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Development of a novel treatment planning test for credentialing rotational intensity-modulated radiotherapy techniques in the UK

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Objective: The increasing use of tomotherapy and volumetric-modulated arc therapy in UK centres will result in more centres choosing to use this technology in a clinical trial setting. The Radiotherapy Trials Quality Assurance (RTTQA) group has developed a new procedure to integrate into the UK intensity-modulated radiotherapy (IMRT) credentialing programme to cover rotational IMRT delivery techniques.

Methods: A planning test [three-dimensional treatment planning system (3DTPS)] was designed specifically for rotational IMRT techniques. The feasibility of using this test in the credentialing programme for rotational IMRT was validated by 10 experienced UK centres. The study included five centres using Varian RapidArcTM (RA) (Varian Medical Systems, Milpitas, CA), two using Elekta VMATTM (VMAT) (Elekta Inc., Norcross, GA) and three using helical tomotherapy (HT) plans. Centres

were asked to carry out their own in-house quality assurance (QA) for the plans submitted for this study. A survey was sent out to centres aiming to gather information on their experience in undertaking the exercise and their QA results.

Results: All centres fulfilled the primary goal by achieving the dose constraints of the primary planning target volume and organ at risk. Seven centres (three RA, one VMAT and three HT plans) were able to fulfil the secondary goal. Among those seven centres, three centres (two RA and one VMAT plans) achieved the tertiary goal. The results of the survey indicated that the 3DTPS test is a clinically relevant and practical planning test to be used.

Conclusion: A planning test for rotational therapy techniques was developed for the RTTQA IMRT credentialing programme.

Advances in knowledge: This study validated the feasibility of a 3DTPS test to be used as

part of a credentialing programme for rotational IMRT techniques in the UK.

In the last decade, there have been rapid changes and progressive development in radiotherapy delivery techniques. The use of intensity-modulated radiotherapy (IMRT) allows individualised highly conformal dose delivery while sparing the surrounding normal tissue. The complex nature of advanced radiotherapy techniques potentially introduces problems and errors in ensuring reproducibility and accuracy of patients' treatment. This is especially true when carried out on a multicentre clinical trial basis [1]. A quality assurance (QA) programme is "a mandatory prerequisite when aiming at high dose, high precision radiotherapy" and is an integral component of any radiotherapy trial as defined by the European Organisation for Research and Treatment of Cancer guidelines for trial protocols in radiotherapy [2,3].

In the UK, the National Cancer Research Institute (NCRI) has established the National Radiotherapy Trials Quality Assurance (RTTQA) group to co-ordinate clinical trial QA work. There is strong evidence to suggest that credentialing could minimise deviation rates for data submitted to clinical trials [4,5]. Thus, the RTTQA group developed a nine-module IMRT credentialing programme including an outlining and planning exercise, centre- and trial-specific questionnaires, process documents, verification of electronic data transfer and independent dosimetry audits [treatment planning system (TPS) checks, fluence and dose distribution verification] [6,7]. This aims to provide an appropriate IMRT audit for each centre, whether they have established the service or are implementing IMRT for the first time through the trial.

A survey carried out by the Institute of Physics and Engineering in Medicine (IPEM) has indicated that, in May 2011, there were 10 UK centres with at least a year's clinical experience in the use of rotational IMRT [Varian RapidArcTM (RA) (Varian Medical Systems, Milpitas, CA), Elekta VMATTM (VMAT) (Elekta Inc., Norcross, GA) and helical tomotherapy (HT)]. A further 20 centres indicated an intention that volumetric IMRT would be implemented by the end of 2011, taking the availability to 50% of radiotherapy centres [8]. With this fast uptake of these new IMRT delivery

techniques, there will be more use in clinical trials, and it is crucial to ensure that the new technology has been implemented correctly at the centres in order to avoid jeopardising trial results. Against this background, the RTTQA group developed a treatment planning test for credentialing a range of rotational IMRT techniques available to be used in clinical trials in the UK.

METHODS

The primary aim of this study was to evaluate the feasibility of a planning test to be used in the RTTQA credentialing programme for rotational IMRT. The test was aimed to be planned as a complex plan generated on a standard set of volumes, which were both clinically relevant and geometrically straightforward, and delivery would be validated by the participating centres' own in-house QA programmes. 10 UK centres identified by the IPEM survey were chosen to participate in this study, as they had already completed the remaining modules of the RTTQA IMRT credentialing programme. The five RA centres used an ECLIPSETM (Varian Medical Systems) planning system with the Varian Analytic Anisotropic AlgorithmTM, the two VMAT centres used a PINNACLE SmartArcTM (Philips Healthcare, Andover, MA) planning system with an adaptive convolution algorithm and the three HT centres used a HIARTTM (TomoTherapy Inc., Madison, WI) planning system with a collapsed cone algorithm.

Based on the recommendations by Van Esch et al [9], Clark et al [7] developed simple TPS tests "dip" and "steps" to include in the conventional IMRT credentialing program. Each plan was planned with a direct single field at a gantry angle of 0° and the isocentre was placed at a 50-mm depth. The "dip" test was designed to verify whether the TPS modelled the multileaf collimator (MLC) positioning and transmission correctly when delivering doses to planning target volumes (PTVs) with an organ at risk (OAR) volume in between. The "steps" test was established to test whether a plan of three different dose levels could be delivered accurately. These tests with simple shaped volumes provided a straightforward way to check the commissioning of the TPS at the centres by comparing the planned and delivered

dose distributions. With the volumetric delivery nature of the rotational IMRT techniques, the dip and steps tests were considered to be insufficient to provide adequate verifications on the TPS, especially in the superior–inferior (SI) directions. Based on the multi-target benchmarking test reported by the American Association of Physicists in Medicine Task Group (AAPMTG) 119 [10], these tests have been modified to incorporate a three-dimensional (3D) TPS test designed specifically for rotational IMRT delivery techniques. This combined test aims to check MLC positioning, transmission and relative dose levels in transverse, coronal and sagittal planes.

A common CT data set consisting of a virtual cylindrical phantom with a diameter of 20 cm was created with slices of 2 mm thickness. The CT data set and the volumes were made available to the participating centres in Digital Imaging and Communications in Medicine (DICOM)-CT format and DICOM-RT-structure-set format, respectively. Taking into consideration the full arc-shaped dose distributions produced by rotational IMRT, the volume set consisted of five PTVs with different dose levels around a cylindrical OAR (diameter of 20 mm) with a gap of 1 cm between the PTV and OAR as shown in Figure 1.

The primary PTV is PTV2 with an anterior–posterior (AP) dimension of 50 mm and length of 40 mm. PTV4 and PTV5, which are identical to PTV2, are situated with PTV2 between them. PTV3 is abutting directly posterior to PTV2 with a length of 120 mm. PTV1 is an

ellipse shape with a width (left–right dimension) of 30 mm and a length of 120 mm and is positioned next to PTV2 with a gap of 5 mm. The dose prescription is to deliver 25 Gy to the primary PTV2, 20 Gy to PTV3 and PTV5 and 15 Gy to PTV1 and PTV4 in 10 fractions, ensuring that the maximum dose to the OAR remains <10 Gy. The PTVs and OARs were positioned this way to mimic a range of common clinical situations and to verify whether the dip and step effects could be produced in all directions simultaneously (Figure 2).

With the advances in complexity of radiotherapy delivery such as IMRT, several reports including the International Commission on Radiation Units and Measurements report 83 [11] have indicated the need to change the way that the dose is reported, from the dose to a point, to doses to volumes such as the minimum, mean and maximum dose received by PTVs [11–14]. Table 1 lists the planning dose constraints that the centres aimed to fulfil. Centres were asked to normalise the 3DTPS plan following their own clinical practice as long as it fulfilled the dose constraint for the PTV2 mean dose. Guided by the AAPMTG119 report, the lower and upper dose constraints were set to $D_{99\%}$ (dose received by 99% of the volume) and $D_{10\%}$ (dose received by 10% of the volume). $D_{10\%}$ could be used for abutting PTVs with different prescription doses [10]. For the OARs, it was more practical to count the OAR as a planning organ at risk (PRV) owing to its close proximity to the PTVs [13,15,16]. The dose constraint was designed to limit the amount of PRV (in absolute

Figure 1. The dimensions and positions of the three-dimensional (3D) treatment planning system volumes in a virtual cylindrical phantom in (a) the transverse plane and (b) 3D visualisation. OAP, organ at risk; PTV, planning target volume.

Figure 2. The “dip” and “step” effects in the three-dimensional treatment planning system test.

volume) receiving a certain dose level. It was set to $D_{1\text{cm}^3}$ (dose received by 1 cm^3 of the volume) of the OAR receiving no more than 10 Gy. Centres were advised that it might not be possible to achieve all of the objectives, and they should spend a similar length of time on planning this exercise as it took to produce a complex clinical rotational IMRT plan. It was a mandatory requirement to achieve the primary goal, and the others were to be prioritised as follows:

- (1) primary goal: to fulfil the objectives for PTV2 (primary PTV) and OAR
- (2) secondary goal: to fulfil the objectives for PTV1 and PTV3
- (3) tertiary goal: to fulfil the objectives for PTV4 and PTV5.

Centres were asked to carry out their own in-house QA for the plans submitted for this study to ensure that the plan was deliverable and that it met their local clinical QA tolerance for IMRT dosimetry. A survey, as shown in Table 2, was sent out to centres aiming to gather information on their comments on the test and their in-house QA results.

Data analysis on plans submitted was performed using the Visualisation & Organisation of Data for Cancer

Analysis (VODCATM) program v. 4.3.3 (MSS Medical Software Solutions GmbH, Hagenhorn, Switzerland) [17]. VODCA was written using Interactive Data Language (IDL®; ITT Visual Information Solutions, Boulder, CO), and it provides a graphical display of the radiotherapy dose distribution and an independent computation of dose–volume histograms for PTV and OAR structures. In addition to the comparisons of dose constraints achieved, the homogeneity index (HI) of each PTV was evaluated between plans to assess the dose variations across the treatment volume. The HI was defined in this study as: $\text{HI} = (D_{2\%} - D_{98\%}) / \text{prescribed dose}$, where $D_{2\%}$ is the dose received by 2% of the treatment volume and $D_{98\%}$ is the dose received by 98% of the treatment volume.

RESULTS

All 10 centres (5 RA, 2 VMAT and 3 HT) used a single isocentre for the 3DTPS. In general, centres spent approximately one working day to complete the exercise. The dose matrix resolution for all plans was chosen based on the local clinical standard. All RA plans were generated with 2 arcs and 177 control points per arc using Varian linear accelerators with 5-mm width MLCs. The mean total number (standard deviation, SD) of monitor units (MUs) is 739 (SD=84) with 160 s

Table 1. The dose constraints for each volume in the three-dimensional treatment planning system test

Volumes	Mean dose	Minimum dose	Maximum dose
OAR	N/A	N/A	$D_{1\text{cm}^3} < 10\text{ Gy}$
PTV1	15 Gy ($\pm 0.5\text{ Gy}$)	$D_{99\%} > 13.5\text{ Gy}$	$D_{10\%} < 16.5\text{ Gy}$
PTV2	25 Gy ($\pm 0.5\text{ Gy}$)	$D_{99\%} > 22.5\text{ Gy}$	$D_{1\%} < 26.75\text{ Gy}$
PTV3	20 Gy ($\pm 0.5\text{ Gy}$)	$D_{99\%} > 18\text{ Gy}$	$D_{10\%} < 22\text{ Gy}$
PTV4	15 Gy ($\pm 1\text{ Gy}$)	$D_{99\%} > 13.5\text{ Gy}$	$D_{10\%} < 18\text{ Gy}$
PTV5	20 Gy ($\pm 0.5\text{ Gy}$)	$D_{99\%} > 18\text{ Gy}$	$D_{10\%} < 22\text{ Gy}$

OAR, organ at risk; PTV, planning target volume.

Table 2. Questions and results of the three-dimensional treatment planning system (3DTPS) test survey

Questions		Answer options
Q1	What were your impressions of the 3DTPS planning exercise? Please score from 1 to 10. 1 to be clinically irrelevant 10 to be clinically relevant	Mean score=6 Median score=7 Range=2–10
Q2	How did you find the planning process of 3DTPS? Please score from 1 to 10. 1 to be hard 10 to be easy	Mean score=6 Median score=7 Range=3–8
Q3	How easy was the 3DTPS planning guidelines document to follow? Please score from 1 to 10. 1 to be unclear and misleading 10 to be clear and easy to understand	Mean score=8 Median score=8 Range=7–10
Q4	How easy did you find the planning goals and their relative priorities to achieve? Please score from 1 to 10. 1 to be difficult to follow 10 to be straightforward	Mean score=6 Median score=7 Range=3–9
Q5	Did you have any difficulties in achieving any dose constraints listed in the 3DTPS planning guidelines?	Primary planning goal • OAR dose constraint=1 centre • PTV2 dose constraints=0 centre
		Secondary planning goal • PTV1 dose constraints=0 centre • PTV3 dose constraints=2 centre
		Tertiary planning goal • PTV4 dose constraints=6 centres • PTV5 dose constraints=3 centres
Q6	Did you validate the delivery of the 3DTPS plan on your own IMRT QA system?	Yes=10 out of 10 centres
Q7	What equipment did you use for the 3DTPS test QA?	• “ScandiDos Delta4®=5centres • PTW 2D array and “Octavius™ Phantom=4 centres • Ion chamber point doses and film analysis=1 centre
Q8	Did you use gamma analysis for QA assessment?	Yes (9 centres) No (1 centre that used point dose measurement and a profile agreement on films with a tolerance of 3%)

IMRT, intensity-modulated radiotherapy; OAR, organ at risk; PTV, planning target volume; QA, quality assurance.

^aScandiDos Delta4 is manufactured by ScandiDos AB, Uppsala, Sweden; Octavius Phantom is manufactured by PTW Freiburg, Freiburg, Germany.

as the combined estimated delivery time for both arcs. VMAT plans were generated with a single arc and 2° control point spacing using Elekta linacs. VMAT 1 and VMAT 2 are optimised with 10- and 5-mm MLCs, respectively. The mean total number of MUs for VMAT plans is 792 (SD=7) with 200 s estimated delivery time. All HT plans were planned with a field width of 2.5 cm and a modulation factor of 2. The pitch was set as 0.43 for HT 1 and 0.287 for HTs 2 and 3. The mean total numbers (SD) of MUs and estimated delivery time for

HT plans are 3830 (SD=710) and 272 s (SD=42), respectively.

All centres (100%) fulfilled the primary goal by achieving the dose constraints of the primary PTV2 and OAR. Seven centres (three RA, one VMAT and three HT plans) were able to fulfil the secondary goal. Among those seven centres, three centres (two RA and one VMAT plans) managed to achieve the tertiary goal. 6 out of 10 centres (60%) failed to achieve the dose

Figure 3. The dose distribution of an example Varian RapidArc (RA), Elekta VMAT (VMAT) and helical tomotherapy (HT) plans on Visualisation & Organisation of Data for Cancer Analysis software. 22.5 Gy [for planning target volume (PTV)2] is shown by the dashed arrow, 18 Gy (for PTV3 and PTV5) is shown by the diamond arrowhead, 13.5 Gy (for PTV1 and PTV4) is shown by the dotted arrow and 10 Gy is shown by the unbroken arrow.

constraints required for PTV4, and the median HI was the largest (0.47 with SD=0.1) out of all the PTVs. Examples of dose distributions by each rotational IMRT technique are displayed in Figure 3. The achieved dose constraints by each centre are summarised in Table 3.

All 10 centres returned the questionnaire for analysis and the results are summarised in Table 2. The median score for the 3DTPS test being clinically relevant is 7 out of 10, and the median score for the planning guidelines being easy and clear to follow is 8 out of 10. All centres delivered the 3DTPS test plans to a phantom as they would for their own patient-specific dosimetry QA. As centres used their own equipment, different measurement planes and tools were used as shown in Table 2. The most common QA assessment tool used

was the gamma index criteria (9 out of 10 centres), which included dose differences and distance to agreement parameters [18], and the QA results are summarised in Table 4. All 3DTPS test plans were verified and passed by the centres' in-house QA programmes and their respective tolerance limits. Six out of nine centres used tolerance criteria of >95% of the analysed area, giving a gamma index <1 at 3% and 3 mm. Six centres indicated that they would use the 3DTPS test again as a QA test for TPS commissioning and upgrades.

DISCUSSION

The RTTQA group is a multidisciplinary team with representation from six UK centres, which undertakes a programme of activities in relation to individual

Table 3. The achieved doses for each volume by 10 centres following the planning instructions. The failed dose constraints are given in bold

Primary goal	PTV2				OAR			
	Mean dose	$D_{99\%} \geq 22.5 \text{ Gy}$	$D_{1\%} \leq 26.75 \text{ Gy}$	HI	$D_{1\text{cm}^3} < 10 \text{ Gy}$			
RA 1	25.0	23.2	26.5	0.11	8.2			
RA 2	25.3	22.8	26.8	0.15	9.4			
RA 3	24.9	22.5	25.5	0.11	8.7			
RA 4	24.9	22.8	26.0	0.11	8.5			
RA 5	24.6	22.5	25.6	0.11	8.5			
VMAT 1	25.0	22.7	26.4	0.13	8.7			
VMAT 2	25.0	22.7	26.1	0.12	9.0			
HT 1	24.9	22.6	25.9	0.12	9.2			
HT 2	24.8	22.9	25.7	0.09	8.5			
HT 3	24.9	22.7	26.0	0.12	8.3			
Secondary goal	PTV1				PTV3			
	Mean dose	$D_{99\%} \geq 13.5 \text{ Gy}$	$D_{10\%} \leq 16.5 \text{ Gy}$	HI	Mean dose	$D_{99\%} \geq 18 \text{ Gy}$	$D_{10\%} \leq 22 \text{ Gy}$	HI
RA 1	15.3	13.4	16.6	0.27	20.1	17.7	21.6	0.23
RA 2	15.2	13.7	16.2	0.21	20.4	18.2	21.5	0.19
RA 3	15.3	13.6	16.5	0.29	20.1	17.8	21.2	0.22
RA 4	15.2	13.5	16.3	0.27	20.2	18.3	21.2	0.19
RA 5	15.1	13.8	15.8	0.17	20.0	18.2	20.6	0.15
VMAT 1	14.9	13.2	16.1	0.34	20.0	17.2	21.6	0.28
VMAT 2	15.2	13.6	16.2	0.28	20.2	18.2	20.9	0.20
HT 1	15.1	13.9	15.6	0.29	20.1	18.2	21.3	0.22
HT 2	14.8	13.5	15.2	0.18	20.2	18.2	21.1	0.23
HT 3	15.3	13.9	16.0	0.34	20.2	18.4	21.3	0.21
Tertiary goal	PTV4				PTV5			
	Mean dose	$D_{99\%} \geq 13.5 \text{ Gy}$	$D_{10\%} \leq 18 \text{ Gy}$	HI	Mean dose	$D_{99\%} \geq 18 \text{ Gy}$	$D_{10\%} \leq 22 \text{ Gy}$	HI
RA 1	15.7	13.6	17.7	0.41	20.2	18.1	21.6	0.22
RA 2	15.5	13.5	16.6	0.33	20.2	18.4	21.1	0.16
RA 3	16.0	13.1	18.5	0.47	20.3	17.4	22.1	0.28
RA 4	16.0	13.9	18.8	0.73	20.2	18.4	21.3	0.27
RA 5	16.0	14.6	17.8	0.49	19.9	18.3	20.5	0.22
VMAT 1	15.9	13.9	18.3	0.47	20.4	18.7	22.1	0.21
VMAT 2	15.8	14.3	17.9	0.41	20.5	18.9	21.7	0.18
HT 1	15.4	13.8	18.7	0.49	20.2	19.0	21.6	0.21
HT 2	15.6	13.8	18.2	0.52	20.1	17.8	21.2	0.27
HT 3	15.6	13.7	18.4	0.47	20.3	18.9	21.9	0.23

$D_{x\%}$, dose received by $x\%$ of the volume; $D_{1\text{cm}^3}$, dose received by 1cm^3 of the volume; HI, homogeneity index; HT, helical tomotherapy; OAR, organ at risk; PTV, planning target volume; RA, Varian RapidArc; VMAT, Elekta VMAT.

Table 4. A summary of the three-dimensional treatment planning system test plan quality assurance (QA) results

Centre	QA equipment	Gamma criteria	Threshold (%)	Tolerance limit	Number of pixels with gamma <1 (%)	Does it pass your clinical QA tolerance?
RA 1	Delta 4	3% and 3 mm	20	>95% of pixels with gamma index >1	99.9	Yes
RA 2	Octavius	3% and 2 mm	20	>95% of pixels with gamma index >1	97.4	Yes
RA 3	Octavius	3% and 3 mm	10	>95% of pixels with gamma index >1	98.7	Yes
RA 4	Octavius	3% and 3 mm	20	>95% of pixels with gamma index >1	100.0	Yes
RA 5	Delta 4	3% and 3 mm	10	>95% of pixels with gamma index >1	99.3	Yes
VMAT 1	Octavius	4% and 4 mm	20	>95% of pixels with gamma index >1	98.2	Yes
VMAT 2	Delta 4	3% and 3 mm	20	>95% of pixels with gamma index >1	95.6	Yes
HT 1	Delta 4	3% and 3 mm	20	>95% of pixels with gamma index >1	100.0	Yes
HT2	Ion chamber and film	Did not use gamma analysis		3% tolerance for chamber measurements and subjective profile assessment on film analysis	+0.2% for the chamber measurement. Good profile agreements on film analysis	Yes
HT 3	Delta 4	3% and 3 mm	20	>95% of pixels with gamma index >1	100.0	Yes

HT, helical tomotherapy; RA, Varian RapidArc; VMAT, Elekta VMAT.

clinical trials, necessary to ensure adherence to a trial protocol. Currently, the group runs 19 UK multicentre clinical trials and has developed and co-ordinated the QA for 6 IMRT trials (ARTDECO, CHHiP, PARSPORT, COSTAR, IMPORT HIGH and PIVOTAL). These have, to date, involved 15 centres; and close links to UK radiotherapy centres have already been established.

Ibbott et al [19] reported that nearly 30% of US cancer centres failed to deliver a dose distribution to a head and neck phantom that agreed with their own treatment plan to within a tolerance criterium of 7% for a dose in a low-gradient region or 4-mm distance to agreement in a high-gradient region. Thus, IMRT treatments might not be always as accurate as required, unless the ability of participating centres to perform these advanced technologies is assessed [1]. Centres that were credentialed in a clinical trial showed a better compliance rate with the

trial protocol, and this may be owing to the constructive feedback from the credentialing process [20]. There is no doubt that additional effort is required from participating centres over the existing QA requirements in the trials. If overly onerous this could affect the trial accrual because of the extra time required for completing the credentialing programme. Thus, it is crucial to obtain an optimum balance by implementing a practical and effective credentialing module for new techniques.

Often, compromises need to be made when PTVs and OARs are in close proximity to one another in complex IMRT planning. It is essential to provide clear planning goals and objectives for participating centres to follow. In this 3DTPS test, all centres were required to achieve the objectives of primary PTV2 coverage and sparing the OAR as the primary planning goal. A secondary planning goal was set for the PTV1 and PTV3 coverage. This

combined the principles of the dip and steps tests to check whether the TPS could still deliver a heterogeneous dose distribution to multitarget volumes while minimising dose to the OAR, which was surrounded by PTVs. The final planning goal, which increased the complexity of modulation, was to push the TPS to produce a plan fulfilling the objectives of PTV4 and PTV5 coverage. This tested the TPS to see if it was possible to produce plans with different dose levels in SI directions after achieving all the previous planning goals.

All plans fulfilled the primary planning goal. The VMAT 1 centre commented on the difficulty of achieving sharp dose gradients required for PTV2, PTV3 and OARs in the primary and secondary planning goals owing to its 10-mm MLCs. The VMAT 1 centre spent a slightly longer time optimising the plan and to put the focus on completing the primary planning goal as stated in the planning guidelines. Questionnaires from participating centres indicated that 6 out of 10 centres had difficulties in achieving dose constraints for PTV4 in which the highest mean HI was found. This could be explained by the extremely high level of modulation required when PTV4 is adjacent to both PTV2 and PTV3 with different prescription dose levels. Although there appear to be differences between centres and different rotational delivery techniques, the aim of this study was not to compare these, and there are insufficient data to do so. The differences may also reflect the areas of expertise of centres concerned, some of which had implemented the rotational IMRT technique for prostate cancer patients, which required less modulation than the case presented here. This is further supported by those centres' comments on 3DTPS not being clinically relevant (one scored 2 out of 10 in Q1 and 3 out of 10 in Q2 of the survey) based on their clinical needs.

This study covered a range of rotational IMRT techniques from the 10 UK centres resulting in 3 types of rotational IMRT delivery techniques. Centres chose similar planning optimisation parameters for the 3DTPS test within each group. This study indicated that the 3DTPS test combined with practical planning guidelines and goals were validated by UK centres that are experienced in rotational IMRT techniques. It aimed to produce planning results that were comparable to a complex clinical IMRT plan with similar

degrees of beam modulation according to the equipment available at the participating centres. This planning test proved to be a useful and feasible credentialing tool. The goals set are achievable on RA, VMAT and HT rotational IMRT delivery techniques available in the UK.

Participating centres performed their own in-house QA and proved that the 3DTPS plans submitted were deliverable within a clinical QA tolerance. Agreeing with the survey (sample size=139 institutions) conducted by Nelms and Simon [21], more than half of the centres involved in this study chose the acceptance testing to be the combined 3% and 3-mm gamma index criteria as their clinical QA standard. We are currently undertaking an audit to perform independent measurements on the plans. This will provide an objective assessment on whether the plans were comparable between centres in terms of the delivery accuracy and associated QA metrics. Standard measurement tools and planes will be used and compared between all pilot centres in order to establish confidence limits and action levels on dosimetry verification for national rotational IMRT benchmarking.

CONCLUSIONS

The nine-module IMRT credentialing programme by the national RTTQA group has been used routinely in UK IMRT trials QA. We have established an extra planning test to cover the rotational IMRT within our IMRT credentialing programme. This study has proved the feasibility of using this 3DTPS test to credential the available rotational IMRT techniques in the UK with clear and detailed planning instructions and goals.

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