

Multicentre knowledge sharing and planning/dose audit on flattening filter free beams for SBRT lung

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Abstract. When implementing new technology into clinical practice, there will always be a need for large knowledge gain. The aim of this study was twofold, (I) audit the treatment planning and dose delivery of Flattening Filter Free (FFF) beam technology for Stereotactic Body Radiation Therapy (SBRT) of lung tumours across a range of treatment planning systems compared to the conventional Flattening Filter (FF) beams, (II) investigate how sharing knowledge between centres of different experience can improve plan quality. All vendor/treatment planning system (TPS) combinations investigated were able to produce acceptable treatment plans and the dose accuracy was clinically acceptable for all plans. By sharing knowledge between the different centres, the minor protocol violations (MPV) could be significantly reduced, from an average of 1.9 MPV per plan to 0.6 after such sharing of treatment planning knowledge. In particular, for the centres with less SBRT and/or volumetric-modulated arc therapy (VMAT) experience the MPV average per plan improved. All vendor/TPS combinations were also able to successfully deliver the FF and FFF SBRT VMAT plans. The plan quality and dose accuracy were found to be clinically acceptable.

1. Introduction

Learning and understanding a new technology and then implementing it for clinical use is a core component of radiotherapy (RT). The rapid technological advances in RT over the last decade have changed cancer treatments such that what was considered cutting edge a few years ago is now routine treatment in most centres [1]. Currently flattening filter free (FFF) beams are becoming more widely available and are being increasingly used for Stereotactic Body Radiation Therapy (SBRT) treatments for lung cancer, often coupled with Volumetric-Modulated Arc Therapy (VMAT) delivery methods. FFF beams have a range of characteristics that have the potential to improve treatment plans in these



situations, including higher dose rate, reduced lateral changes in beam hardening, reduced leakage and less out-of-field dose.

When implementing a new technology, many centres have collaborating institutions they can contact for good advice and published literature that can help and guide them to a safe implementation. This is often done by comparing the new technology to a well established one. For FFF technology, the natural comparison would be the conventional Flattening Filter (FF) technology. This has been done for FFF treatments for one specific vendor and treatment planning system (TPS) combination in several publications [2] and other vendor/TPS combinations are also now beginning to appear in the literature [3]. The next implementation step is often an internal and/or external dose audit; to validate the dose accuracy as sufficiently high for clinical use [4]. This has not been reported often for VMAT [5] and not at all for FFF.

The two purposes of the study were:

- I) to audit the treatment planning quality and dose accuracy of SBRT VMAT treatments for lung tumours, for both FFF and FF beams, where the plans were created on different planning systems for delivery on different accelerators; and hence to assess the impact of different linacs, beam energies, TPSs and department experience for SBRT FFF VMAT lung treatments
- II) to evaluate if sharing knowledge across the different centres with different TPS/linac combinations would improve plan quality.

2. Method and material

Three patients with a solitary lung tumour were selected, where one patient had a tumour close to the ribs, one close to the bronchial tree and one in the free part of the lung according to RTOG0915 [6]. The prescription doses were 48Gy/4fr., 50Gy/5fr., 54Gy/3fr. and the organ at risk (OAR) dose constraints were as specified by a combined protocol of RTOG0915 and Leeds Teaching Hospitals NHS Trust for an Australian SBRT phase II trial [6].

The three patient's CT-datasets and corresponding DICOM RT structures of targets and OAR were provided to six different cancer treatment centres for SBRT planning using FF and FFF VMAT beams. The centres were not allowed to change the provided structures, however they were allowed to add additional optimisation structures. All evaluation was performed on the provided structures. The different centre's linac/TPS combinations were: Elekta Agility/Monaco, Varian TrueBeam/Eclipse, Varian TrueBeam/Pinnacle, TomoTherapy/HiArt (TomoTherapy only with FFF plans) and two centres with Elekta Agility/Pinnacle. VMAT was used on all conventional linacs for all plans with a 200 degree arc avoiding the contra lateral lung. Mainly 6 MV FF and 6 MV FFF beams were used, however one centre used 10 MV FFF. The centres were encouraged to create the treatment plans in collaboration between a radiation therapist (dosimetrist) and a medical physicist.

The plan metrics evaluated were GTV and PTV mean doses, volume of PTV covered by 100% of the prescribed dose, mean and max organ at risk doses, integral dose (patient dose outside PTV), target conformity ($CI_{PTV} = V_{D100\%} / V_{PTV}$), and dose spillage conformity ($CI_{spillage} = V_{D50\%} / V_{PTV}$). Following the SBRT protocol, target coverage, organ sparing and conformity were evaluated as according to the protocol (per protocol). When the planning objectives were not met they were classified as minor or major protocol violations as defined in RTOG0915 [6].

To reduce the SBRT and/or VMAT experience level differences between centres, each centre was asked to plan the three patients according to the protocol and to upload the results to the principal investigator. A workshop was then arranged where each plan was discussed and debated by the radiation therapist and a medical physicist from each centre. The centres were given the opportunity to replan the patients before final submission. Three centres had clinical experience with both VMAT and SBRT and were classed as experienced. Three centres had no or limited clinical experience with VMAT and SBRT on the specific linac and were classed as having limited experienced.

The treatment plans were delivered on a specific linac in each centre and dose accuracy was measured on the Sun Nuclear ArcCHECK phantom. The clinically acceptable level was set to 95% gamma pass rate for 3% (of max dose) and 3mm.

Statistical significance was tested with Wilcoxon signed-rank non-parametric test, significant level was set to $p < 0.05$.

3. Results

For all vendor combinations, differences in plan quality between FF and FFF plans were small and likely to be of no clinical relevance when evaluating target doses and OARs (table 1). After replanning, the dose spread was reduced for target mean doses and CI_{spillage} . The most significant difference between centres was the number of minor protocol violations (MPV) per plan, which seemed to correlate to the amount of clinical SBRT VMAT experience. The three most experienced centres had an average of 0.6 MPV per plan for both FF and FFF plans whereas the two centres with limited experience had 3.7 MPV per plan. The average MPV was significantly improved ($p=0.002$) after the sharing knowledge workshop and replanning.

Table 1. Bold number indicate statistically significant improvements after replanning

	Initial planning				Replanning			
	FF		FFF		FF		FFF	
Target dose	Mean	SD	Mean	SD	Mean	SD	Mean	SD
GTV mean dose [%]	114.7	8.9	115.0	7.4	119.2	7.3	118.4	6.3
PTV mean dose [%]	110.1	5.0	110.6	4.5	112.3	3.8	111.9	3.8
PTV $V_{100\%}$ [%]	98.6	0.6	98.9	0.8	98.8	0.7	99.0	0.6
OAR dose								
Cord max dose [Gy]	10.5	4.1	10.5	3.6	10.5	3.9	10.3	4.3
$V_{20\%}$ Lung-PTV [%]	5.1	2.0	5.3	2.0	4.9	1.8	4.8	1.8
Conformity								
Patient-PTV mean dose [Gy]	2.02	0.38	2.03	0.45	1.94	0.30	1.88	0.34
$CI_{\text{PTV}} V_{D100\%}/V_{\text{PTV}}$	1.14	0.10	1.18	0.18	1.10	0.06	1.11	0.06
$CI_{\text{spillage}} V_{D50\%}/V_{\text{PTV}}$	6.14	1.74	6.26	1.84	5.58	0.70	5.51	0.71
Minor protocol violation pr plan								
MPV total group	1.7	2.0	2.1	2.0	0.5	0.7	0.7	1.0
MPV high experience	0.4	0.7	0.8	1.0	0.4	0.7	0.6	1.0
MPV limited experience	3.7	1.8	3.6	1.7	0.5	0.8	0.8	1.2

The dose measurements on the ArcCheck phantom were all but one within the pre-set clinically acceptable tolerance, with a $98.0 \pm 2.6\%$ and $96.5 \pm 1.9\%$ pass rate for FF and FFF plans, respectively.

4. Discussion

The VMAT optimisation algorithm is very different in the four TPSs [7-10], however the plan quality across the vendor/TPS combinations differed little on these three patients both for FF and FFF plans. Before the knowledge sharing workshop, the plans from the centres with limited experience showed signs of less optimal VMAT delivery. The number of MPVs were significantly reduced after the replanning; and also the general VMAT optimisation appeared to have improved indicating sub-optimal user inputs to the planning process before the knowledge sharing workshop.

At the knowledge sharing workshop, the joint discussion crossed several topics. For VMAT, a non-zero collimator angle is highly advisable, one TPS created better plans with collimator angles around 10 degrees, whereas the two other TPSs worked well around 25 to 35 degrees. Normalisation of the

final dose to fit specific objectives, specifically target doses, were used in all TPSs; however one centre avoided this by finalising the calculation with 15 or less optimisation iterations. SBRT protocols often do not specify a maximum dose to the target thereby allowing for target over-dosage. This can reduce dose to the OAR, since demanding the homogenous target dose forces the TPS to modulate the beam more. Cancers in the lung have a range of OARs near the target and even though the treatment plan might meet all protocol objectives, there will still be benefits for the patients if it is possible to reduce OAR doses even further as long as it doesn't compromise target dose objectives. It is therefore important to make OAR prioritisation clear for the planner and a good consensus is often best reached by a multi disciplinary team discussion.

5. Conclusion

FFF can be used for SBRT planning, independent of the specific combination of linear accelerator vendor and treatment planning system. Centres with less experience in SBRT and VMAT did less well in the initial analysis but reduced MPVs occurred after knowledge sharing and replanning. The dose metric accuracy was only tested on the replanned treatment plans and was found to be good. All vendor/TPS combinations can produce and deliver FFF SBRT VMAT treatments to acceptable clinical requirements.

6. References

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