000210

Original Article

Improving the identification of male pelvic structures in post-prostatectomy patients on cone-beam CT: a region of interest atlas study

K. Sahota[1], L. Bell[1,2], J. Cox[2], J. Atyeo[1]

[1]*Faculty of Health Science, The University of Sydney, Sydney, Australia,* [2]*Department of Radiation Oncology, Royal North Shore Hospital, Pacific Highway, St Leonards, NSW 2965, Australia*

(Received 11 December 2011; revised 07 February 2012; accepted 08 February 2012)

Abstract

Purpose: To investigate the benefits of a regions of interest atlas for radiation therapists (RTTs) to aid in the identification of male pelvic structures in radiotherapy for prostate cancer, post-prostatectomy.

Methods and materials: Recruiting 35 radiation therapists from the Royal North Shore Hospital, a pretest-post-test study design was employed, with the atlas as the intervention. Using two patient CT data-sets, structure identification was scored as correct or incorrect and RT confidence levels were recorded using a visual analogue scale. The number of years of experience of each RT was also documented. Statistical significance was calculated using the Wilcoxon signed ranks test, paired samples *t*-test and chi-square tests.

Results: A statistically significant improvement was found between the pre-test and post-test in terms of both structure identification ($p < 0.001$) and confidence ($p < 0.001$) levels, with use of the atlas. The atlas was of use to staff of varying experience levels. Structures that were not normally used for target volume localisation were the hardest to identify.

Conclusion: Regions of interest atlases should be implemented to help identification of areas of anatomical complexity.

Keywords

cone-beam CT; prostate cancer; pelvic anatomy; region of interest atlas

INTRODUCTION

In Australia, prostate cancer is the second most common form of cancer and cause of death in men[1]. For treatment, following a prostatect–

Correspondence to: Associate Professor Jennifer Cox, Department of Radiation Oncology, Royal North Shore Hospital, Pacific Highway, St Leonards, NSW 2065, Australia. Tel: +61 2 9926 6029. Fax: + 61 2 9926 6833. E-mail: jcox@nsccahs.health.nsw.gov.au; jenny.cox@sydney.edu.au

omy, adjuvant or salvage radiation therapy is often employed. This is usual when tumour cells are still present in the margins or seminal vesicles, and also when prostate specific antigen, not present immediately after surgery, begins to rise after a period. There is accumulating evidence that adjuvant radiation therapy for these patients is superior to observation alone[2]. Treatment delivery methods have improved dramatically with the ability to deliver higher doses that conform to the outlined planned target volume. Correspondingly, the need for improved imaging modalities to accurately and specifically localise target volumes has also increased[3].

Until recently, bony landmarks in the pelvic area, visualised using electronic portal imaging or kilo-voltage planar imaging, were used to check the alignment of the treatment field prior to radiation delivery, but many institutions are moving to soft-tissue visualisation with volumetric imaging such as cone beam CT[4,5]. In post-prostatectomy patients, it has been shown that the movement of the surrounding organs influences the position of the prostate bed, thereby making bony landmarks alone inadequate for field alignment[5]. Currently there are no guidelines in place for the use of cone-beam CT to aid the delivery of radiation to the target field, which leaves a gap in protocol and knowledge.

Region of interest (ROI) atlases are documents that illustrate the relevant structures in a body area using a series of CT slices. Similar to the clinical situation on the treatment machines, on each slice with both CT and cone beam CT scan images, the atlases show the anatomical structures. These can be used as a reference guide to aid radiation therapists in beam alignment, thereby improving treatment accuracy. Van Kranen and colleagues showed that ROI atlases could improve the identification of the movement of clinically relevant structures in head and neck cancer[4]. Their study incorporated a ROI atlas that was in current clinical use, as well as including structures not in the atlas. They recommended implementation of several ROIs for correction protocols, in addition to those that were already being used. Further studies similar to this need to be undertaken to establish whether the same effect of improving identification using an atlas is transferrable to other anatomical sites, such as the prostate bed[5]. An ROI atlas could potentially become a clinical document used to improve day-to-day accuracy in treatment field set-up for patients with prostate cancer.

This study aimed to analyse the effect of a ROI atlas in assisting radiation therapists (RTTs) to correctly identify structures in the male pelvis of the post-prostatectomy patient. The structures included were determined from the literature and through discussions between a radiation oncologist and an experienced RTT (LB). These structures are those that need to be included within the planning target volume (PTV) and also those that need to be avoided.

The hypotheses for this study were that a ROI atlas would significantly improve the identification of structures by RTTs, as well as increase their confidence in their ability to correctly identify structures. It was also hypothesised that years of experience would influence results, with the younger, more recently educated RTTs performing at a better level. Also it was predicted that some lesser known structures, such as the mesorectal facia, would be harder to identify than others that were commonly known, such as the bladder and rectum.

METHOD

The study was conducted at the Royal North Shore Hospital (RNSH) with ethics approval obtained from Northern Sydney Central Coast Health (1012−00317) and ratified by the University of Sydney (13508). To ensure participant confidentiality, a numerical coding system was generated that was only accessible to the researchers.

Thirty-five radiation therapists from Royal North Shore Hospital were recruited as participants through information sessions conducted at the hospital. Informed consent was gained prior to participation in the study. For each RTT, the length of time they had worked in the profession was recorded.

This quantitative study consisted of a pre-test and post-test design with the ROI atlas considered the intervention. Two retrospective de-identified data-sets were used, of a 67- and a 72-year-old man, who had both undergone radical prostatectomy and been treated by a course of radiation therapy of seven and eight weeks respectively, with the planning target volume defined according to the Australia-New Zealand consensus guidelines[6]. Patient one had implanted surgical clips and patient two did not. Consequently, there were thirteen structures to be identified for patient one, including three clip identifications and ten anatomical structures, and ten structures for patient two. Each image set consisted of a fused CT and one cone-beam CT data set on the 'offline review' system at RNSH, which is very similar to the real clinical situation on the treatment machine when RTTs are assessing field placement.

A pre-written script was read to each participant prior to the test, ensuring that the instructions were the same for each participant. The participants had the list of structures on a sheet in front of them and identified each structure in the list order. They were scored after each structure as having identified it correctly (assigned 1) or incorrectly (assigned 0). They also marked their confidence level in correctly identifying each structure using a 10cm visual analogue scale graded from 0 (no confidence) to 10 (extremely confident). Once pre-tests had been completed, each participant was given a copy of the ROI atlas, with a minimum of two days elapsing before they participated in the post-test, and the participants having the atlas for an average of seven days. The post-test was carried out in the same manner as the pre-test, with the difference being that participants could refer to the atlas at any point during the post-test. The study was conducted in a clinical examination room in the Radiation Oncology department. The conditions in the room were kept the same for each participant to control for any external variables; this included chair, keyboard and mouse setup, as well as lighting conditions.

Statistical analysis was performed using the Statistical Package for Social Sciences (SPSS). The Wilcoxon signed-rank test for paired samples was used to analyse the scoring of the participants to test the statistical significance of the ROI atlas as an intervention. Each individual's confidence level between the pre-test and post-test was compared using a paired samples t-test. In all comparisons, a p-value of <0.05 was considered statistically significant.

Lastly, the effect that experience had on the results was analysed with the participants being classified into three groups of experience, ranging from 0−1 year, 1−6 years and greater than 6 years. The groups were designed to account for the large number of relatively young RTTs, and to achieve approximately equal sized groups. There were 9 participants in group 1 (< 1 year experience), 12 in group 2 (1−6 years experience) and 10 in group 3 (>10 years experience).

RESULTS

A total of 31 radiation therapists completed the pre- and post-tests. Table 1 shows the means for the structure identification scores. The mean identification score, being graded as correct (1) or incorrect (0), indicates that a value closer to 1 equates to a higher number of correct identifications. The post-test scores, with the atlas, were significantly higher than the pre-test scores, without the atlas, for both patients (patient 1: $Z = 9.33$, $p < 0.001$ and patient 2: $Z= 9.98$, $p < 0.001$).

There was also significant improvement in the RTT confidence levels between the pre-test and post-test for both patients (patient 1: $t\ (402) = 20.56$, $p < 0.001$ and patient 2: $t\ (309) = 17.13$, $p < 0.001$) (see Table 2).

In the pre-test for both data sets, the structure identification scores for the three experience groups were significantly different (patient 1:

Table 1. Scoring of structures for each participant in pre- and post-tests (Wilcoxon signed rank test for paired samples): a score closer to 1 equates to better identification accuracy.

	Pre-test		Post-test		
	Total correct scores (%)	Mean RTT scores (SD)	Total correct scores (%)	Mean RTT scores (SD)	Significance
Patient 1	256 (55.1%)	0.55 (0.5)	382 (82.2%)	0.82 (0.58)	Z = 9.33, $p < 0.001$
Patient 2	195 (52.4%)	0.53 (0.5)	307 (82.5%)	0.83 (0.38)	Z = 9.98, $p < 0.001$

RTT = radiation therapist, SD – standard deviation

Table 2. Confidence levels of radiation therapists in pre- and post-tests (paired samples t test). Confidence is scored on a linear analogue scale from 0 to 10.

	Pre-test	Post-test	
	Mean confidence per RTT (SD)	Mean confidence per RTT (SD)	Significance
Patient 1	4.63 (3.07)	7.55 (1.87)	t (402) = 20.56, $p < 0.001$
Patient 2	5.14 (1.72)	7.65 (3.05)	t (309) = 17.13, $p < 0.001$

RTT = radiation therapist, SD – standard deviation

Table 3. Comparison of structure identification scores for the three RTT experience levels.

	Patient one		Patient two	
	Pre-test	Post-test	Pre-test	Post-test
Chi square	13.5	9.9	7.9	4.2
df	2	2	2	2
Significance	0.010*	0.070	0.019*	0.123

RTT = radiation therapist. df = degrees of freedom, *significant at p<0.02 level.

$\chi^2(2, N = 256) = 13.5$, $p < 0.05$, and patient 2: $\chi^2(2, N = 195) = 17.9$, $p < 0.05$), with group two (1 to 6 years experience) scoring the highest (see Table 3 and Figure 1). In the post-tests, there was no significant difference in the structure identification scores of the three experience levels.

Table 4 shows that some structures were consistently more difficult to identify, with the pubic muscles and break in pubic symphysis being least often identified correctly. The general trend of improvement in identifying structures using the atlas, however, can be seen for all structures.

DISCUSSION

Since patients are increasingly receiving higher dose treatment, with techniques such as intensity-modulated radiation therapy, target area

https://doi.org/10.1017/S1460396912000210 Published online by Cambridge University Press

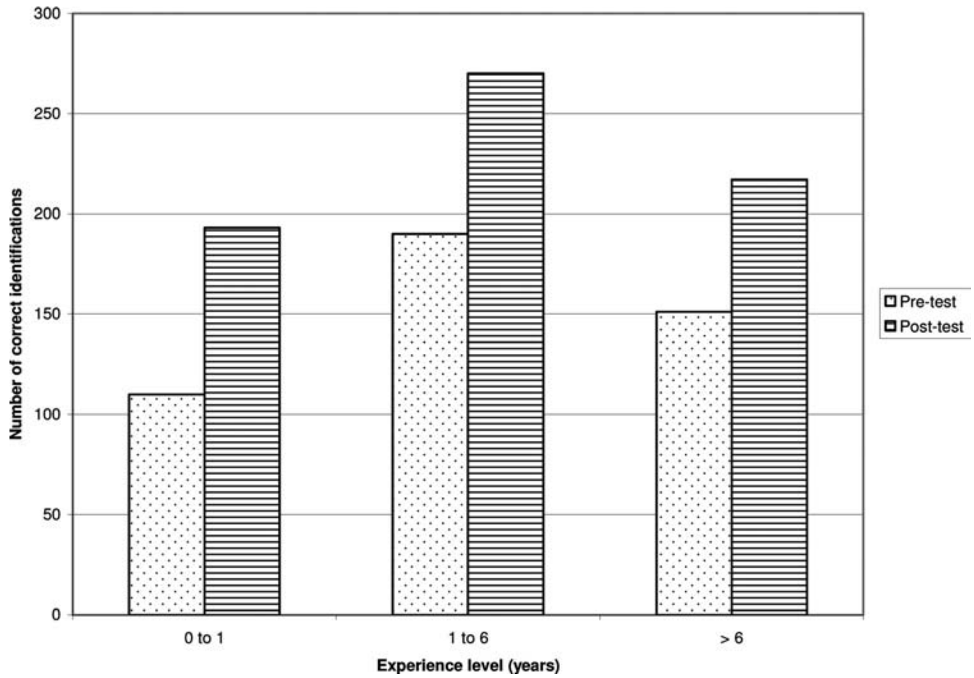

Figure 1. Correct identification in pre-test and post-test for the three RTT experience levels (patients one and two combined).

Table 4. *Percentage of correct identifications for each structure in the pre- and post-tests in order of ascending level of improvement (patients one and two combined).*

Structure	Pre-tests (% of correct identifications)	Post-tests (% of correct identifications)	Level of improvement (%)
Anterior rectal wall – inferior	96.8	98.4	1.7
Posterior bladder wall - superior	95.2	98.4	3.4
Para-rectal surgical clips	21.0	22.6	7.6
Anterior rectal wall - superior	82.3	88.7	7.8
Posterior pubic symphysis	90.3	100.0	10.7
Posterior bladder wall – inferior	87.1	96.8	11.1
Other vascular clips	38.7	43.5	12.4
Seminal vesicle surgical clips	43.5	50.0	15.0
Seminal vesicle surgical bed	80.6	96.8	20.1
Penile bulb	22.6	50.0	221.2
Anterior border mesorectal fascia	22.6	67.7	300.0
Levator ani muscle	25.8	88.7	344.0
Inferior obturator foramen	11.3	43.5	385.0
Break in pubic symphysis	6.5	74.2	1142.0
Pubic muscles	3.2	77.4	2419.0

identification is correspondingly requiring improvement. In the case of post-prostatectomy cancer patients, the prostate bed is difficult to treat with radiation therapy, as it is a highly mobile area that is influenced by the movement of surrounding organs[7]. Knowledge of the structures that surround this area is of utmost importance in accurately assessing the location of the bed on a daily basis before radiation treatment.

It was shown in this study that an ROI atlas that identified relevant structures in post prostatectomy cancer patients significantly aided radiation therapists in both accuracy and confidence in structure localisation, thereby supporting our hypothesis of a marked improvement with the use of the atlas. After atlas administration for patients one and two, the overall number of correct identifications increased by 149% and 157% respectively. The confidence the RTTs felt when using the atlas also improved, with average confidence levels increasing by 163% and 149% for patients one and two respectively.

The results of this study are consistent with others that have involved the investigation of interventions of an educational nature. Beckelman et al.[8] used a teaching intervention, head and neck anatomy seminars, to achieve an improvement in the contouring of clinical target volumes (CTVs). Similarly, Tai et al.[9] used one-on-one training for radiation oncologists for the contouring of target volumes and found less variability post-training compared to pre-training. Specific to atlases, Fuller et al.,[10] demonstrated that using an atlas in the area of rectal cancer volume delineation produced increased contour agreement among radiation oncologists, with the interobserver standard deviation decreasing by 0.2–0.8cm after the introduction of the atlas. Van Krenen et al.[4] used their ROI atlas in the area of head and neck cancer, modifying it with the addition of several new structures. They found large set up errors to be associated with treatment of this region, with current margins being inadequate to account for them. They recommended the use of multiple regions in the atlas to reduce the impact of setup variation.

One of the important aspects of this study is that the prostate bed is a difficult area to treat, so the potential for improvement is large, which is supported by the statistically significant improvement in structure and organ identification. The atlas can also improve structure identification accuracy by any RTT. Group two (1–6 years of experience) tended to perform better across the range of tests, but was only significantly better than the other groups in the pre-tests. Hence, although this recently educated, moderately experienced, group initially performed better, as predicted, the ROI atlas improved the performance of all groups, irrespective of years of experience as an RTT.

Further to this, patterns could be seen that suggested some structures were consistently harder to identify than others. The surgical clips, inferior obturator foramen and penile bulb were not well identified throughout the study and although identification was improved with the atlas, the results were still poor. These inaccurate identifications are likely to be due to a combination of factors such as: the structures are rarely used in matching, the RTTs recognise the structure, but do not know its name, or that the structure is inherently difficult to visualise. If in the future these structures are deemed important to identify, an educational program might be needed.

A positive aspect of this atlas is that it did not require any extra training to be implemented for use. The atlas was given to each individual and used during the post-test with minimal explanation, with each person using it according to their own needs and preferences. Initially, the use of an atlas might slow down treatment times, but over time, with learning in practice, structure identification time is likely to reduce. RNSH has also had considerable experience with image-guided radiotherapy (IGRT), so it is possible that the RTTs using the ROI atlas were able to make better use of it in structure identification than would those with little experience in the use of CBCTs. These results indicate, however, that institutions that are about to introduce IGRT should consider using a ROI atlas from the outset, to ensure correct identification of crucial pelvic structures.

It was beyond the scope of this study to determine how other important factors, such as the clinical sections where the RTTs spent most of their time (e.g. treatment, simulation), their educational experience and specialities influenced the scoring and confidence of the RTTs. For example, some of the radiation therapists specialise in breast or prostate treatment, which is likely to increase their knowledge base and confidence in that particular area. However, the fact that no significant difference in improvement with the atlas was seen among the three experience groups indicates that the atlas can reduce the effects of varied experience levels.

The results of this study have strong implications for clinical practice. By using the ROI atlas of the pelvic region, RTTs can improve structure identification in post-prostatectomy patients. With increasing skill in this area, target alignment would improve, which could lead to higher accuracy in treating the target, while avoiding healthy tissue. Our participant sample was large and included a diverse range of radiation therapists with different areas of strength and years of experience, indicating that the results could be replicated at other centres.

CONCLUSION

An ROI atlas of the post-prostatectomy pelviss has the potential to improve treatment outcome by helping to more accurately align the high dose region to the target, thereby reducing the amount of healthy tissue irradiated. ROI atlases should be used for high dose techniques to any area with complex anatomy.

ACKNOWLEDGEMENTS

The authors thank Dr A Kneebone for his work on the development of the ROI atlas and the Royal North Shore Hospital radiation therapists for their co-operation.

References

1. Ambrosini GL, Fritschi L, de Klerk NH, Mackerras D, Leavy J. Dietary patterns identified using factor analysis and prostate cancer risk: a case control study in Western Australia. Ann Epidemiol 2008; 18:364–370.
2. Sidhom MA, Kneebone AB, Lehman M et al. Post-prostatectomy radiation therapy: consensus guidelines of the Australian and New Zealand Radiation Oncology Genito-Urinary Group. Radiother Oncol 2008; 88:10–19.
3. Létourneau D, Wong JW, Oldham M et al. Cone-beam-CT guided radiation therapy: technical implementation. Radiother Oncol 2005; 75:279–286.
4. van Kranen S, van Beek S, Rasch C, van Herk M, Sonke JJ. Setup uncertainties of anatomical sub-regions in head-and-neck cancer patients after offline CBCT guidance. Int J Radiat Oncol Biol Phys 2009; 73:1566–1573.
5. Schniffner D, Gottschalk A, Lometti M, Aubin M, Pouliot J, Speight J, Hsu I, Shinohara K, Roach M. Daily electronic portal imaging of implanted gold seed fiducials in patients undergoing radiotherapy after radical prostatectomy. Int J Radiat Oncol Biol Phys 2006; 67:610–619.
6. Sidhom MA, Kneebone AB, Lehman M et al. Post-prostatectomy radiation therapy: consensus guidelines of the Australian and New Zealand Radiation Oncology Genito-Urinary Group. Radiother Oncol 2008; 88:10–19.
7. Redding DJ, Bragg CM. Assessment of the dosimetric consequences of prostate movement through rectal distention for patients receiving 3DCRT. J Radiother Pract 2010;1–12.
8. Bekelman JE, Wolden S, Lee N. Head-and-neck target delineation among radiation oncology residents after a teaching intervention: a prospective, blinded pilot study. Int J Radiat Oncol Biol Phys 2009; 73:416–423.
9. Tai P, van Dyk J, Battista J, Yu E, Stitt L, Tonita J, Agboola O, Brierley J, Dar R, Leighton C, Malone S, Strang B, Truong P, Videtic G, Shun Wong C, Wong R, Yousef Y. Improving the consistency in cervical esophageal target volume definition by special training. Int J Radiat Oncol Biol Phys 2002; 53:766–774.
10. Fuller C, Nijkamp J, Duppen J, Rasch C, Thomas C, Wang S, Okunnieff P, Jones W, Baseman D, Patel S, Demandante C, Harris A, Smith B, Katz A, McGann C, Harper J, Chang D, Smalley S, Marshall D, Goodman K, Papanikolaou N, Kachnic L. Prospective randomized double-blind pilot study of site-specific consensus atlas implementation for rectal cancer target volume delineation in the cooperative group setting. Int J Radiat Oncol Biol Phys 2011; 79:481–489.