Available online at www.sciencedirect.com

ScienceDirect

journal homepage: http://www.elsevier.com/locate/rpor

Original research article

Assessment of the Monitor Unit Objective tool for VMAT in the Eclipse treatment planning system

Sara Jiménez-Puertas[a,*], *David Sánchez-Artuñedo*[b], *Marcelino Hermida-López*[b]

[a] *Servicio de Física y Protección Radiológica, Hospital Universitario Miguel Servet, Paseo Isabel la Católica 1-3, 50009, Zaragoza, Spain*

[b] *Servei de Física i Protecció Radiològica, Hospital Universitari Vall d'Hebron, Pg. Vall d'Hebron 119-129, 08035 Barcelona, Spain*

ARTICLE INFO

Article history:
Received 3 November 2017
Accepted 2 February 2018
Available online 25 February 2018

Keywords:
VMAT
RapidArc
Eclipse
Monitor units

ABSTRACT

Aim: This work aims to achieve the highest possible monitor units (MU) reduction using the *MU Objective* tool included in the Eclipse treatment planning system, while preserving the plan quality.

Background: The treatment planning system Eclipse (Varian Medical Systems, Palo Alto, CA) includes a control mechanism for the number of monitor units of volumetric modulated arc therapy (VMAT) plans, named the MU Objective tool.

Material and methods: Forty prostate plans, 20 gynecological plans and 20 head and neck plans designed with VMAT were retrospectively studied. Each plan (*base plan*) was optimized without using the MU Objective tool, and it was re-optimized with different values of the Maximum MU (*MaxMU*) parameter of the MU Objective tool. MU differences were analyzed with a paired samples *t*-test and changes in plan quality were assessed with a set of parameters for OARs and PTVs.

Results: The average relative MU difference ($\overline{\Delta MU}$) considering all treatment sites, was the highest when $MaxMU = 400$ (−4.2%, $p < 0.001$). For prostate plans, the lowest $\overline{\Delta MU}$ was obtained (−3.7%, $p < 0.001$). For head and neck plans $\overline{\Delta MU}$ was −7.3% ($p < 0.001$) and for gynecological plans $\overline{\Delta MU}$ was 7.0% ($p = 0.002$). Although similar MU reductions were observed for both sites, for some gynecological plans maximum differences were greater than 10%. All the assessed parameters for PTVs and OARs sparing showed average differences below 2%.

Conclusion: For the three studied clinical sites, establishing $MaxMU = 400$ led to the optimum MU reduction, maintaining the original dose distribution and dosimetric parameters practically unaltered.

* *Corresponding author.*
E-mail addresses: jpfcsara@gmail.com (S. Jiménez-Puertas), d.sanchez.artunedo@gmail.com (D. Sánchez-Artuñedo), mhermida@vhebron.net (M. Hermida-López).

https://doi.org/10.1016/j.rpor.2018.02.001

1. Background

The incorporation of intensity-modulated techniques to radiotherapy is supposed to improve dose sparing and conformity compared to conventional 3DCRT techniques, but also implies the delivery of a higher number of monitor units (MU).[1] The increase in MU entails more secondary radiation dose and, therefore, a higher risk of developing secondary cancers.[2,3]

Volumetric modulated arc therapy (VMAT) is a technique based on a simultaneous variation of MLC position, gantry angle and dose rate to improve dose sparing and to shorten the treatment time.[4,5] In modulated techniques, the total MU are not linearly related to prescribed dose, and factors as leaf or gantry speed may substantially affect the total MU of a plan.

In the Eclipse treatment planning system v.11.0.13 (Varian Medical Systems, Palo Alto, CA), the Progressive Resolution Optimizer (PRO3) algorithm is included for VMAT planning, in which three different tools can be differentiated: *Dose Volume Objective*, *Normal Tissue Objective* and *MU Objective* (see Fig. 1). The first two affect the dose homogeneity and conformity in the tumor and dose sparing in healthy tissue. As dose homogeneity and conformity demands rise, the leaf movement often produces many small area segments resulting in increased MU. Conversely, the MU Objective aims to decrease the total MU of the plan. MU Objective and Normal Tissue Objective tools are not mandatory to optimize a plan, so it is a choice of the users to include them in the optimization process.

Several parameters may be adjusted in the MU Objective tool, namely, Maximum MU (*MaxMU*), Minimum MU (*MinMU*) and Strength (*S*). The MU goal is defined by *MinMU* and *MaxMU*, and the priority enforced by the MU reduction goal is defined by the *S* value. In PRO3 algorithm the plan goals are defined by relative priorities assigned to dose–volume histogram (DVH) constraints that the user is asked to specify in the Dose Volume Objective section. The greater the value of a priority of a constraint, the more probable it is that the constraint will be reached, which is useful in conflicting constraints. In the MU Objective tool, the *S* parameter ranges from 0 to 100 and it is not in the same scale as the previous priorities.

Apart from the manufacturer definition, there are no further explanations in literature about how the MU Objective tool works or how it reduces the MU and its utilization may envelop a compromise between the MU reduction and the plan quality.

Ahamed et al.[6] studied the MU Objective tool for ten hypopharinx cancer patients to quantify differences between MU deprived plans and those freely optimized. Clemente et al.[7] investigated the maximum MU reduction for prostate plans in seven patients and reported the dose differences to organs at risk (OARs). Bao-Tiang et al.[8] followed a similar procedure in stereotactic ablative VMAT lung plans obtaining a MU reduction higher than 200 MU/Gy without compromising the target dose coverage and the OARs dose sparing. These

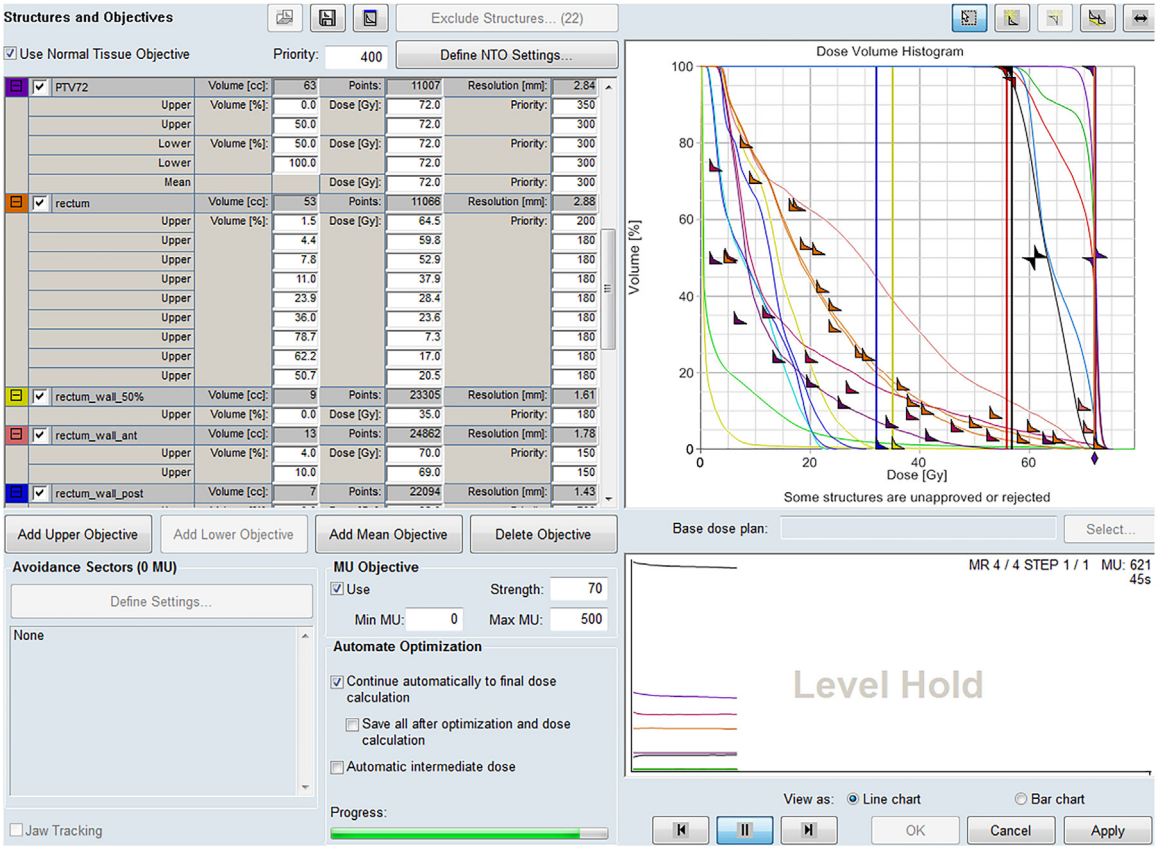

Fig. 1 – MU Objective tool in Eclipse Progressive Resolution Optimizer.

studies evaluated the effect of the MU Objective tool on the total MU and reported the changes obtained in dosimetric parameters.

2. Aim

This work aims to achieve the highest possible MU reduction using the MU Objective tool while preserving the plan quality as unaltered as possible. As the MU Objective tool acts as a 'black box', we have evaluated this tool empirically. To improve the statistics and to find recommended values of the MU Objective parameters without losing the PTV dose coverage and OARs dose sparing, we analyzed a higher number of patients for the prostate, head and neck, and gynecological sites than in previous works. These sites represent 93% of the patients treated with VMAT in our institution.

3. Materials and methods

We retrospectively studied the last 40 prostate plans, 20 gynecological plans and 20 head and neck plans treated with RapidArc (Varian implementation of VMAT) in 2016 at our center.

Prescribed doses for prostate plans were 57 Gy or 59.5 Gy for the prostate plus seminal vesicles PTV and 72 Gy or 77 Gy for the simultaneous integrated boost to the prostate PTV, in 30 or 35 fractions. For gynecological plans, prescribed doses were 45 Gy or 50.4 Gy in 25 or 28 fractions. For head and neck plans, prescribed doses were 60 Gy or 70 Gy for the tumoral region plus affected lymph nodes, and 54 Gy for non-affected lymph nodes in 30 or 35 fractions.

We used one full arc for the prostate and two full arcs for the head and neck and gynecological sites. Plans were optimized with the PRO3 algorithm and calculated with the Acuros XB algorithm with 2.5 mm grid resolution in the Eclipse treatment planning system v.11.0.31 using 6 MV photon beams with a maximum dose rate of 600 MU/min.

Fig. 1 displays the interface of PRO3 in Eclipse during the optimization of a prostate plan. At the top-left corner of the screen, the Normal Tissue Objective, the Dose Volume Objective and priorities of the OARs and PTVs are specified. To the right, the DVH and the evolution of the optimization process are displayed. At the bottom-left corner, the MU Objective tool and its parameters are available to use.

Clemente et al.[7] studied the effect of the MU Objective tool on the MU variation for $S = 50$ and $S = 100$. The highest mean MU reduction was obtained for $S = 100$ ($\Delta MU = -28\%$) at the expense of a high variation in the target mean homogeneity index value ($\Delta HI = -23\%$). Following the manufacturer suggestion to set the S parameter from 50 to 100, we set $S = 70$ for all the tests reported. As in previous studies, we kept $MinMU = 0$ and fixed values of other optimization parameters, as dose constraints, arc-length or collimator angle, to separately assess the influence of the *MaxMU* parameter on the calculated MU.

For each patient, a plan was optimized without using the MU Objective tool, called *base plan*, with the corresponding MU called *MUbase*. This plan was re-optimized with the following *MaxMU* values: 400, 500, 600, 700, 800, 1000 and 1200; thus generating seven additional plans, called *re-optimized plans*. In each re-optimization, the dose constraints and their priorities remained unchanged to evaluate only the MU Objective tool influence on the final MU. Once the whole set of plans was re-optimized and re-calculated, the differences obtained in the cumulative DVH and in MU were analyzed with a paired samples t-test ($\alpha = 0.05$). Plan quality was assessed with the dosimetric parameters indicated in Table 1 for OARs, and with the average dose, dose coverage (D2%, D98%), dose conformity (V95%, V107%) and dose homogeneity (D5%–D95%) for the PTVs.

4. Results

Fig. 2 reports the average relative MU difference ($\overline{\Delta MU}$) as a function of the *MaxMU* value considering all treatment sites. Three results are observed:

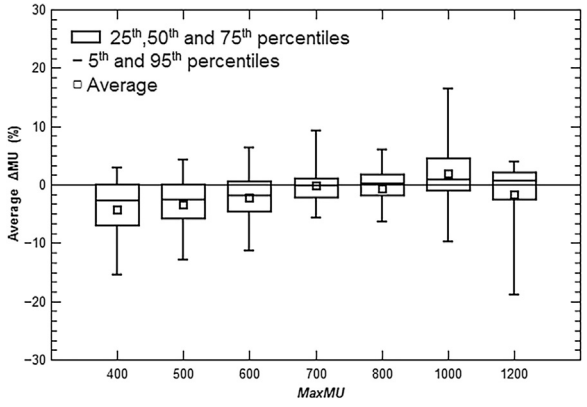

Fig. 2 – Global MU variation according to *MaxMU* values.

Table 1 – Dosimetric parameters evaluated for OARs.

Sites	OARs	Parameters analyzed apart from average dose
Prostate	Rectum	V50Gy, V60Gy, V70Gy
	Bladder	D2%, D67%, V30Gy
	Femoral heads	D2%, V45Gy
Gynecological	Rectum	V30Gy, V40Gy, V45Gy, D50%
	Bladder	V30Gy, V40Gy, V45Gy
	Bowel	V40Gy, D30%
	Femoral heads	V30Gy, D2%
Head and neck	Mandible	V70Gy
	Spinal cord and brainstem	D2%
	Parotids glands	D33%, D50%, D66%

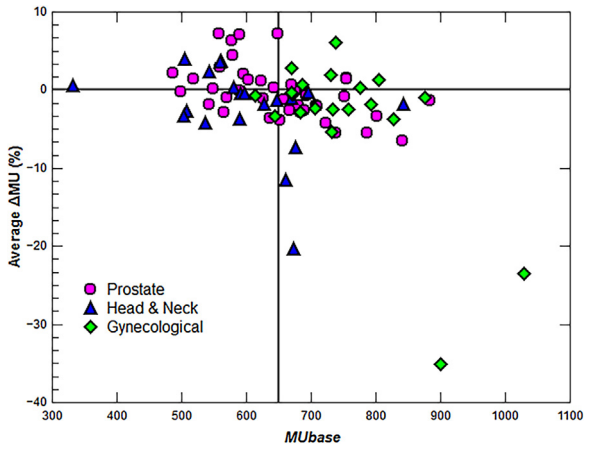

Fig. 3 – MU reduction according to *MUbase* for each treatment site.

Table 2 – *MaxMU* values with the largest average MU reduction for each clinical site.

Sites	*MaxMU*	$\overline{\Delta MU}$(%)	*p*
Prostate (*MUbase* > 650 MU)	500	−3.7%	<0.001
Gynecological	400	−7.0%	0.002
Head and neck	400	−7.3%	<0.001

- MU reduction was the highest when *MaxMU* = 400 (−4.2%, $p < 0.001$).
- A trend of decreasing the $\overline{\Delta MU}$ is observed when using a *MaxMU* value greater than 400.
- The resulting MU tend to increase for *MaxMU* values higher than *MUbase*, as 1000 and 1200.

Fig. 3 displays the relative $\overline{\Delta MU}$ according to *MUbase* for different clinical sites. Each point represents one patient where the $\overline{\Delta MU}$ was obtained considering the whole different *MaxMU* values. Only for prostate plans, a differentiated behavior was found according to *MUbase*. For *MUbase* greater than 650, the $\overline{\Delta MU}$ is −2.2% ($p < 0.001$), being the maximum for *MaxMU* = 500 (−3.7%, $p < 0.001$). On the other hand, for prostate base plans with *MUbase* lower than 650, $\overline{\Delta MU} = +1.7\%$ ($p < 0.001$).

Table 2 summarizes the value of *MaxMU* that involves the maximum $\overline{\Delta MU}$ obtained for each treatment site.

For all OARs in prostate plans, the average differences of each parameter were lower than 0.2%, except for the femoral heads, with an average dose difference of +1.3% ($p = 0.002$), and in hot–spots ($\overline{\Delta D2\%} = +1.4\%$, $p = 0.005$). As for the coverage, conformity and homogeneity in PTVs, differences were lower than 0.4%.

For gynecological plans, the only statistically significant difference was found in the bladder for V40Gy(%), becoming of +0.9% ($p = 0.007$). In a small set of patients, maximum differences greater than 10% were found, corresponding to plans with the highest MU reductions, up to 333 MU.

Head and neck results showed the maximum decrease in $\overline{\Delta MU}$ of all analyzed sites without compromising the OARs sparing. The average differences for all dosimetric parameters were below 0.7%, this value being the maximum average difference obtained in D2% and D5%–D95% for the high-dose PTV and in D50% for the parotid glands. Differences in the rest of dosimetric parameters for OARs and PTVs were lower than 0.3%. Unlike gynecological plans, all particular differences were lower than 5%, which confirms that the MU reduction maintaining the plan quality is a global trend for this site.

5. Discussion

Second malignancies risk in radiotherapy associated with secondary radiation dose is an issue of concern when developing new treatment techniques with high modulation,[2,3] due to the increase in MU. With the Eclipse MU Objective optimization tool, we investigated a practical method to reduce the MU keeping the plan quality unaltered. With fixed values of *S* = 70 and *MinMU* = 0, an optimal value of the *MaxMU* parameter to reach the maximum $\overline{\Delta MU}$ was obtained for different treatment sites.

For prostate plans, we obtained the lowest $\overline{\Delta MU}$ in comparison to other clinical sites being statistically significant only for *MUbase* greater than 650. Although the plan quality stayed unaltered, the variability in $\overline{\Delta MU}$ made it difficult to ensure satisfactory results in all cases. When *MUbase* was lower than 650, the trend is to increase the final MU. This trend becomes more pronounced when using a *MaxMU* value higher than *MUbase* (see Fig. 2), which is an unexpected result, as a higher *MaxMU* value is not supposed to incorporate an additional restriction that affects *MUbase*.

For gynecological plans, particular cases showed the greatest dosimetric differences related to the greatest $\overline{\Delta MU}$ values, demanding an additional evaluation of these re-optimized plans.

For head and neck plans, the maximum $\overline{\Delta MU}$ was achieved with the lowest dosimetric differences, making the optimization tool a useful choice for this site.

Clemente et al.[7] achieved a $\overline{\Delta MU} = -28\%$ for prostate plans with *S* = 100, *MaxMU* = 0.5 × *MUbase* and *MinMU* = 0, although differences in mean dose for the bladder and femoral heads were −12.4% and +9.6%, respectively. We did not achieve such a high MU average reduction but all dosimetric differences were below 2%. This implies a MU reduction keeping the plan practically unaltered, especially for plans with *MUbase* greater than 650.

Ahamed et al.[6] investigated three values of *MaxMU*: 0.8 × *MUbase*, 0.65 × *MUbase* and 0.5 × *MUbase*; and reported superior quality scores for base plans of hypopharinx plans. They reported a MU decrease between 8.6% and 34.7% for *MaxMU* = 0.8 × *MUbase*. In our study, the average dosimetric differences were lower than 0.7%, but with a lower $\overline{\Delta MU}$ (−7.3%) for *MaxMU* = 400.

6. Conclusion

For the prostate, gynecological, and head and neck sites, a plan of similar quality to the base plan was obtained with lower MU. To improve the statistical results, we assessed a bigger set of VMAT plans than in previous publications. Establishing *MaxMU* = 400 leads to the optimum MU reduction in most

cases, keeping the original dose distribution and dosimetric parameters practically unaltered.

Conflict of interest

None declared.

Financial disclosure

None declared.

Acknowledgements

The authors thank Marc Sancho and Diego Carrasco for their help in the data collection.

REFERENCES

1. Wolff D, Stieler F, Welzel G, et al. Volumetric modulated arc therapy (VMAT) vs. serial tomotherapy, step-and-shoot IMRT and 3D-conformal RT for treatment of prostate cancer. *Radiother Oncol* 2009;**93**(2):226–33.
2. Hall EJ. Intensity-modulated radiation therapy, protons, and the risk of second cancers. *Int J Radiat Oncol Biol Phys* 2006;**65**(1):1–7.
3. Kry SF, Salehpour M, Followill DS, et al. The calculated risk of fatal secondary malignancies from intensity-modulated radiation therapy. *Int J Radiat Oncol Biol Phys* 2005;**62**(4):1195–203.
4. Otto K. Volumetric modulated arc therapy: IMRT in a single gantry arc. *Med Phys* 2008;**35**(1):310–7.
5. Teoh M, Clark CH, Wood K, Whitaker S, Nisbet A. Volumetric modulated arc therapy: a review of current literature and clinical use in practice. *Br J Radiol* 2011;**84**(1007):967–96.
6. Ahamed S, Singh N, Gudipudi D, et al. Assessment of monitor unit limiting strategy using volumetric modulated arc therapy for cancer of hypopharynx. *Phys Med* 2017;**35**:73–80.
7. Clemente S, Cozzolino M, Chiumento C, Fiorentino A, Caivano R, Fusco V. Monitor unit optimization in RapidArc plans for prostate cancer. *J Appl Clin Med Phys* 2013;**14**(3):4114.
8. Huang BT, Lin Z, Lin P-X, Lu J-Y, Chen C-Z. Monitor unit optimization in stereotactic body radiotherapy for small peripheral non-small cell lung cancer patients. *Sci Rep* 2015;**5**:18453.