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Dose planning objectives in anal canal cancer IMRT: the TROG ANROTAT experience

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Abstract

Introduction: Intensity modulated radiotherapy (IMRT) is ideal for anal canal cancer (ACC), delivering high doses to irregular tumour volumes whilst minimising dose to surrounding normal tissues. Establishing achievable dose objectives is a challenge. The purpose of this paper was to utilise data collected in the Assessment of New Radiation Oncology Treatments and Technologies (ANROTAT) project to evaluate the feasibility of ACC IMRT dose planning objectives employed in the Australian situation. **Methods:** Ten Australian centres were randomly allocated three data sets from 15 non-identifiable computed tomography data sets representing a range of disease stages and gender. Each data set was planned by two different centres, producing 30 plans. All tumour and organ at risk (OAR) contours, prescription and dose constraint details were provided. Dose–volume histograms (DVHs) for each plan were analysed to evaluate the feasibility of dose planning objectives provided. **Results:** All dose planning objectives for the bone marrow (BM) and femoral heads were achieved. Median planned doses exceeded one or more objectives for bowel, external genitalia and bladder. This reached statistical significance for bowel V30 ($P = 0.04$), V45 ($P < 0.001$), V50 ($P < 0.001$), external genitalia V20 ($P < 0.001$) and bladder V35 ($P < 0.001$), V40 ($P = 0.01$). Gender was found to be the only significant factor in the likelihood of achieving the bowel V50 ($P = 0.03$) and BM V30 constraints ($P = 0.04$). **Conclusion:** The dose planning objectives used in the ANROTAT project provide a good starting point for ACC IMRT planning. To facilitate clinical implementation, it is important to prioritise OAR objectives and recognise factors that affect the achievability of these objectives.

Introduction

The optimal treatment technique for anal canal cancer (ACC) has traditionally presented a challenge to the radiotherapy community. The highly irregular target volumes associated with ACC combined with the presence of numerous organs at risk (OAR) within close proximity means that achieving the ideal therapeutic ratio can be problematic.[1] Traditionally used radiotherapy techniques, such as three-dimensional conformal radiation therapy, can result in severe acute toxicity potentially impacting treatment continuity. These acute and late toxicities included moist skin desquamation, diarrhoea, dysuria, marrow suppression, perineal skin atrophy and fibrosis and femoral neck fractures.[1–6] The impact of these acute toxicities is that some patients may require a treatment break to recover from their toxicities or may not actually complete treatment, potentially leading to a compromise in tumour control.[7–9] It is difficult with traditional techniques to reduce dose to

many OAR and therefore minimise toxicity. Intensity modulated radiotherapy (IMRT) allows highly conformal treatment plans to be produced and is well suited for use in ACC to minimise OAR dose and toxicity whilst still delivering the prescribed dose to the tumour thus enabling the patient to complete the intended treatment without interruption.[10,11]

The use of IMRT in ACC is still relatively new in Australia. A survey of 16 radiotherapy departments around Australia in 2010 showed limited use and experience of IMRT in ACC.[12] One of the major challenges associated with introducing IMRT planning for ACC is establishing achievable dose planning objectives to facilitate adequate dermatologic, gastrointestinal, genitourinary and bone marrow (BM) sparing whilst maintaining prescribed high doses to the tumour. The aims of the study were to (1) evaluate the ability of plans created during a technology assessment project to meet a defined set of planning objectives and (2) identify factors that may impact on the ability to meet these planning objectives. This information could assist departments inexperienced with IMRT for ACC in selecting achievable dose planning objectives for use.

Methods

Data collection

The data utilised in this investigation were collected from part of the Assessment of New Radiation Oncology Treatments and Technologies (ANROTAT) project. This project was undertaken by the Trans Tasman Radiation Oncology Group (TROG) in response to a commission by the Australian Government Department of Health and Ageing to develop and pilot an evaluation framework of new technologies with a view to providing improved funding for IMRT if evidence compiled by the project was compelling.[13] The purpose, objectives and specific details of the project are described in the ANROTAT protocol.[12,13] Data collection occurred between June 2011 and April 2012. The ACC section of the ANROTAT project consisted of five component studies including credentialing, dosimetry and prospective toxicity and quality of life assessment. The data collected in the IMRT dosimetry component of the project have been utilised in this investigation.

Data set details

Fifteen non-identifiable retrospective computed tomography (CT) data sets were selected. Eligibility criteria included histological confirmation of squamous cell carcinoma, intention to electively irradiate all pelvic nodal groups up to L5-S1 interspace (including mesorectal, presacral, internal iliac, external iliac, ischiorectal fossa, obturator and inguinal groups) and planned for radical chemoradiotherapy. Patient CT data sets were excluded if there was evidence of metastatic disease, if they had prior pelvic radiotherapy or surgery (e.g. vaginal hysterectomy) or had a hip prosthesis. The selection comprised a mix of different stages for both male and female patients, all positioned supine, who met the eligibility criteria (Table 1). Stage T1N0 was excluded, as some centres do not routinely electively irradiate the inguinal nodes in this setting. Ethics approval was obtained for use of the retrospective data sets for all participating centres.

Ten radiotherapy centres across Australia participated in the project. This included public and private, metropolitan and rural and large and small departments. Each of the participating centres were allocated three of the 15 data sets, and prepared an IMRT plan for each data set. Each data set was planned by two centres. The plans and associated documentation were then submitted for review by the project team. The review team consisted of two radiation oncologists and three radiation therapists.

Contouring

As the purpose of this investigation was to evaluate dose distribution and not to assess variations in contouring, all target volumes and OAR structure sets were included with each CT data set. Target volume contours were marked and reviewed by two radiation oncologists and were delineated using the guidelines proposed by the Australasian Gastrointestinal Trials Group (AGITG).[14]

Table 1. Data set characteristics.

Characteristic	Number (n = 15)
Sex	
Male	7
Female	8
Median age (range)	58 (42–83)
T stage	
2	7
3	6
4	2
N stage	
0	6
1	3
2	4
3	2
Stage	
2 (T2-3N0)	5
3A (T1-3N1, T4N0)	4
3B (T4N1, AnyTN2-3)	6

Target volumes provided were planning target volume (PTV) 45 Gy (elective volume), PTV54 Gy-p (primary volumes with 'p' representing primary), PTV54 Gy–n1, n2 and n3 ('n' represents node with the '1, 2, 3' representing the number of involved nodes). A 1 cm clinical target volume (CTV) to PTV margin was employed for all data sets. If the PTV contour extended outside the skin, it was cropped to the skin surface. For planning purposes, objective PTV volumes cropped 5 mm from the skin surface were created by the centre for plan optimisation. OAR contours provided included BM, bowel, left and right femoral head and necks, external genitalia and bladder.[12] The bowel was delineated as a cavity, 15 mm superior to the cranial aspect of the PTV, extending inferiorly to the recto-sigmoid junction based on the study by Devisetty and colleagues.[12,16] External genitalia included the perineum with the cranial extent at the upper level of the pubic symphysis.

Prescription and dose constraints

All IMRT plans were generated using a simultaneous integrated boost technique according to the ANROTAT protocol.[12] The prescription consisted of two dose levels (1) PTV-45 Gy receiving 45 Gy and (2) PTV-54 Gy receiving 54 Gy delivered over 30 fractions. Dose coverage requirements and dose planning objectives for OAR for the ANROTAT protocol are shown in Table 2. The primary objective was to achieve target volume coverage followed by the OAR dose constraints and planning objectives listed in order from most to least important. These constraints were adapted from the Radiation Therapy Oncology Group (RTOG) 05-29 phase 2 study protocol that assessed IMRT in anal cancer with one exception.[17] The small bowel constraint was modified to bowel based on data published by Devisetty and colleagues.[16] This paper provided dose–volume correlation with acute bowel toxicity in ACC patients undergoing chemoradiation, and hence supported the ANROTAT project's health economic analyses. At the commencement of the ANROTAT project, there was no other relevant literature providing OAR dose correlation with acute toxicity in ACC radiotherapy.

Centres were directed that effort should be made to achieve the listed dose constraints but were advised that constraints cannot always be achieved, and therefore planning objectives were specified listed in order from highest to lowest priority. Failure to meet some dose constraints would result in minor or major deviations (Table 3). These deviations were set by the group to assist in assessing clinical safety and compliance. The only OAR that major deviation levels were specified for were the bowel and femoral heads as these were the only two OAR with published dose–volume toxicity data in ACC patients for acute bowel toxicity and femoral neck fractures.[16,18] The threshold levels for these structures were based on these studies.

Table 2. IMRT dose planning objectives/constraints.

Structure	Dose constraint
Target volumes	D98 ≥ 95%
	D2 ≤ 115%
Bowel	V30 ≤ 350 cm^3
	V35 ≤ 150 cm^3
	V45 ≤ 20 cm^3
	V50 = 0 cm^3
Left and right femoral heads	V40 ≤ 35%
	V44 ≤ 5%
Bone marrow	V30 ≤ 50%
	V40 ≤ 35%
	V50 ≤ 5%
External genitalia	V20 ≤ 50%
	V30 ≤ 35%
	V40 ≤ 5%
Bladder	V35 ≤ 50%
	V40 ≤ 35%
	V50 ≤ 5%

Dose planning objectives are listed in descending order of priority. Dx, dose covering x% of the volume; Vx, volume of organ receiving xGy.

Table 3. Plan review definitions of major and minor deviations.

Structure	Acceptable	Minor	Major
PTVs	D98 ≥ 95% D2 ≤ 115%	D98 ≥ 90% to <95% D2 > 115%	D98 < 90%
Small bowel	V30 ≤ 350 cm^3 V45 ≤ 20 cm^3 V50 = 0 cm^3	V30 > 400 cm^3 V45 > 30 cm^3	V30 > 450 cm^3 V50 > 0 cm^3
Femoral heads	V40 ≤ 35% V44 ≤ 5%	V44 > 5% to ≤10%	V44 > 10%

PTVs, planning target volumes; Dx, dose covering x% of the volume; Vx, volume of organ receiving xGy.

Dosimetric assessment

All plans were submitted electronically in DICOM RT or RTOG format for review using the Focal treatment planning system (Elekta AB, Stockholm, Sweden).[19,20] Data export included dose–volume histograms (DVHs) for all target and OAR volumes; however, the DVHs were recalculated using the Focal treatment planning system to ensure consistency in volume calculation methods.[21] The quality assurance team reviewed each plan and recorded the actual calculated dose for the target volumes and OAR for each of the specified dose constraint and planning objective levels.

Planning technique

Centres were instructed to follow their departmental procedures with regard to IMRT planning technique; however, a recommendation to use seven to nine beams was made.[12] For centres unfamiliar with IMRT planning for ACC, an IMRT planning guide was included as an appendix to the protocol.[12]

Statistics

Data were analysed using the Stata (version 12.1; StataCorp LP, College Station, TX) program. Doses to target volumes and OAR, were recorded for all submitted IMRT plans. Statistical analysis included basic descriptive statistics and the *t*-test or Wilcoxon signed rank test (where data were not normally distributed) to establish what dose objectives were actually achieved for each OAR. The Mann–Whitney test was used to compare groups based on gender and *N* stage in the achievability of dose objectives and logistic regression was used to determine factors of significance in the ability to achieve the dose objectives. Factors considered were gender, *T* stage and *N* stage. *N* stage was investigated as a whole, in addition to being divided into two groups: (1) *N*0–*N*2 and (2) *N*3 only. *N*3 disease was considered as a separate group as this stage included bilateral inguinal or internal iliac involvement that results in higher doses delivered to the pelvis and surrounding OAR. A *P*-value of 0.05 was considered statistically significant.

Results

Planning data

Data sets were planned using a median of 9 (range 7–21 beams) co-planar, step-and-shoot IMRT beams. The large number of beams required in some instances can be attributed to the requirement of a 'carriage shift' in the transfer of the beams from the treatment planning system to the linac (meaning some beams were split into two). Of the 30 plans submitted, an average total monitor units (MU) of 965 with a range of 476–1683 MU was recorded for 27 plans. The total MU was not recorded for three plans. The average time purely spent planning (not including review or quality assurance time) was 343.7 min (range 50–868 min).

Target volumes

A total of 30 IMRT plans were reviewed and target volume coverage was achieved. The mean coverage of 98% of PTV45 Gy, PTV54 Gy-p and PTV54 Gy-n (D98) was at least 95% of the prescribed dose level with mean doses of 44.9, 51.9 and 51.5 Gy respectively.

OAR volumes

A comparison of OAR dose planning objectives and the achieved dose/volumes is shown in Table 4. The percentage of plans that failed each OAR dose planning objective, in addition to the percentage of plans that classified as a major deviation for the applicable OAR, is displayed in Table 5. Median planned doses exceeded one or more of the planning objectives for the bowel, external genitalia and bladder with more than 50% of plans failing two out of three planning objectives assessed for these OAR. In contrast, all median planned doses for the BM and femoral head and necks met the defined planning objectives. The median planned volume significantly exceeded the prescribed dose constraint/planning objective by 39.9 cm^3 for bowel V45 ($P < 0.001$) and 1.1 cm^3 for bowel V50 ($P < 0.001$), 16.3% for external genitalia V20 ($P < 0.001$), 16.5% for bladder V35 ($P < 0.001$) and 6.2% for bladder V40 ($P = 0.01$).

A statistically significant difference was demonstrated between the median volumes achieved for bowel V30 ($P = 0.04$) and BM V30 ($P = 0.03$) and BM V40 ($P = 0.05$) when considering patient gender. Differences were approaching statistical significance for the bowel V45 and V50 objectives. Specifically, the median volume for these OAR in female patient data sets exceeded the male data sets (Table 6). The bowel volume was greater in females than males with an average volume of 617.8 and 421.2 cm^3 respectively. However, achieved volumes were less than the specified OAR planning objective.

As a function of *N* stage, a statistically significant difference in the achievability of V50 ($P = 0.05$) for BM was found. *N* stage was further divided into 2 groups: *N*0–*N*2 patients and *N*3 patients. Based on this grouping, the median planned volumes for all dose planning objectives were higher in those with *N*3 disease for the bowel and external genitalia and for the BM V30 dose level (Table 6). This reached statistical significance for BM V50 ($P = 0.03$) and external genitalia V30 ($P = 0.03$) and V40 ($P = 0.01$). The mean bowel and BM volumes for the *N*3 group were 783.8 and 559.3 cm^3 respectively. Comparatively, the mean bowel and BM volumes for *N*0–*N*2 patients were 486.4 and 466.1 cm^3 respectively.

When these factors were tested in the logistic regression model, gender was found to be the only factor of statistical significance in the likelihood of achieving the

Table 4. Comparison of OAR dose planning objectives/constraints with the mean value from submitted plans. Absolute volumes are indicated in units of cm^3, remaining values are a percentage of the defined volume.

OAR	Dose level (Gy)	Dose planning objective/constraint (%)	Median achieved volume (range) (%)	*P*-value
Bowel	V30	350 cm^3	217.1 cm^3 (974.7)	0.04*
	V45	20 cm^3	59.9 cm^3 (916.2)	<0.001*
	V50	0 cm^3	1.1 cm^3 (865.7)	<0.001*
Left femoral head	V40	35	17.1 (48.4)	<0.001*
	V44	5	2.7 (35.4)	0.04*
Right femoral head	V40	35	14.2 (46.8)	<0.001*
	V44	5	2.0 (30.2)	0.02*
Bone marrow	V30	50	45.8 (40.5)	0.03*
	V40	35	22.9 (36.9)	<0.001*
	V50	5	0.01 (8.9)	<0.001*
External genitalia/perineum	V20	50	66.3 (56.8)	<0.001*
	V30	35	32.7 (81.0)	0.81
	V40	5	4.9 (47.5)	0.36
Bladder	V35	50	66.5 (58.6)	<0.001*
	V40	35	41.2 (80.0)	0.01*
	V50	5	2.0 (29.8)	0.68

OAR, organs at risk; Vx, volume of organ receiving xGy.
*Denotes statistical significance.

Table 5. Percentage of plans that failed each OAR dose planning objective.

OAR	Dose level (Gy)	Fail (%) (% major deviation)
Bowel	V30	30 (13.3)
	V45	73.3
	V50	50 (50)
Left femoral head	V40	13.8
	V44	24.1 (10.3)
Right femoral head	V40	6.7
	V44	26.7 (10)
Bone marrow	V30	23.3
	V40	10
	V50	6.7
External genitalia/perineum	V20	80
	V30	50
	V40	46.7
Bladder	V35	73.3
	V40	60
	V50	40

OAR, organs at risk; Vx, volume of organ receiving xGy.

bowel V50 constraint ($P = 0.03$) and the BM V30 constraint ($P = 0.04$). Logistic regression demonstrated that the model based on gender correctly classified 70% and 76.7% of data sets to achieve the V50 bowel and V30 BM planning objectives respectively.

Discussion

Published data on the use of IMRT in ACC are limited in comparison to other treatment areas such as head and neck and prostate cancer. North American studies, such as the RTOG 05-29 trial, have demonstrated that ACC IMRT provides acceptable tumour control and toxicity.[17] Dosimetric studies have reported that dose to surrounding OAR, such as bowel, BM, external genitalia, bladder and femoral heads can all be significantly reduced with IMRT, whilst still delivering the prescribed dose to the tumour.[2,10,15,22] However, setting the priorities for each of these OAR planning objectives in IMRT is challenging in ACC due to the number of OAR.[15] The greatest challenge in ACC IMRT is the limited published evidence of specific toxicity data and has led to planning objectives that are not entirely evidence based or which are adapted from other cancer sites.

This study showed that planning objectives set for the femoral heads and BM were achieved for all dose levels. In contrast, median planned dose/volume was significantly exceeded for: the V45 and V50 for the bowel ($P < 0.001$ and 0.001), external genitalia V20 ($P < 0.001$) and bladder V35 and V40 ($P < 0.001$ and $P = 0.01$). This was further supported by 73% of plans failing to meet the V45 bowel objective, 80% of plans failing to meet the external genitalia V20 and 73.3% and 60% of plans failing to meet the bladder V35 and V40 objectives respectively (Table 5). These results are similar to those reported in a study by Devisetty et al. comparing IMRT to helical tomotherapy in ACC.[16] Using OAR dose

Table 6. OAR dose/volumes achieved according to grouping.

OAR	Constraint dose level (Gy)	Median achieved volume/dose (range) (cm^3/%)			Median achieved volume/dose (range) (cm^3/%)		
		Male	Female	*P*-value	*N*0–2	*N*3	*P*-value
Bowel (cm^3)	V30	188.4 (280.5)	318.7 (974.7)	0.04*	216.0 (599.7)	440.6 (872.1)	0.23
	V45	36.3 (317.3)	132.3 (916.2)	0.06	59.9 (452.1)	152.4 (884.9)	0.36
	V50	0 (286.5)	20.6 (865.7)	0.06	1.0 (424.1)	33.8 (865.7)	0.45
Bone marrow (%)	V30	44.6 (22.7)	47.3 (34.8)	0.05*	45.7 (33.3)	54.6 (40.5)	0.22
	V40	20.9 (19.6)	25.2 (33.9)	0.05*	22.9 (25.9)	32.0 (36.9)	0.46
	V50	0.01 (0.1)	0.05 (8.9)	0.21	0.01 (1.2)	3.8 (8.9)	0.03*
External genitalia/perineum (%)	V20	61.5 (32.7)	74.3 (56.8)	0.20	61.5 (56.8)	80.8 (31.4)	0.09
	V30	33.7 (39.0)	29.6 (81.0)	0.36	30.7 (80.1)	47.1 (58.6)	0.03*
	V40	4.9 (47.5)	4.7 (43.1)	0.80	4.3 (47.5)	29.8 (27.8)	0.01*

OAR, organs at risk; Vx, volume of organ receiving xGy.
*Denotes statistical significance.

planning objectives also based on the RTOG 05-29 trial, they found that the bowel V30 and V50 and bladder V30, V40 and V50 constraints could not be achieved.[16] In contrast to the present study, they found that all planning objectives set for the external genitalia could be achieved.[16] In the present study, 80% and 50% of plans failed to achieve the V20 and V30 planning objectives respectively (Table 5). One reason for this difference is our study included the perineum with the external genitalia contour, with more of the perineum receiving dose when the inguinal nodes are treated. None of the plans compromised target volume coverage at the expense of external genitalia dose.

There could be numerous reasons why certain OAR dose planning objectives could not be achieved. In the ANROTAT project, the protocol stated that the primary objective of the plan was to achieve the required target volume coverage followed by the OAR listed in order of priority. Major and minor deviations were only specified for the bowel and femoral heads, with the other planning objectives provided as a guide to minimise dose to other OAR. Consequently, it is possible that some objectives were relaxed in order to meet those deemed a higher priority with major deviation thresholds specified. Bowel and femoral heads were given high priority as bowel toxicity should be reduced to minimise treatment breaks, and late femoral fractures have been reported following ACC radiotherapy. Another reason could be attributable to the range of experience amongst the participating centres in the use of IMRT, and specifically ACC IMRT with some centres indicating that they had not planned or planned very few IMRT ACC patients previous to this study. This was in part demonstrated by the great range of planning times that were recorded by the participating centres. Joseph and colleagues commented that the quality of the plan produced could be highly user dependent and can depend on both the experience of the planner and the time and effort expended by the planner in the optimisation process.[23]

This study sought to ascertain patient and tumour factors that could influence the likelihood of achieving these constraints. The strongest relationship found was that between gender and the ability to meet the bowel and BM dose planning objectives. It was found that the median planned volumes exceeded the V45 and V50 bowel dose planning objectives in female patients. This finding is not surprising due to the differences in pelvic anatomy between men and women.[23] In this study, women had a larger bowel volume within the pelvis and therefore, more dose delivered. Bivariate analysis also demonstrated a link between *N* stage and the volume of irradiated BM. When dividing *N* stage into *N*0–*N*2 versus *N*3 stage disease, significant

relationships were found with external genitalia V30 and V40 also. The median volume exceeded the planning objective for all dose levels for bowel and external genitalia for those in the *N*3 group. *N*3 disease represents a more advanced stage of ACC, which includes either bilateral inguinal or bilateral internal iliac nodes. Delivering 'boost' doses to involved lymph nodes will result in higher doses delivered to the bowel, BM and the perineum and external genitalia.

There are many important points that can be taken from this study. Firstly, in order to establish realistic OAR planning objectives for use in ACC IMRT, consistent contouring is imperative. The purpose of the ACC contouring guidelines published by the AGITG was to facilitate consistency in practice.[14] The establishment of OAR planning objectives in ACC IMRT, however, can be problematic as target volumes vary between patients, disease stages, variation in bowel and external genitalia/perineum volumes can be significant based on a patient's gender and body habitus. However, if target and OAR volumes are contoured in accordance with the AGITG guidelines, the following recommendations can be made based on the results of the current study: OAR planning objectives for the femoral head, BM and the bowel V30 are realistic for use in daily practice. It is important to note that the femoral head and bowel V30 dose constraints were based on published clinical evidence of dose–toxicity correlation.[16,18] It was found that the remaining planning objectives for the bowel, external genitalia and bladder were not able to be consistently achieved with the treatment planning systems available for the study, and as such, may need to be relaxed, or potentially omitted in the case of lower priority OARs (refer to Table 3).

From our data, the irradiation of higher volumes of bowel and BM to higher doses in patients with *N*3 disease and in females should be expected. Positioning the patient prone on a 'belly board' for example, may reduce the volume of bowel irradiated, particularly for female patients with higher stage nodal disease or ensuring good bladder filling to displace bowel superiorly out of the irradiated field. Strict bladder planning objectives may not be relevant when planning ACC IMRT, as DVH toxicity data correlation is not well established for the bladder.[17,24] The lower planning objectives for the external genitalia, if including the perineum, (i.e., V20) may be removed. Realistic planning objectives or better understanding of what is achievable in terms of OAR doses, has the potential to minimise planning time (the mean planning time in this study was 5.7 h) as radiation therapists will not spend excess time attempting to achieve goals that are unable to be met. Ultimately, the development of appropriate dose constraints for OAR in ACC IMRT can only be properly generated from dose–toxicity correlations, which is currently lacking, particularly in terms of acute toxicity outcomes, in ACC. Our study has generated hypotheses for testing in future, larger studies and data that centres are able to review and compare their own planning data with.

A major limitation of the study was that it was not specifically designed for the purpose of assessing the feasibility of dose planning objectives in IMRT for ACC but involved analysing data collected as part of the ANROTAT project. Consequently, inter-centre variation was not able to be adequately assessed as there was not one common data set planned by all centres. Another limitation is the small sample size included in this study, although being a representative mix, means that cautious interpretation of the results should be undertaken as it may have impacted on the power of the analysis to detect significant differences. It should also be noted that there were differences in the way OAR volumes were contoured between the RTOG study (on which the OAR dose planning objectives were based) and the current study. Further prospective investigation involving larger sample sizes and correlation with toxicity data is warranted and the establishment of a patient registry would be beneficial.[25]

Conclusion

The dose planning objectives for the femoral heads, BM and bowel V30, used in the ANROTAT project, provide a good starting point for ACC IMRT planning. Achievability of other dose planning objectives for the bowel and constraints for external genitalia and bladder can be more heavily influenced by factors such as sex and *N* stage. To facilitate the successful use of OAR dose planning objectives, it is important to prioritise the objectives and recognise factors that affect their achievability. As centres gain more experience in IMRT planning for ACC and more specific toxicity data become available, these dose planning objectives should be reviewed and further refined.

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Conflict of Interest

The authors declare no conflict of interest.

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