Original paper

Plan quality improvement by DVH sharing and planner's experience: Results of a SBRT multicentric planning study on prostate

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ABSTRACT

Purpose: To evaluate, in a multi-institutional context, the role of Dose Volume Histogram (DVH) sharing in order to achieve higher plan quality, to harmonize prostate Stereotactic Body Radiation Therapy (SBRT) plans and to assess if the planner's experience in SBRT could lead to lower dose at organs at risk (OARs).

Methods: During the first phase five patients enrolled for prostate SBRT were planned by multiple physicists according to common protocol. The prescription dose was 35 Gy in 5 fractions. Dosimetric parameters, modulation index (MIt), plan parameters, and planner experience level (EL) were statistically analyzed. During the second phase median DVHs from all centers were shared and physicists replanned one patient of the five, aiming at inter-planner harmonization and further OARs sparing. Data were summarized by Spearman-correlogram (p < 0.05) and boxplots. The Kruskal-Wallis test was used to compare the re-plans to the original plans.

Results: Seventy-eight SBRT plans from 13 centers were evaluated. EL correlated with modulation of plan parameters and reduction of OARs doses, such as volume receiving 28 Gy of rectum (rectum-V28Gy), rectum-V32Gy, and bladder-V30Gy. The re-plans showed significant reduced variability in rectum-V28Gy and increased PTV dose homogeneity. No significant difference in plan complexity metrics and plan parameters between plans and re-plans were obtained.

Conclusions: Planner's experience in prostate SBRT was correlated with dosimetric parameters. Sharing median DVHs reduced variability among centers whilst keeping the same level of plan complexity. SBRT planning skills can benefit from a replanning phase after sharing DVHs from multiple centers, improving plan quality and concordance among centers.

1. Introduction

Radiation therapy (RT) is a non-invasive treatment option for prostate cancer. RT was historically limited in its attractiveness by the duration of a conventional RT course of 7–9 weeks. The low α/β ratio for prostate stimulated the introduction of stereotactic body radiation therapy (SBRT) [1–4]. SBRT is a RT approach that prescribe high focused doses delivered in few fractions to small targets. Furthermore, the available technological improvements in accuracy of dose delivery [5–11] eased the implementation of clinical trials in prostate SBRT [12–21].

In this context, the quality of the delivered RT and the protocol

Table 1
Institutional data from the survey questionnaire distributed to participants.

Center	TPS	Linac	Technique	E.L. Prostate SBRT	E.L. SBRT	MaximumDose Rate MU/min	Collimator Angle (°)
A	Eclipse	TrueBeam	VMAT	3	3	2400	15–45
B	Eclipse	TrueBeam	VMAT	2	2	600	5
C	Eclipse	Unique	VMAT	2	3	600	45
D	Masterplan	Synergy	SF-IMRT	1	2	500	0
E	Eclipse	Clinac	VMAT	2	2	600	30
F	iPlanRT	Clinac	VMAT	1	3	300	90
G	Pinnacle	Trilogy TX	SF-IMRT	1	3	300	0
H	Eclipse	Clinac	VMAT	1	1	600	0–5
I	Eclipse	TrueBeam	VMAT	1	3	600	10
J	Monaco	Synergy	VMAT	1	2	500	0
K	Eclipse	Trilogy	VMAT	2	3	600	30
L	Masterplan	VersaHD	VMAT	2	3	600	0
M	Eclipse	Truebeam	VMAT	2	2	600	30–90

compliance are essential for RT trial outcomes [22]. In recent years, several reports on the use of Volumetric Modulated Arc Therapy (VMAT) technique for prostate SBRT have been published, showing both the dosimetric feasibility of this approach in terms of highly conformal plans, MU efficiency, rapid delivery [23,24] and excellent clinical pathologic and biochemical control outcomes [25–27]. To achieve these goals, the design of the clinical trial QA should be improved [28] in terms of planning compliance by the physicist side. The international radiotherapy clinical trials community acknowledges the strategic usefulness of ongoing efforts toward global harmonization of clinical trials QA [29]. To prevent confounding factors in the future studies it is crucial to minimize variability in the treatment plan quality, achieving sufficient patient accrual for the required statistical power.

In order to mitigate large variation between institutes, the participating hospitals are required to create plans that are compliant with protocol specifications and sufficiently homogeneous to build robust multi-institutional based clinical trials [30]. Recent studies show independence of plan quality from machine or technology in general, whereas planner skill seems to be more critical [31]. Training and education during the implementation of new radiotherapy methodologies and techniques could enhance planner's skills, improve the average plan quality and minimize the variability among treatment planners.

The need for standardization of treatment planning to minimize plan variability is gaining attention [32]. The main concern remains the assessment of the attainable tradeoff between the PTV coverage and OARs sparing and the safe deliverability of the plan. Some authors suggest Knowledge Based Planning (KBP) as a robust, although time-consuming, solution to reduce variability in a single center and among centers [33–36]. Other authors [37,38] showed that information sharing of a crowd of experienced planners could help finding better solutions for all participants in multi-institutional studies [39,22], reducing the variability between centers and planners and lowering the mean dose to the OARs.

In 2013, the Italian Association of Medical Physics (AIFM) established a Working Group (WG) dedicated to the physics of SBRT technique named "Dosimetry, physics, and radiobiology of image guided hypofractionated ablative radiotherapy" with the aim to strengthen the standardization of SBRT planning and practice for many anatomical regions in a multi-institutional framework. In particular, SBRT multi-planning studies were conducted on liver [40], lung [41], prostate [37] and spine [42]. The last two studies highlighted the reduction of mean doses to the organs at risk (OARs) and harmonization of the dose to the target thanks to the knowledge sharing [39]. However, in all these studies no quantitative analysis of plan complexity was conducted.

The aims of this study were: (i) to evaluate if previous experience in SBRT planning could have an impact in reducing the doses to the OARs and (ii) to assess the potential advantages of the DVH sharing before re-planning to reduce the OARs' doses and differences in target coverage. In this crowd-based approach, the objective is homogeneity among the centers. To that aim, improvements in prostate SBRT planning by sharing the results from different centers with various technologies were investigated. Various dosimetric parameters, metrics regarding plan complexity and metrics related to the plan parameters were considered. Only VMAT or static fields intensity modulated radiation therapy (SF-IMRT) plans were considered in order to analyze common characteristics.

2. Materials and methods

The present study consisted of two phases. During the first phase, each center planned independently five prostate SBRT plans following a common protocol. In the second one, a single patient case was re-planned aiming to harmonize the results.

2.1. Optimization I: plan

The reference center selected five prostate patients enrolled for SBRT. The anatomical structures were delineated by an experienced radiation oncologist and consisted of body, clinical target volume (CTV), planning target volume (PTV), rectum, bladder, and femoral heads. For further information we refer to Marino et al. [37]. Cases were anonymized and sent to other centers through DICOM-RT objects and their IODs (Information Object Definitions): the "RT Image IOD" including the CT images and the "RT Structure Set IOD".

The prescription dose was 35 Gy in 5 fractions to PTV. The minimum PTV coverage request was that at least 95% of PTV to be covered by 95% of the prescription dose (PTV-V95 > 95%). No limit to the maximum dose was defined, allowing planners to use their own institutional protocols. Centers, independently from their experience level, planned with their institutional preferences on: dose normalization to the PTV, isocenter position, field geometry, optimization parameters. Regarding OARs constraints, the protocol of Alongi et al. was considered [43,44]:

- rectum: V18Gy (i.e. the volume receiving 18 Gy) < 35%, V28Gy < 10%, V35Gy < 5%;
- bladder: V18Gy < 40%, V30Gy < 15%, maximum dose (D_{max}) < 38 Gy;
- femoral heads: V25Gy < 10%.

In case of overlap between PTV and OARs, priority was given to the OARs.

For each patient the following data were collected:

(I) PTV and dose volume histogram (DVH) of OARs exported in native format;
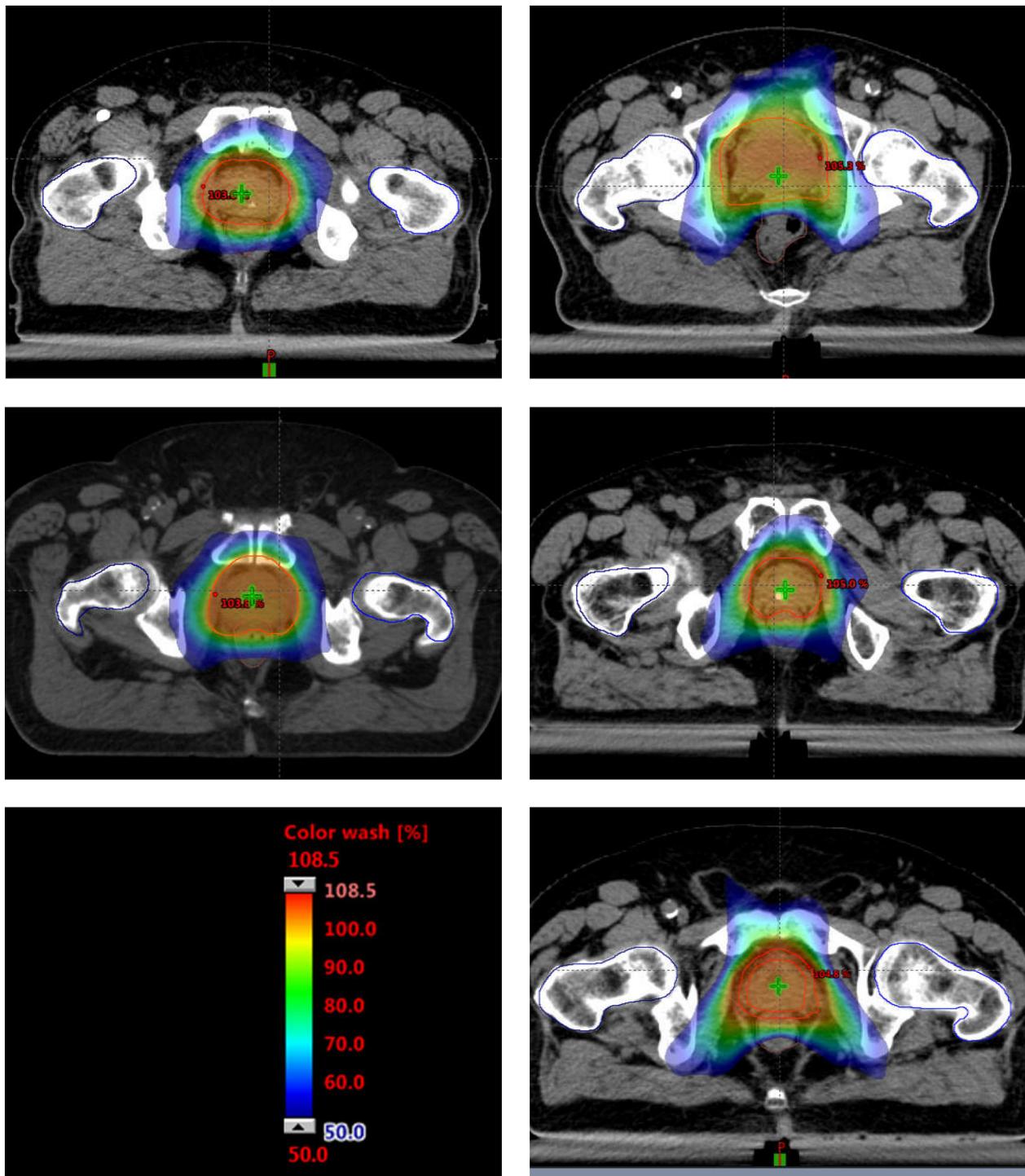(II) DICOM "RT Plan IOD" objects, containing geometric and dosimetric data and information.

Fig. 1. Transversal representative view with planned isodoses for the 5 cases. Colourwash ranging from 50%–Dmax was used.

Additionally, each participant filled in a questionnaire consisting of data related to equipment, including: Linac model, leaf dimensions at the isocenter, treatment planning system (TPS) model, dose calculation algorithm, setup calibration machine. Furthermore, the planner's experience level for SBRT (EL_{SBRT}) was scored as:

- EL = 1: no experience in SBRT planning
- EL = 2: low-medium experience in SBRT planning (1–100 patients)
- EL = 3: high experience in SBRT planning (> 100 patients)

Moreover, experience level specific to prostate planning $EL_{prostate}$

$_{SBRT}$ was assessed with the same score.

2.2. Optimization II: re-plan

The DVH for each plan and the median DVH (mDVH) were calculated from all participants and DVH and mDVH were shared among centers. Institutions were asked to re-plan a specific case aiming to reduce the DVHs differences among centers. For comparison purposes, after this re-planning phase the parameters from DVH in native format and DICOM RT Plan IOD were collected again.

Table 2

Statistics of all institutional data from the first phase "Optimization I". Parameters are grouped in dosimetric data, plan parameters and complexity scores. Minimum, 1st quartile, median, mean, 3rd quartile, maximum and IQR are reported.

Parameter Type	Parameter	Min	1st Quartile	Median	Mean	3rd Quartile	Max	IQR
Dosimetric Parameters	PTV-D50% (%)	98.4	100.4	102.3	102.8	105.2	108.9	4.8
	PTV-D95% (%)	94.4	96.0	99.8	98.8	100.4	102.9	4.4
	PTV-D2% (%)	100.4	102.7	104.6	106.0	108.9	115.4	6.2
	PTV-D98% (%)	86.8	95.9	98.4	97.4	99.3	102.5	3.4
	PTV-HI	1.02	1.06	1.08	1.09	1.10	1.29	0.04
	Rectum-V32 Gy (%)	3.45	6.1	7.8	8.8	9.9	24.0	3.8
	Rectum-V28 Gy (%)	5.5	11.1	14.0	14.9	18.0	350	6.9
	Rectum-V18Gy (%)	12.9	29.0	37.1	36.0	43.5	61.8	14.5
	Bladder-V30Gy (%)	2.5	5.6	8.7	9.4	12.3	31.2	6.7
	Bladder-V18 Gy (%)	6.5	16.6	27.1	26.4	34.4	57.2	17.8
Plan Parameters	Mean Gap (mm)	8.99	21.67	25.46	28.42	34.69	52.32	13.02
	Arc Length (deg)	0	356	360	430	716	716	360
	Collimator Angle (deg)	0	0	30	24.8	30	90	30
Complexity Indices (all plans)	MCS	0.100	0.215	0.190	0.232	0.270	0.450	0.055
	PI	1.750	7.260	3.430	8.298	12.010	21.460	4.750
	LT_Al (mm/deg)	0.744	1.175	1.021	1.175	1.314	1.710	0.138
	MIt	0.162	0.611	0.497	0.630	0.735	1.248	0.124
Complexity Indices (VMAT plans)	MCS	0.110	0.230	0.195	0.243	0.270	0.450	0.040
	PI	1.750	7.970	5.425	9.272	12.315	21.460	4.345
	LT_Al (mm/deg)	0.744	1.175	1.021	1.175	1.314	1.710	0.138
	MIt	0.324	0.628	0.535	0.671	0.754	1.248	0.125
Complexity Indices (SF-IMRT plans)	MCS	0.100	0.110	0.100	0.116	0.130	0.140	0.020
	PI	2.330	2.920	2.730	2.940	3.208	3.590	0.288
	LT_Al (mm/deg)	–	–	–	–	–	–	–
	MIt	0.162	0.167	0.166	0.178	0.191	0.203	0.024

2.3. Data analysis

Three types of data were collected from the first optimization: dosimetric parameters, metrics regarding plan complexity and metrics related to the plan parameters. Concerning the dosimetric parameters, the following data were collected from the native DVH: rectum-V32Gy, rectum-V28Gy, and rectum-V18Gy, bladder-V30Gy and bladder-V18Gy; PTV-D50% (i.e. the encompassing percent dose to the 50% of the volume), PTV-D98%, and PTV-D2%. Moreover, homogeneity Index (PTV-HI) was defined as PTV-D2%/PTV-D98%.

The DICOM RT Plan IOD were used to evaluate complexity metrics. In particular the following complexity scores, defined for VMAT and SF-IMRT plans, were considered:

- Modulation Complexity Score (MCS) [45] evaluates the complexity of the MLC patterns used, by combining both the variability in the shape of segments and variations in their area. This index uses a fixed range from 0 to 1: the lower the value of the MCS the higher the complexity.
- Leaf Travel (LT_AL) evaluates the complexity of the MLC patterns by the average distance travelled by the moving leaves. LT_AL originates from LT by Masi [46], defined for VMAT treatments consisting of a single full arc. LT_AL was created to allow for comparisons between plans with a different number of arcs or with partial arcs, and was defined as LT divided by the corresponding arc length (typically about 360 deg for single arcs and about 720 deg for double arcs). The higher the value of the LT_AL the higher the complexity.
- Plan Irregularity (PI) from Du [47] describes the deviations of aperture shapes from a circle, being 1 for a perfect circle. The higher the value of PI the higher the complexity.
- Modulation Index total (MIt) from Park [48] considers variations considers both variations in MLC speed and acceleration and variations in gantry rotation speed and dose rate. The higher the value of MIt the higher the complexity.

Additionally, other metrics were computed to describe the plan parameters:

- *mean Gap*: the average leaf pair opening (in mm) for all the leaves inside the radiation field;
- *Arc Length*: total length (in degrees) of the arcs used in VMAT plans;
- *Collimator Angle*: Maximum Collimator angle used (deg, deviation from 0°).

A Spearman rank correlation matrix was computed to investigate the potential dependence between selected multiple variables relative to plans produced during Optimization I before DVH sharing. The significance value threshold was set to 0.05. Statistical significance of the difference between variables in Optimizations I and II was evaluated by the non-parametric Kruskall-Wallis test, in order to investigate if the significant results derived during exploratory data analysis changed remarkably from Optimization I to Optimization II. Significance level was set to 0.05.

DVHs were read with open source R package "DVHmetrics" [49], an add-on package for the free statistical environment R (R Development Core Team, 2017, version 3.4.4) [50,51] with applications in radiation oncology. The in-house software Plan Analyzer [52], was used to compute the complexity metrics. Statistical methods to characterize and display data were developed using the statistical software R (https://www.r-project.org).

3. Results

Thirteen Italian centers participated to the study. The findings are reported in the following three subsections: (i) institutional data, (ii) optimization I, (iii) optimization II.

3.1. Institutional data

The data on equipment, techniques and experience level in SBRT planning for each participant are summarized in Table 1. In particular,
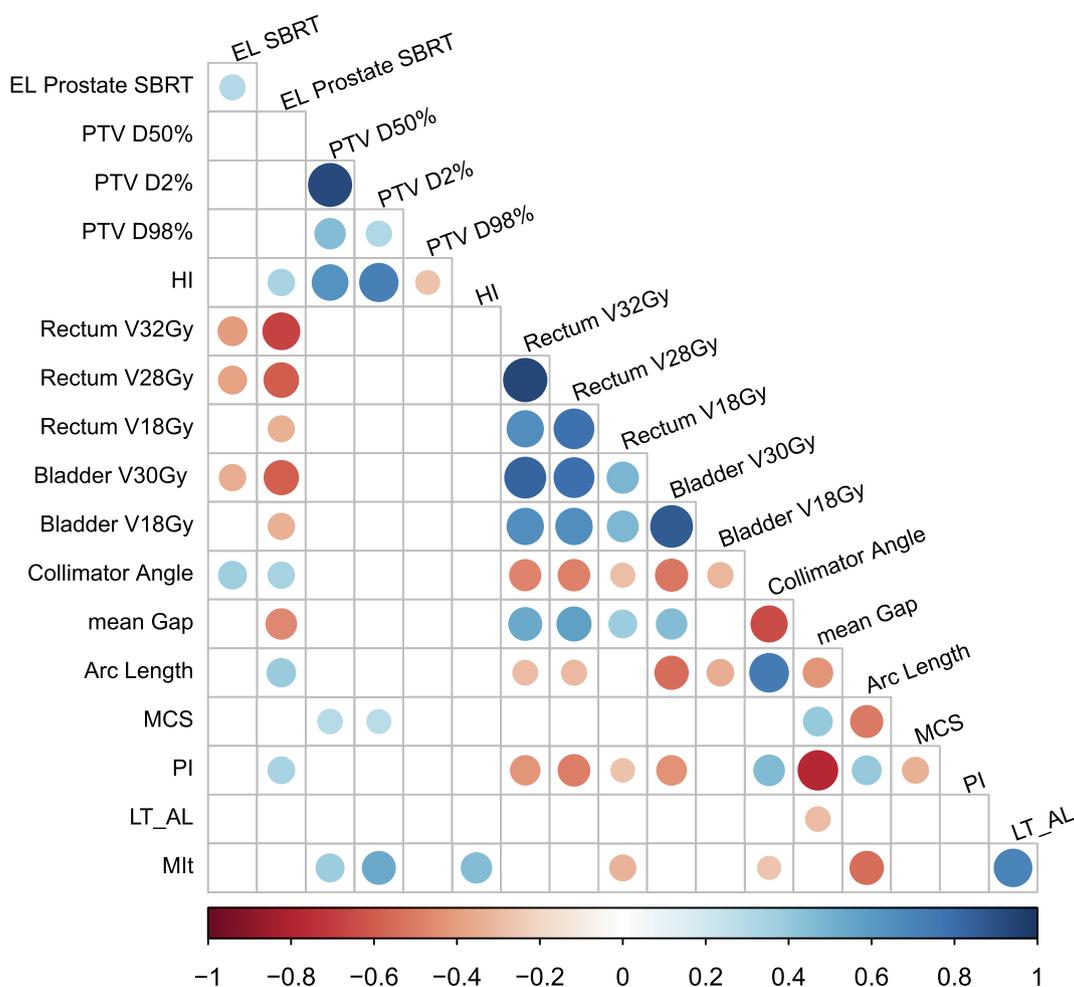
Fig. 2. Spearman correlation matrix comprising all the dosimetric, plan and complexity variables from the Optimization I phase. The size and the color of each circle both indicate the magnitude of the Spearman coefficient, with red and blue denoting negative and positive correlations respectively. Non significant results are left blank; p-value was set at p = 0.05.

2 and 11 centers adopted, respectively, SF-IMRT and VMAT. All plans were verified in terms of quality and deliverability and were considered acceptable according to each center's QA procedures.

3.2. Optimization I: plan

In the 1st phase, 65 SBRT prostate plans from 13 centers were collected. Fig. 1 shows CT images with representative planned isodoses for the 5 cases. Protocol dose objectives were achieved in most cases. Rectum and bladder constraints were the hardest to achieve. Center D failed V32Gy and V28 Gy; center G failed rectum 32 Gy for most cases and other rectum and bladder constraints for case #3; center H failed most of the various rectum and bladder dose objectives. Center J failed bladder V18Gy.

Plan performance was measured along with PTV and OAR's dosimetric parameters: data are summarized in Table 2 and details are reported in Supplementary material in Fig. 1(a–n). Data analysis showed two outliers for the PTV dosimetric parameter D98% (both from center J), five outliers for the homogeneity index (one from center E and the remaining from center J). Regarding rectum V32Gy, outliers were all plans from the center H and one plan from center D. For bladder, only the V28 Gy parameter showed an outlier (center H).

Concerning plan parameters, the InterQuartile Range (IQR) of the mean Gap was quite large and there were no outliers. The complexity analysis showed two outliers for MCS (Center J and L).

Regarding the comparison among variables, the Spearman correlation matrix shown in Fig. 2 highlights the strength of the coefficients ρ for correlations with p values less than 0.05. The correlogram suggests that planners with high experience level in SBRT prostate planning achieved lower OAR doses with a very high statistical significance ($p < 0.001$ for all the OAR investigated dosimetric parameters). Experience level in SBRT (without specific skills correlated to prostate planning) showed weaker correlation except for V18Gy. $EL_{prostate\ SBRT}$ strongly correlated ($p < 0.001$) with mean Gap and with geometrical parameters such as the collimator angle and the arc length ($p < 0.005$). The only complexity score that correlated with the experience level was the PI ($p < 0.005$). PI was correlated with OAR dose ($p < 0.001$). Regarding the fulfilment of dose constraints, dosimetric data correlated with plan parameters: mean Gap correlated positively with at least $p < 0.001$ for all OAR dosimetric parameters except for V18Gy values. Arc length was almost strong correlated ($p < 0.001$) with both bladder and rectum dose values, except for V18Gy Rectum and V18Gy Bladder where correlation was weak. Complexity index MIt was strongly correlated only with the PTV maximum dose value D2% ($p < 0.001$). We found similar results in terms of correlation even with analysis restricted to the 55 VMAT plans only (Fig. 2 in Supplementary material).

3.3. Optimization II: re-plan

Participants were asked to replan a specific case aiming at the median DVHs from Optimization I. Fig. 3 reports the related PTV and
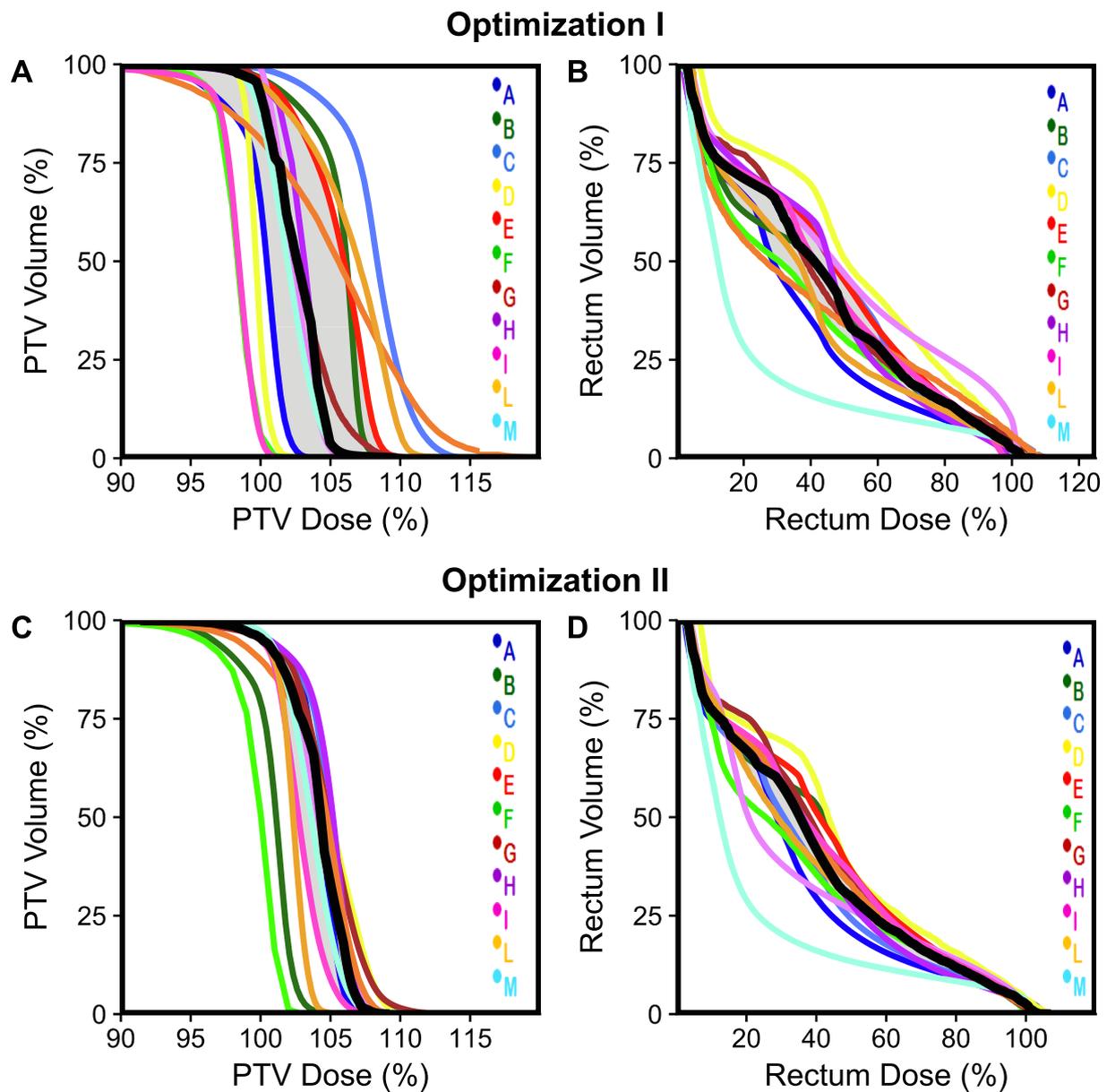
Optimization I

Optimization II

Fig. 3. PTV and rectum institutional DVH curves before DVH sharing (A, B) and after re-planning (C, D).

rectum institutional curves before DVH sharing and after re-plan. Results of the re-planned study are provided in details in Fig. 3 (a-q) in Supplementary material. The PTV coverage (PTV-D98%) strongly improved in terms of IQR from 4.7% to 0.6% and the median value from 5.5% to 2.5%. The median target dose D50% showed 3 outliers under the 1st quartile (centers B, F, J). Maximum dose to the PTV (PTV-D2%) had also an improved IQR (from 6.3% to 1.4%) with 3 outliers (for centers B,F and L). Regarding the rectum DVH, the outliers found in the first optimization disappeared and median values for V28Gy, V32Gy and V18Gy improved from 14.4% to 11.8%, from 8.1% to 6.7% and from 37.4% to 28.6%, respectively. With regard to bladder doses, IQR greatly improved from 5.5% to 1.7% (V30Gy) and from 13.1% to 5.9% (V18Gy). About plan parameters, the mean Gap was weakly reduced from 30.2 to 27.3 and other plan quantities remained practically unchanged. Similar results were obtained for complexity metrics: IQR and median values did not differ between Optimization I and Optimization II.

Figs. 4 and 5 show overall differences among selected parameters in phase I for all the patients and in phase II for patient #5, grouped by the $EL_{prostate\ SBRT}$. The significant p values are reported for each

comparison. The results between the first and the second phase were compared using the Kruskall-Wallis test. It can be noted that all the dosimetric parameters statistically significant during the first phase, are no longer significantly different in phase II. No correlation was found between complexity metrics and $EL_{prostate\ SBRT}$, except for PI.

4. Discussion

Significant correlation between the $EL_{prostate\ SBRT}$ and the achieved dose constraints was obtained during the first phase of the study. In particular, $EL_{Prostate\ SBRT}$ is highly correlated with OARs dose constraints: the more experienced planners created better plans in terms of OAR sparing and PTV dose constraints. We found a less significant correlation between general EL_{SBRT} (not specific to prostate planning) and OAR doses, suggesting a critical role for specific training.

After the re-planning phase, median values for OARs doses were lower and IQR values were approximately halved, with the greatest decrease shown by the higher OARs doses. PTV's IQR dose constraints were approximately halved too. Furthermore, all participating centers homogeneously fulfilled all the requested goals for both target coverage
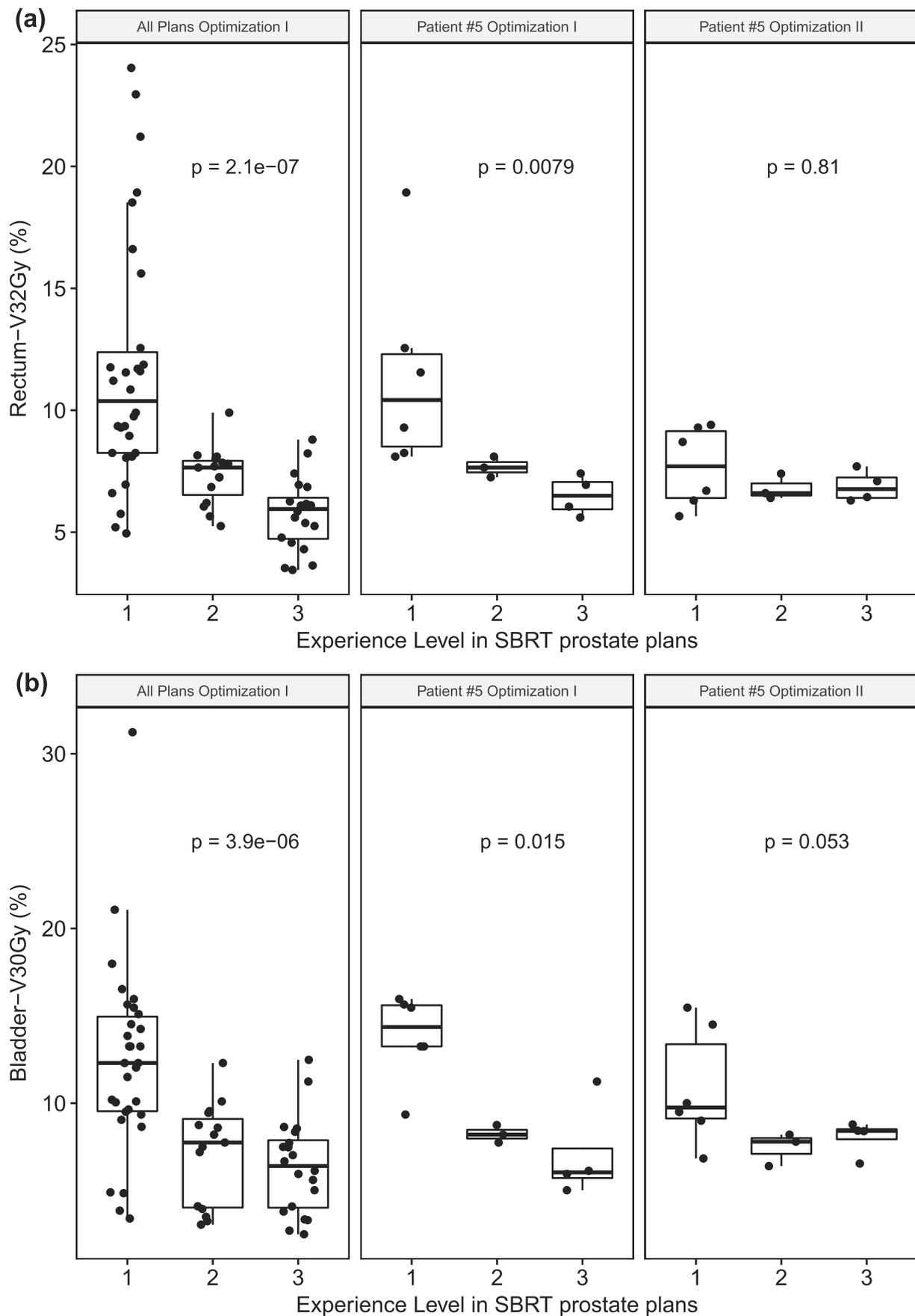
Fig. 4. Dosimetric parameters rectum-V32Gy (a) and bladder-V30Gy (b) stratified along with experience level EL in SBRT prostate planning. On the left, data from all 65 plans from phase I (Optimization I), in the middle only data for patient # 5; on the right, data for patient #5 after the replanning phase (Optimization II).
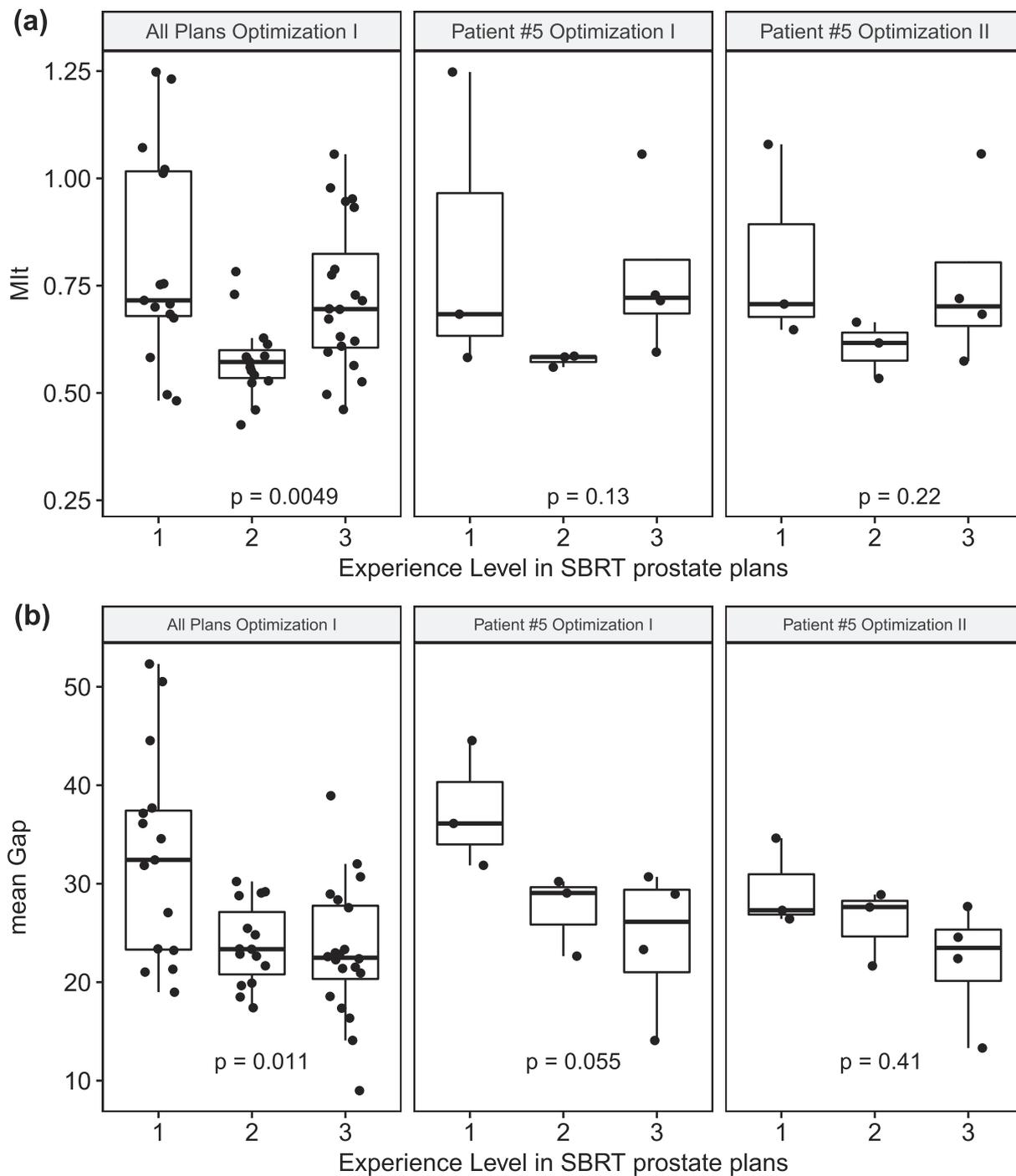
Fig. 5. Modulation Index "MIt" (a) and mean Gap (b) stratified along with experience level EL in SBRT prostate planning. On the left, data from all 65 plans from phase I (Optimization I), in the middle only data for patient # 5; on the right, data for patient #5 after the replanning phase (Optimization II).

and dose limits to OARs: even less experienced planners were able to achieve plan quality metrics alike the more experienced ones. The second phase definitely improved homogeneity among all participating centers and pointed out the advantage of the training phase based on the re-planning and DVHs sharing.

Our findings on experience in SBRT planning could be framed in the European survey regarding contemporary SBRT approaches carried out in 45 centers in 6 selected countries [53]. During the survey, centers were asked to fulfill a comprehensive questionnaire with regard to their institutional SBRT history and practice. In particular, the majority of the participating radiation oncologists thought that SBRT should be primarily performed in experienced centers. Indeed, experience in

SBRT has been proved to improve clinical outcome in the multicenter lung SBRT DEGRO working group. Analyzing SBRT for pulmonary metastases in 700 patients treated in 20 centers, Rieber et al. [54] detected a learning curve for SBRT practice and reported that SBRT patients planned at more experienced institutions showed better local control. The same research group requires to include in future studies and recommendations a major homogenization, since optimized treatment planning should always follow ALARA (As Low As Reasonably Achievable) principle [55]. Achieving global harmonization of planning is a major challenge for further multicenter clinical trials in order to improve protocol compliance and consistency in RT trials [56].

Beyond DVH fulfillment, also complexity metrics could potentially

be an evaluable plan quality indicator for planning benchmarking, since highly complex plans might be less accurate in dose calculation and treatment delivery. Recently, an increasing interest in quantifying quality planning in a multi-institutional assessment was observed [57]. Our results showed that even re-planning strategy bringing a major degree of dosimetric standardization could be carried out without complexity worsening: on one side more common aims lead to more uniform doses among institutions and on the other side complexity metrics remains almost unchanged. This finding is in line with the multi-institutional dosimetry audit by McGarry [58], where the dosimetric plan quality metric was not correlated with MCS. The results reported by McNiven [45] on prostate planning in conventional fractionation permitted to establish a threshold MCS value of 0.8 as a cutoff to identify potential failure in pre-treatment dosimetry. They found a mean value of 0.59 for 20 prostate IMRT plans with static beams. We obtained much lower MCS values (mean 0.232, max 0.45), indicating the high complexity of our SBRT prostate plans compared to that SF-IMRT plans in conventional regimen. Our results are also lower compared to those of Masi [46], who found an MCS mean value of 0.41 in 142 plans (of which 80 prostate in conventional fractionation). Instead, our results are more similar to McGarry et al. [58], who found an MCS mean value of 0.226 for 39 VMAT plan on a virtual phantom in a multi-institutional study, and to Hernandez et al. [59] who found MCS values under 0.5 based on a planning multicenter comparison on a mock head-and-neck and prostate cases adapted from those proposed in TG-119. The latter presented results dealing with other complexity indices. In particular, the MIt parameter ranging from 0.5 to 1.75 are quite different in comparison to our results, ranging from 0.15 to 1.25, suggesting a higher complexity in our SBRT plans in terms of this parameter. Since the MIt is very sensitive in plans that modulate the dose rate and the gantry speed, our results indicate again a marked higher complexity in the SBRT prostate plans. As pointed out by AAPM [60], complexity indices could be useful measurements of beam modulation to ensure that centers achieve safely and homogeneously IMRT plans. Nevertheless, in multi-institutional comparisons where multiple TPS, planners and Linacs are typically involved, complexity metrics could be sensitive to the optimization engines in TPS model. Hernandez et al. [59] found that the variability of the MIt depends on the TPS and acceptable ranges or threshold levels should be assessed for each specific TPS model. In our study complexity metrics didn't correlate with institutional dosimetric performance, as recently assessed by a multi-centre audit of VMAT planning [52]. In our study, experience level in prostate SBRT planning was correlated with plan parameters, suggesting that the more experienced the planner, the more various degree of freedom are strategically used in planning optimization, regardless of the TPS and Linac vendor.

We would like to highlight that this study was focused on calculated dose distributions comparison, without considering other essential aspects regarding target definition, dose delivery, on board imaging, real-time beam monitoring for error detection for which further evaluation is required [61].

As shown by Moustakis et al. [55,62] in multiplanning studies on lung and spinal radiosurgery, user experience and understanding of the optimization system appear to be the driving factors for plan quality. Furthermore, institutional gain of knowledge and planning skills improvement could be applied to the emerging automated engines [63,64,65]. The cooperation among centers could likely improve performance of machine learning and automated planning by increasing the quality of the input plans through driven a multi-institutional crowd-based approach.

5. Conclusions

SBRT planning can benefit from a re-planning phase after median DVH sharing among participants, improving plan quality and concordance among centers. Continuous improvement and crowd

knowledge dissemination can minimize variability among treatment planners and increase plan quality whilst keeping the same planning complexity degree. This study confirmed that specific planner's experience in prostate SBRT was correlated with dosimetric parameters. Efforts in DVH sharing in multiplanning studies could be strategic for specific training purposes. Overcoming the influence of the experience level on SBRT planning should be considered of primary relevance during the implementation of SBRT techniques and before participating in clinical trials.

Where crowd knowledge can be extracted and spread, the mean quality of treatment planning can be continuously improved, beyond limiting the variation among planners.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ejmp.2019.05.003.

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