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Dosimetric evaluation of IMRT Step and Shoot/ Sliding and Window (SS / SW) and VMAT Treatment Plans for Nasopharyngeal Cancer

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ABSTRACT

Introduction: Radiotherapy of Oto-Rhino-Laryngology (ORL) sphere is difficult due to complex geometries and very sensitive organs around the target volume. This weapon has benefited from the advances of the Volumetric Modulated Arc Therapy (VMAT) technique that combines the advantages of dynamic arc therapy techniques with those of Conformal Radiotherapy with Intensity Modulated (CRIM) by stationary beams.

Material and Methods: The treatment plans of 10 patients were compared and treated with Intensity Modulated Radiation Therapy (IMRT) Step and Shoot (SS), Sliding window (SW), and VMAT (6MV X-ray beam). Three target volumes were used: PTV۔ Gy, PTV 63 Gy, and PTV 56 Gy. The organs at risk were the spinal cord, the brainstem, the parotid gland. The dose was delivered once a day, five days a week and in 35 sessions in Simultaneous Integrated Boost (SIB).

Results: The SS technique permitted better parotid sparing, inducting thus to limiting late complications such as xerostomia. The VMAT technique led to better protection of the brainstem by reducing about 6 Gy while for the spinal cord the doses received were almost equal. There was no statistically significant difference between the different techniques.

Conclusion: The results confirm the conformational capacities of these innovative techniques, from a dosimetric and above all clinical point of view as well as their ability to cover the target volumes while largely respecting the constraints on organs at risk.

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Introduction

Radiotherapy consists of treating tumours by using high-energy ionizing radiation, the biological effects of which lead to the death of cancer cells. The objective of this therapeutic weapon is to deliver a sufficient tumoricidal dose to eradicate the tumour and at the same time the lowest possible dose to spare neighbouring healthy tissues reducing thus the risk of complications. Nowadays, irradiation techniques have considerably evolved to achieve this objective [1].

Indeed, recent developments in radiotherapy techniques have emerged, and more particularly for conformational radiotherapy with IMRT [2] which itself has given rise to VMAT [3] which permitted for sculpted irradiation, where high dose regions are adjusted to target volumes, even those of complex shape. During the treatment of cancers by external radiotherapy, it is advisable to spare as much as possible the healthy tissues adjacent to the tumor. In the present work, among these healthy tissues, some structures are particularly sensitive to irradiation [4], such as:

- The spinal cord, and the brainstem, which could be seriously affected by the radiation leading to permanent and irreversible disability.
- The salivary glands (parotid and submandibular glands) that their irradiation can cause a long-term dry mouth (xerostomia), which can affect the patient's dentition.

The risk for these organs is a long-term side effect, so they are considered in the planning the treatment to spared them as much as possible. So, the big problem with radiotherapy is to preserve healthy tissue while destroying cancerous tissue. There are different ways to best achieve this goal.

To limit the irradiated area as much as possible, many beams are used to carry out the treatment. This is made possible with the appearance of 3D conformational radiotherapy (3D-CRT) and the development of radiotherapy techniques in IMRT and VMAT [2,3]. Indeed, the tumor receives the doses deposited by all the beams, whereas the healthy tissues are a priori only crossed by a single beam and therefore receive a much lower dose [5]. This is all the

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truer as the number of beams used is high because the dose per beam is then all the lower. So, the contribution of 3D conformational radiotherapy with modulation of the fluence of each beam has two main advantages [4]:

- On the one hand, it makes it possible to sculpt isodoses of complex shape which can conform to the tumor whatever its shape, which makes it possible to spare OAR even better.
- In addition, the modulation of fluence makes it possible to deliver a homogeneous dose to the tumor.

RTC-3D in Cavum cancer is performed mainly in several steps / series: [6] that requires a LINAC with multileaf collimator, and a dosimetry treatment planning system (TPS):

- A dose of 40 Gy is delivered to the tumor volume using two beams of opposing lateral photons.
- Subsequently, the treatment field is reduced to exclude the Spinal Cord and a dose of 10 Gy is delivered using two reduced lateral photon beams.
- Then we add 10 Gy at the level of the hidden region which includes the Spinal Cord with an electron beam. Then, we add a Boost of 20 Gy on the tumor alone; to complete 70Gy at tumor volume. For non-palpable supraclavicular lymph nodes, a dose of 50 Gy is delivered with an anterior photon beam while sparing the spinal cord and larynx with MLCs, so the total dose given to the tumor is 70 Gy, and 50 Gy to supraclavicular ganglia.

Like every treatment technique, RTC3D has its own limits, this can be seen at the level of High-Dose irradiated Volume (HDV) that does not consider the dose received by the OARs after irradiation with electrons, which cannot permit quantifying the risk to which OARs are exposed. There is also the risk of overdose because of the junction between the 2 lateral fields and the anterior one. Thus, the displacement of the manipulator and the installation of the applicators and the covers (in mode electron) increases the time of treatment, finally there are late complications such as xerostomia due to the high dose received in the parotid glands and an increase in the dose in the brainstem and spinal cord. Hence the interest in the treatment of cavum cancer by new techniques such as IMRT and VMAT. These allow better treatment in a shorter time, a dose limited to OARs and good precision at the tumor level. [7]

This study is focus on the analysis, explanation, and comparison of the different techniques of external beam radiation therapy. The aim is to compare the Volumetric Modulated Arc Therapy (VMAT) technique and the IMRT technique: Step and Shoot and Sliding and Window for a series of patients treated for cavum cancer.

The cavum location has been chosen because it is the most frequent cancer among Oto-Rhino-Laryngology (ORL) cancers in Morocco. Moreover, it remains at the locoregional stage for a long time and is very sensitive to radio-chemotherapy.

Materials and Methods

The study was carried out on a heterogeneous series of 10 patients, treated with IMRT and VMAT, presenting nasopharyngeal tumors at different non-metastatic stages (Table 1). The patients were supine and received a personalized, 5-point thermoformed mask-type restraint immobilizing the head and neck, and imaging was performed from the top to the lower edge of the clavicle.

The target volumes and OAR were defined from images acquired on a CT scanner of the Big Bore type (Siemens) with a section thickness of 3 mm. The delimitation of the volumes was in accordance with the recommendations of ICRU reports 50 and 83 [8, 9, 10] and international recommendations [11, 12] (PRV =OAR+3mm) the target volumes have been defined excluding the surface area 3 mm thick.

Table 1.Characteristic of the patients studied.

Patients	Localisation	Stades	Gender	age
1	Nasopharynx	T3N3M0	M	41
2	Nasopharynx	T3N2M0	M	28
3	Nasopharynx	T2N2M0	F	55
4	Nasopharynx	T3N2M0	M	46
5	Nasopharynx	T1N0M0	F	67
6	Nasopharynx	T4N1M0	M	32
7	Nasopharynx	T4N0M0	M	58
8	Nasopharynx	T3N2M0	M	38
9	Nasopharynx	T3N0M0	F	33
10	Nasopharynx	T2N1 M0	F	22

Three PTV were defined: PTV 70 Gy was defined as the volume of the primary tumor site and a 3D margin of 5 mm; PTV 63 Gy was defined as the volume of high-risk subclinical disease plus a 3D margin of 5 mm; PTV 56 Gy was defined as the volume of subclinical disease at low risk plus a 3D margin of 5 mm.

For reverse planning, target volumes were defined excluding the 3mm thick surface area. The dose is delivered once a day, five days a week and in 35 sessions in integrated Boost (Simultaneaous Integrated Boost (SIB)): either fraction of 2 Gy on the PTV 70 Gy, 1.8 Gy on the PTV 63 Gy and 1.6 Gy on the PTV 56 Gy. The dose targets on PTV are that 95% of tumor volumes should receive at least 95% of the prescribed dose and 98% of tumor volumes should receive at least 90% of the prescribed dose.

The main objective of this study was to minimize the dose as much as possible not only for OARs, but also for healthy tissue, while maintaining maximum homogeneity of the dose at target volumes. More precisely, D 98% $\geq$ 95% of the prescribed dose must be reached as a minimum and D 2% $\leq$ 107% as a maximum.

The dose calculation is done by the TPS, which creates the ballistics and calculates the dose distribution from the CT images. The Treatment Planning System (TPS) used in our study is Monaco version 5.11(Algorithm: Monte Carlo Photon Grid Spacing

(cm):0.30, Statistical Uncertainty (%) per Calculation: 1.00) from Elekta company, which is based on reverse planning. These treatment ballistics using beams of photons X of 6 MV, the Photon X of 18MV is not being recommended for IMRT and VMAT treatment due to neutron production [13]. The principle is to determine dose of targets, whether to organs at risk or to the area to be irradiated thanks to an algorithm (Monte Carlo) of calculation will develop the best possible ballistics according to the constraints. This optimization process will make it possible to obtain modulated beams which will give a distribution as close as possible to the ideal dose distribution.

The accelerator used is an Elekta Infinity dedicated to make the new techniques that have already been presented, that can deliver beams of several energies in electron mode, namely 6. 9, 12, 15 and 18 MeV and two in photon mode: 6 and 18 MV. It comprises an Agility-type MLC system which has 160 blade energies of 5 mm thickness at the isocentre, allowing the shape of the beam to be adapted and conformed to that of the tumor or of the area to be irradiated. In addition, it is equipped with an XVI on-board imaging system for the repositioning of the patient in three dimensions, based on the isocentre and the reference scanner sections sent from the TPS [14].

The scanner used for this study is from the SIEMENS Somatom Definition AS brand installed in 2012, composed of 16 strips dedicated to the acquisition of three-dimensional images. It is equipped with an X-ray tube operating under five high voltage ranges: 70. 80. 100. 120 and 140 kV, under a power supply of 80KW. The current of the tube is respectively 500,650, 650, 666 and 571 mA [7].

The 2D / 3D digital verification system optimized for rotational processing techniques, works with the user-friendly and intuitive OmniPro-ImRT application software for complete verification of the plan and Quality Assurance of IMRT / VMAT treatments and consists of:

- 1020 Ionization chambers.
- Parallel reading of all ionization chambers.
- Stand angle sensor for easy stand setup and easy alignment indicated by LEDs [15].

Dosimetric planning.

Table 2. IMRT constraint properties.

Structure Name	Cost Function	Threshold Gy	ISO Constraint	Structure Name	Cost Function	Threshold Gy	ISO Constraint
PTV70	Target Penalty		67.00	PAROTID LT	Parallel	30.000	30.00
	Quadratic Overdose	71.00	0.050		Serial		66.500
PTV63	Target Penalty		60.000		Parallel	40.000	20.00
	Quadratic Overdose	65	0.800	PAROTID RT	Parallel	30.000	30.00
PTV56	Target Penalty		54.000		Serial		66.500
	Quadratic Overdose	57.000	0.500		Parallel	40.000	20.00
LENS LT	Quadratic Overdose	8.000	0.020	BRAINSTEM	Serial		40.000
LENS RT	Quadratic Overdose	8.000	0.020	BRAINSTEM PRV	Serial		43.000
OPTIC N. RT	Quadratic Overdose	45.000	0.080	THYROID GLAND	Serial		54.000
OPTIC N. LT	Quadratic Overdose	45.000	0.080	LARYNX	Serial		50.000
OPTIC N. RT PRV	Quadratic Overdose	48.000	0.1	ORAL CAVITY	Serial		55.000
OPTIC N. LT PRV	Quadratic Overdose	48.000	0.1	MANDIBLE	Parallel	50	40.00
SPINAL CORD	Serial		38.000		Serial		64.000
SPINAL CORD PRV	Serial		41	OPTIC CHIASM	Serial		40.00
EYE LT	Parallel	30.000	35.00	OPTIC CHIASM PRV	Serial		43
EYE RT	Parallel	20.000	35.00	POST NECK	Quadratic Overdose	60.000	0.050
ESOPHAGUS	Parallel	40	50.00		Quadratic Overdose	52.000	0.100
COCHLEA RT	Maximum Dose		55.000	BODY	Quadratic Overdose	63.500	0.100
COCHLEA LT	Maximum Dose		55.000		Quadratic Overdose	58.500	0.600

Three treatment techniques were applied for each patient (SS, SW, and VMAT). The VMAT plans were optimized with the MONTE CARLO algorithm (version 5.11), using two arcs of 360^0, to deliver the prescribed dose and the collimator was set to 0^0 with an opening which allowed finer modulations.

For the IMRT plan (SS / SW), Seven equi-distributed beams were always used with the arm angles: 207 °, 258 °, 309 °, 0 °, 51 °, 102 ° and 153 ° (Figure1). The doses have been designed to limit the maximum value and the same requirements for PTV and OAR coverage have been fixed for IMRT and VMAT.

Same constraints have been used for the three processing techniques (IMRT SS, IMRT SW, VMAT). Table 2 groups the IMRT constraints properties for both target the organs at risk.

Total number of segments of a maximum of 200, a minimum segment size of 6 cm² and 4 MU minimum per segment were considered.

All the treatment plans presented were carried out by the same operator. General plans were performed to cover at least 95% of PTV with the prescribed prescription dose, while keeping the maximum dose below 107% of the prescribed dose level limit.

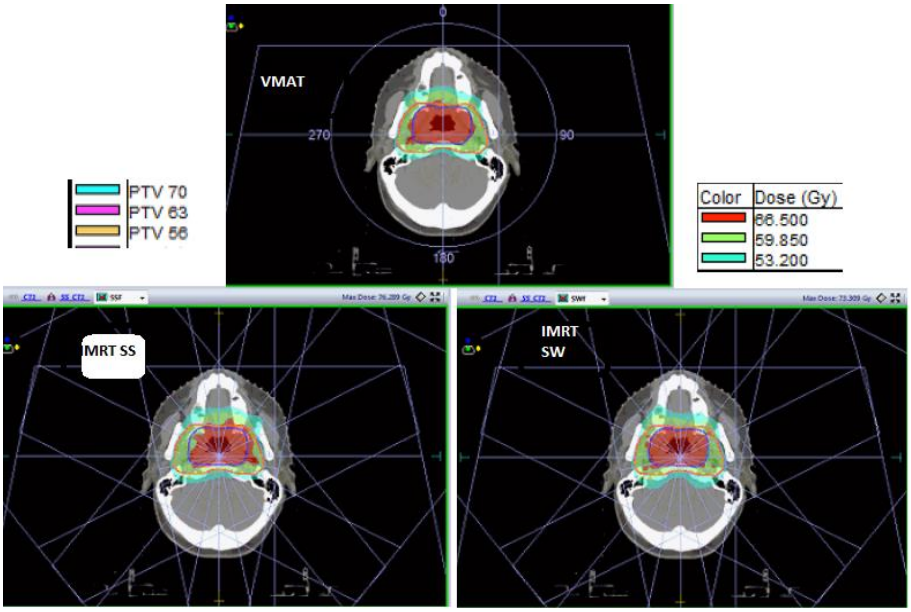

Figure 1. Representation of treatment ballistics used for SS, SW and VMAT

Table 3. Definition of conformation indices

Index name	formula	objective	Description
Homogeneity index	HI = (D2% - D98%) /D50%	0	Difference of the maximum and minimum dose normalized by the median dose.
Compliance index	CI = Va/Vs	1	Ratio between the volume of the reference isodose and the volume of the structure of interest.
Coverage index	CO = D95%/ DR	1	Ratio of minimum dose to reference dose (95% of prescribed dose)
Target volume coverage	TCO = 100* VS.R/ VS	100%	Ratio between the volume of the structure of interest covered by the reference isodose and the volume of the structure of interest expressed in%.
Overlap report	OR = VS.R/ (Vs U VR)	1	Ratio between the volume of the structure of interest covered by the reference isodose and the volume of the structure of interest, and the union of these two volumes.
The number of conformations	CN =VS.R / VS * VS.R /VR	1	Ratio between the volume of the structure of interest covered by the reference isodose and the volume of the structure of interest ratio between the volume of the structure of interest covered by the reference isodose and the volume of the isodose reference.

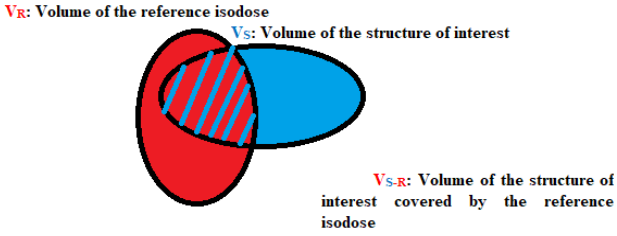

Figure 2. Definition of the volumes used for the calculation of the indices.

Dosimetric Analysis For each treatment plan

Dosimetric values were calculated. These are either quantitative or qualitative clinical variables representing the usual criteria for comparing radiotherapy treatment plans classified into 3 categories:

Tools related to the volume distribution of the dose

The dose volume histograms (DVH) are quantitative evaluation tools used to describe the heterogeneous distribution of dose received by the irradiated volumes. The cumulative High-Dose irradiated Volume HDV represents the volume of the organ, which receives a dose equal to or greater than the given dose. On the Y axis is the percentage of volume considered receiving a dose equal or greater than the corresponding dose given on the X axis, Ideal treatment plan is characterized by the fact that 100% of the volume to be treated receives 100% of the prescribed dose. The analysis of the dose volume histogram makes it possible to compare the mean dose (Dmoy), the minimum dose (Dmin) and maximum (Dmax) received by all the voxels of the organs considered.

Usual dosimetric quality index

The indices are based on the definition of the volumes, according to figure 2 and the formulas in Table 3 (Definition of the volumes used for the calculation of the indices).

Statistical analysis

The purpose of the statistical tests is to check whether the observed differences are significant. An original statistical application based on two general hypotheses is considered, taking in account the null hypothesis H0: no difference and the alternative hypothesis H1: there is a difference. To perform this study, we need the following:

Population: sample of "n" patients, with "n" as large as possible, including nasopharyngeal or cavum tumor locations.

Dosimetric comparison criteria: calculated and compared for each patient from the different treatment plans.

Statistical test to assess the statistical significance of the deviations observed at a defined risk threshold. Estimation of the deviation and the average percentage is performed with a confidence interval.

Gamma Index

The Gamma index introduced to compare and evaluate the dose distribution in 2D and 3D, is defined by:

$$\gamma = min\sqrt{\frac{\delta D^2}{\delta Dmax^2} + \frac{\delta r^2}{DTA^2}} \quad (1)$$

With:

$\delta r = r_r - r_c$

$\delta D = D_c r_c - D_r r_r$

- δr is the distance between the reference point r_r and the point to be evaluated r_c.
- δD is the difference between the dose at point r_r and that at point r_c.
- δDmax is the tolerance criterion for the dose (%);
- DTA is the tolerance criterion for the distance (%).

If γ> 1, the correspondence between the point to be evaluated and the reference point is outside the tolerance criterion. If γ <1, the correspondence between the point to be evaluated and the reference point is in the tolerance criterion. The surface which represents the tolerance criterion is an ellipsoid defined by relation 2.

So that the dose distribution to be evaluated can be compared to the reference dose distribution, the latter must contain at least one point inside the tolerance ellipse.

$$1 = min\sqrt{\frac{\delta D^2}{\delta Dmax^2} + \frac{r^2}{DTA^2}} \quad (2)$$

To start the treatment, the plans carried out by the percentage of the gamma index should be validated. This test was performed for a patient with CAVUM cancer. It was observed that the variation between the measured plane and the plane calculated by the Matrix, based on the gamma index, are superimposed with a small negligible deviation (Figure 3), (tolerance defined by the physicist 3% and 3 mm), which validates the treatment plan.

Placement and treatment: Installation and treatment (CBCT technique "Cone beam computed tomography"). To avoid different positioning deviations from the planned position of the patient image, an on-board imaging system is used. Then, the patient's position is compared to that of the patient model by comparing the images acquired before the treatment session (CBCT) with the reference one from the patient's model (image from the dosimetry scanner). This permits that the 3D images to be registered for the translation along X, Y, Z and the rotation along Rx, Ry, Rz (Figure 4).

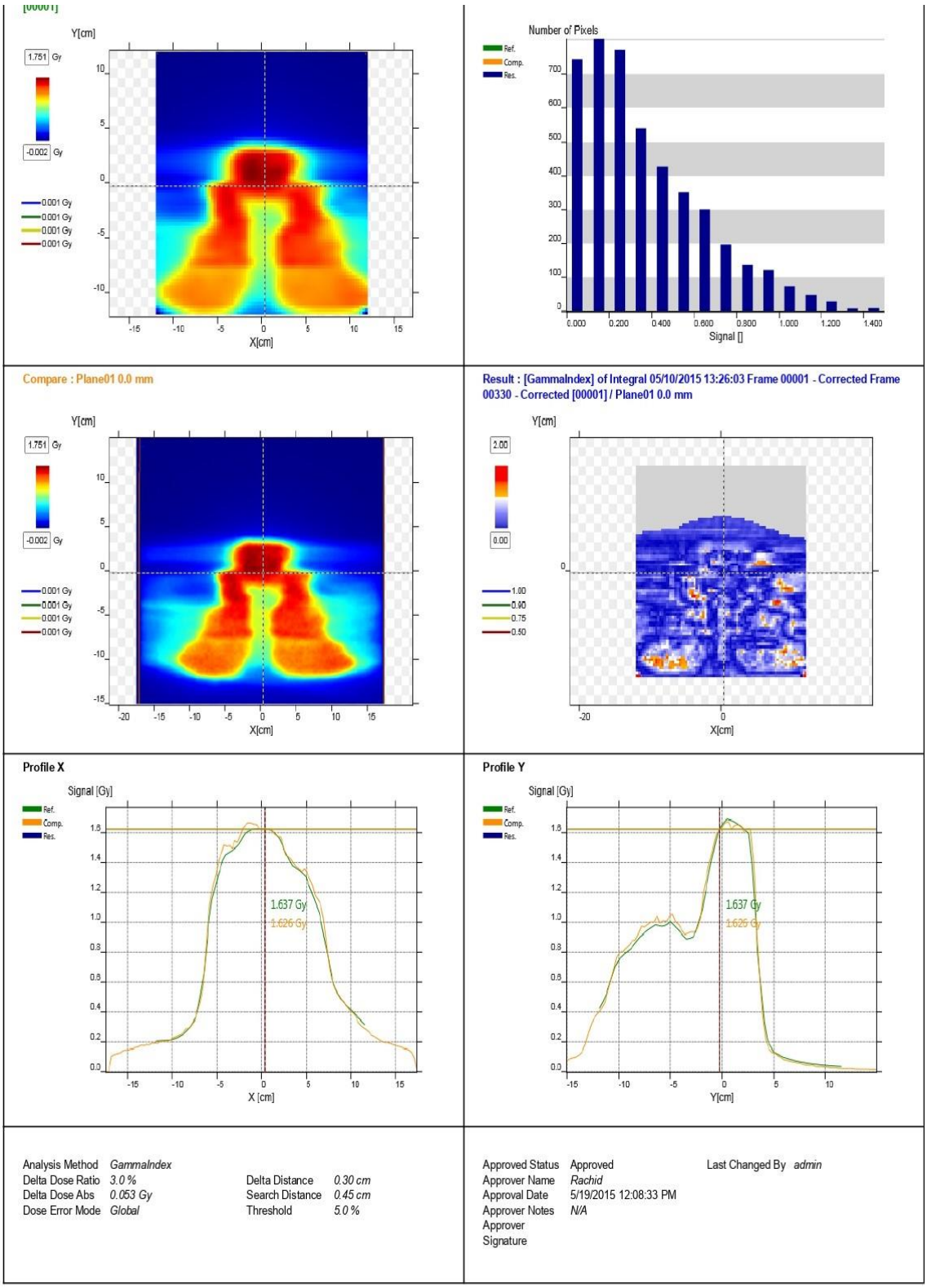

Figure 3. Patient quality control measured plan and calculated plan, the plans carried out by the percentage of the gamma index and the dose profile on the X and Y plane

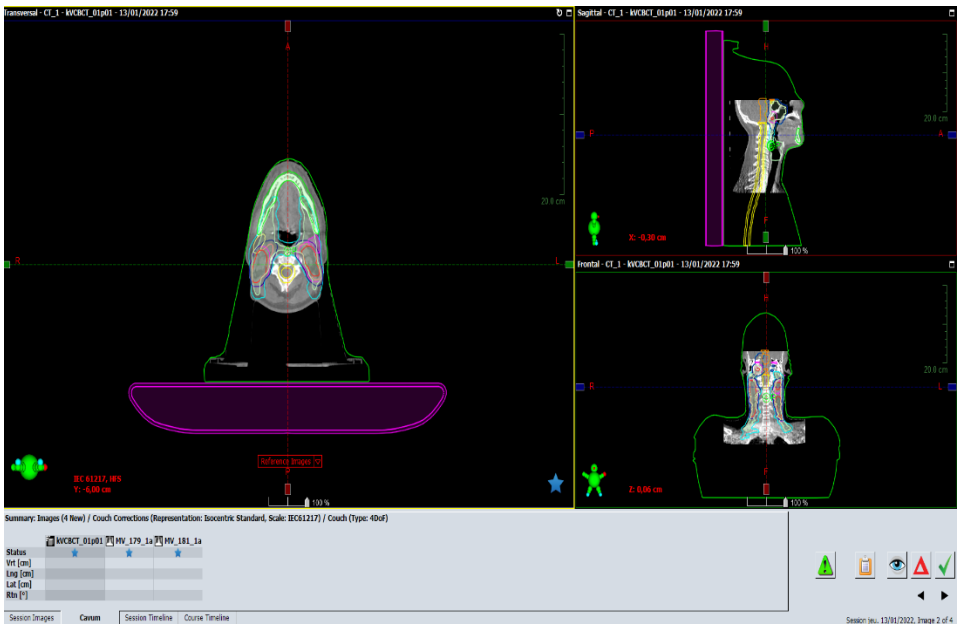

Figure 4. CBCT of an ORL patient before treatment with the delineation of OARs

Results

Interpretation of mean dose values obtained for patients.

Analyses of the average values of doses delivered at target volumes.

The quantitative analysis of the dose distributions is summarized in figure 5. Table 4 shows that these three techniques offer very good dosimetric results which allow good coverage in the three PTVs. The differences noted on the volume receiving 50% of the dose and on the maximum dose are low. To analyse these results, statistical tests were carried out on dose ranges and specific dose points which appeared interesting regarding the HDV curves (Figure 6). The dosimetries were analysed on Graph Pad Prism 7 version 7.04.

Depending on the volumes analysed, dosimetric indices were compared. The SS, SW and VAMT designs were compared using a paired ANNOVA test, with a cut off for a statistically significant level at p<< 0.05. On PTV, the value of P being much greater than the significance level 0.05 (therefore retains the null hypothesis) 0.1 <p <0.99. The dose distribution in the three treatment plans do not therefore differ significantly.

Analyses of average dose values delivered to OARs [16].

These techniques made it possible to respect the prescribed constraints and the savings of the OARs (table 5 Figure 7). The SS one permitted reductions in the maximum dose received by the spinal cord, parotids, chiasma, eye, and lens, while the average dose of the latter was low in the plans made with the SW technique. On the other hand, VMAT led decreases in the average and maximum dose received by the brainstem. For the parotid gland SS led up to optimize the doses received in relation to SW and VMAT. In OARs, the value of P being much greater than the significance level 0.3 <p <0.99, we can therefore conclude that the dose received by OARs with the three treatment plans did not differ significantly.

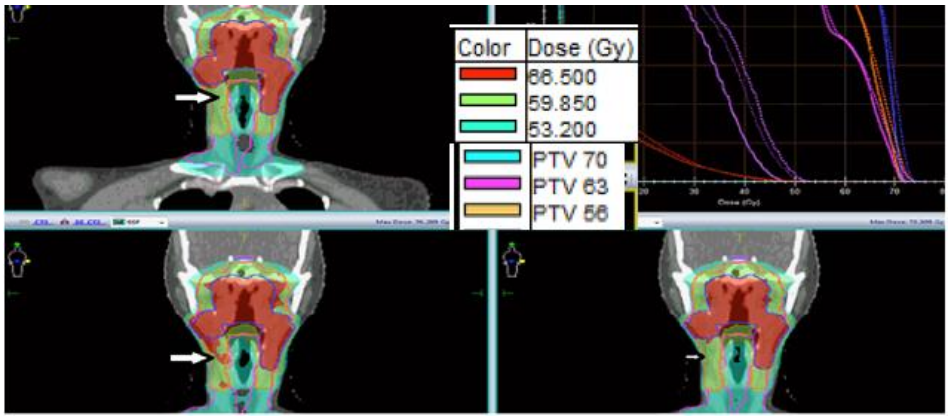

Figure 5. Distribution of the dose in a coronal and sagittal plane obtained in SS, SW and VMAT for a typical patient treated for cancer of the nasopharynx sphere. PTVs with prescription doses of 56 Gy, 63 Gy and 70 Gy are shown in blue, green and sky blue, respectively.

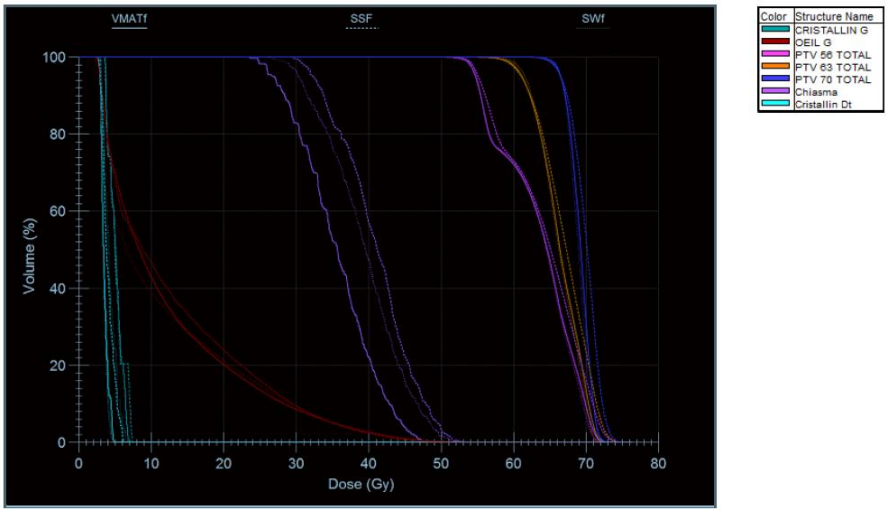

Figure 6. HDV obtained in S&S (broken line), SW (thin broken line) and VMAT (continuous line) technique.

Table 4. Dosimetric comparison, between plans made using S&S, SW and VMAT techniques, average values of the doses received by the target volumes obtained at three dose levels (SIB).

Techniques	SS	SW	VMAT	Relative gap(%) $(X_{VMAT}- X_{SS})\times 100$ / X_{SS}	Relative gap(%) $(X_{VMAT}- X_{SW})\times 100$ / X_{SW}	Relative gap(%) $(X_{SW}- X_{SS})\times 100$ / X_{SS}	P-value
PTV 70				%	%	%	
D98%(GY)	66.09±2.18	66.55±1.00	66.57±1.67	0.7%	0.03%	0 .7%	0.266
D2%(GY)	73.31±0.328	72.6±0.235	72.45±0.269	-1.2%	-0.2%	-1%	0.772
D_{mean}%(Gy)	68.14±1.048	69.02±0.327	69.49±0.588	1.9%	0 .7%	1.3%	0.219
PTV63				%	%	%	
D98%(GY)	56.13±2.425	58.07±1.063	57.96±1.353	3.2%	-0.2%	3 .3%	0.219
D2%(GY)	68.11±2.147	69.04±1.549	68.7±1.73	0.9%	-0.5%	1.4%	0.935
D_{mean} %(GY)	63.16±2.783	64.71±1.583	65.02±1.832	2 .9%	0.5%	2.4%	0.671
PTV56				%	%	%	
D98%(GY)	52.78±1.522	53.78±0.463	53.36±0.864	1.1%	-0.8%	1 .7%	0.1436
D2%(GY)	61.46±3.563	62.72±3.743	62.63±3.773	1 .9%	-0.1%	2%	0.9987
D_{mean} (GY)	57±1.665	57.21±1.43	57.02±1.594	0.04%	-0.33%	0 .4%	0.8393

Analysis of the mean values of the dosimetric indices

To dosimetrically analyse our treatment plans, we have recourse to the table 6 conformation indices which permit a geometric analysis, of the dose distribution, and can facilitate the dosimetry one. A statistical analysis was performed, using the p-value test to compare the difference between the modalities used. Knowing that the ideal value of the homogeneity index is 0,100% for the coverage of the target, and 1 for the other indices, the analysis of our results was based on these objectives.

• The homogeneity index was close to the ideal value for the three PTV with the SW technique than with the SS and VMAT techniques, with a p-value between 0.06 and 0.71.

• The compliance index was more compliant in VMAT for the last two PTV, and in SW for the first PTV, and $0.54 < p < 0.99$.

• The coverage index was very close to the ideal value for the three technologies. The SW technique covers the PTV 70 and PTV 56 well, and PTV 63 in VMAT; with the p-value between 0.07 and 0.22.

• Target coverage was better in SW, with p between 0.26 and 0.70.

• The number of conformations was far from the ideal value for PTV 56 in the three techniques, on the other hand it was poor for PTV 70, and perfect for PTV 63 of 1.07 in VMAT, with $0.43 < p < 0.98$

• Overlap Ratio was close or equal to the ideal value in SW for the first two PTV, and in SS for the last, with p between 0.53 and 0.78. It was noticed that the differences between the plans are all not significant; because they exceed the significant threshold of $p < 0.05$, as well as in most of the time the conformation indices are more in conformity with the objectives and the ideal values in SW than in SS and in VMAT. These new techniques require very precise control of the geometric position of the patient by on-board imaging before the irradiation session so as not to degrade tumor coverage.

Table 5. Dosimetric comparison, between plans made in S&S, SW and VMAT techniques, average values of the doses received by the organs at risk obtained at three dose levels (SIB).

	OAR\Techniques	VMAT	SW	SS	P- value
Spinal cord	D2%(Gy)	38.17 ± 1.429	37.58 ± 1.601	36.6 ± 1.887	0.7967
	Dmean(Gy)	27.85 ± 2375	27.32 ± 3.143	27.01 ± 2.77	0.9771
PRV Spinal Cord	D2%(Gy)	42.17 ± 1.429	42.58 ± 1.601	42.6 ± 1.887	0.7967
	Dmean(Gy)	29.85 ± 2375	28.32 ± 3.143	28.01 ± 2.77	0.9771
Brainstem	D2%(Gy)	41.89 ± 7.524	50.92 ± 1.992	50.19 ± 1.899	0.352
	Dmean(Gy)	28.16 ± 6,29	31.64 ± 4.243	34.05 ± 2.027	0.665
PRV Brainstem	D2%(Gy)	48.89 ± 7.524	53.92 ± 1.992	53.19 ± 1.899	0.352
	Dmean(Gy)	30.16 ± 6,29	33.64 ± 4.243	35.05 ± 2.027	0.665
Left Parotid	Dmean(Gy)	25.17 ± 3.7	25.61 ± 3.669	23.42 ± 3.373	0.901
	V 15 (Gy) (%)	62.14 ± 8.11	62.85 ±8.05	63.27 ± 8.08	0.952
	V26Gy(%)	39.84 ± 6.24	38.2 ± 6.553	38.56 ± 6.545	0.822
	V30Gy(%)	30.13 ± 4,403	29.57 ± 4932	29.52 ± 4.884	0.715
	V45Gy(%)	16.38 ± 2,438	16.53 ± 2877	13.72 ± 2.424	0.523
Right parotid	Dmean(Gy)	24.17 ± 3.55	24.11 ± 3.669	23.62 ± 3.373	0.901
	V 15 (Gy) (%)	70.14 ± 10.11	70.75 ±9.05	70.27 ± 9.08	0.952
	V26Gy(%)	43.84 ± 6.24	42.6 ± 6.553	42.56 ± 6.545	0.822
	V30Gy(%)	32.13 ± 4.403	32.57 ± 4.932	34.52 ± 4.884	0.715
	V45Gy(%)	19.38 ± 2.438	19.53 ± 2.877	15.72 ± 2.424	0.523
Chiasma	D2%(Gy)	42.92 ± 9.386	43.16 ± 7.484	42.08 ± 7.757	0.995
	Dmean(Gy)	24.17 ± 9.48	23.38 ± 8.82	24.05 ± 8.213	0.997
	PRVChiasma				
	D2%(Gy)	45.92 ± 9.386	46.16 ± 7.484	45.08 ± 7.757	0.995
	Dmean(Gy)	24.17 ± 9.48	23.38 ± 8.82	24.05 ± 8.213	0.997
Right eye	D2%(Gy)	18.72 ± 14.67	15.71 ± 9.195	2.05 ± 5.257	0.905
	Dmean(Gy)	5.548 ± 1.93	5.925 ± 0.989	5.683 ± 0.476	0.978
	Left eye				
	D2%(Gy)	15.55 ± 1.573	14.86 ± 9.076	14.33 ± 7.539	0.914
	Dmean(Gy)	5.6 ± 3.219	5.445 ± 3.17	5.719 ± 3.053	0.998
Right Lens	D2%(Gy)	6.225 ± 1.331	5.135 ± 0.550	5.782 ± 1.718	0.737
	Dmean(Gy)	4.028 ± 0.852	4.712 ± 0.471	4.902 ± 0.678	0.948
	left lens				
	D2%(Gy)	6.782 ± 1.718	7.135 ± 0.550	8.225 ± 1.331	0.737
	Dmean(Gy)	4.902 ± 0.678	4.712± 0,471	5.028 ± 0.852	0.948
Left Crystalline	D2%(Gy)	7.585 ± 2.176	8.48 ± 2.971	8.77 ± 1.701	0.934
	Dmean(Gy)	5.06 ± 0.797	5.153 ± 0.829	5.361 ± 1.111	0.972
	Right Optic Nerve				
	D2%(Gy)	18.8 ± 3.941	15.75 ± 1.538	12.22 ± 3.316	0.432
	Dmean(Gy)	4.17 ± 0.154	3.67 ± 0,1605	3.418 ± 0.004	0.054
Left Optic Nerve	D2%(Gy)	20.62 ± 4.592	16.79 ± 4.269	14.77 ± 3.89	0.655
	Dmean(Gy)	4.153 ± 0.13	3.609 ± 0.074	3.597 ± 0.074	0.041
	Oral Cavity				
	D2%(Gy)	56.782 ± 1.718	54.135 ± 0.550	53.225 ± 1.331	0.737
	Dmean(Gy)	40.902 ± 0.678	39.712± 0,471	39.028 ± 0.852	0.848
Larynx	D2%(Gy)	58.585 ± 2.176	58.48 ± 2.971	58.77 ± 1.701	0.734
	Dmean(Gy)	35.06 ± 0.797	35.153 ± 0.829	35.361 ± 1.111	0.572
	Left Cochlea				
	D2%(Gy)	48.8 ± 3.941	45.75 ± 1.538	42.22 ± 3.316	0.432
	Dmean(Gy)	24.17 ± 0.154	23.67 ± 0,1605	23.418 ± 0.004	0.054
Right Cochlea	D2%(Gy)	39.8 ± 3.941	38.75 ± 1.538	32.22 ± 3.316	0.532
	Dmean(Gy)	24.17 ± 0.154	23.67 ± 0,1605	23.418 ± 0.004	0.054
	Mandible				
	D2%(Gy)	59.8 ± 3.941	58.75 ± 1.538	55.22 ± 3.316	0.532
	Dmean (Gy)	40.17 ± 0.154	39.67 ± 0,1605	39.418 ± 0.004	0.054

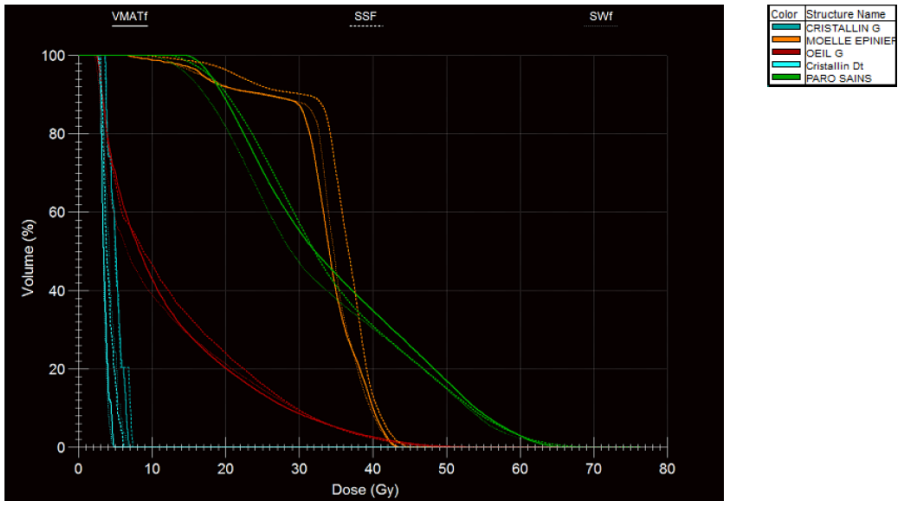

Figure 7. HDV obtained in S&S (broken line), SW (thin broken line) and VMAT (continuous line) technique for risky organs

Table 6. Dosimetric indices calculated on plans made using S&S and VMAT techniques, average values obtained on 10 patients treated at three dose levels (SIB).

	SS	SW	VMAT	p-value
PTV 70				
Homogeneity index	0.168	0.109	0.119	0.2144
Compliance index	0.365	0.557	0.507	0.5451
Coverage index	0.937	1.010	0.975	0.2216
Target coverage%	38.179	56.175	48.873	0.7089
The number of conformations	0.484	0.574	0,534	0,9381
Overlap ratio	0.414	0.574	0.514	0.7829
PTV 63				
Homogeneity index	0.227	0.166	0.167	0.0614
Compliance index	0.577	0.595	0.607	0.9937
Coverage index	0.967	0.974	0.984	0.0703
Target coverage%	50.875	76.344	70.246	0.6139
The number of conformations	0.830	1.202	1.079	0.4301
Overlap ratio	0 .560	0.911	0.769	0.53339
PTV 56				
Homogeneity index	0.260	0.206	0.212	0.7131
Compliance index	0.352	0.375	0.412	0.9459
Coverage index	0.971	0.980	0.979	0.185
Target coverage%	60.124	82.107	74.738	0.2641
The number of conformations	2.260	2.594	2.426	0.983
Overlap ratio	1.016	1.924	1.450	0.5415

Discussion

The present investigation's results, shown that the dose distributions, homogeneity, and dose conformation at PTV are similar between the three techniques (Figure 6) of RCMI S&S, SW and VMAT. Theo et al have summarizing the results of studies published between 2009 and 2011 for the treatment of several locations including the neck and head [17]. Many authors have shown similar results on the coverage of the target volume obtained in RCMI by stationary beams and in VMAT under the condition sometimes of using two arcs [18-23].

The OARs are significantly better spared in the VMAT technique only for the D2% and Dmoy received by the marrow. Regarding OAR sparing, previous studies have shown very small differences or equivalent results between stationary beam IMRT techniques, S&S or SW and VMAT techniques (arctherapy) [18, 24]. However, for higher doses, there are no significant differences between the three techniques. Bertelsen et al found an increase in volume receiving less than 17 Gy and a decrease in volume receiving doses between 17 and 50 Gy in VMAT technique [24]. Regarding the low doses, we did not measure any major differences between the three techniques.

The present work pointed out that differences in measured doses are less than or equal to 3% of the prescribed dose. To obtain dose distributions satisfying the set criteria, two-arch ballistics were used. In a previous study, Guckenberger et al found that to have

results like S&S, two or three arcs were necessary in VMAT in the case of complex target volumes such as the integrated boost treatment of the ORL sphere [24]. These different results are explained by the reverse optimization rules. Identical inverse constraints were used in S&S and in VMAT.

A major improvement of VMAT and Dynamic Multileaf Collimator (DMLC) compared to the S&S technique is the decrease in the number of MUs (-29%). In previous studies with ORL cases, the decrease in MU number ranged from 8.5% to 60.0% [18] [19] [24]. These differences are due to the types of stationary beam IMRT technique used in the comparison [24, 25]. Another major improvement of VMAT is the reduction in treatment delivery time: on average 5 min are needed in VMAT technique and 10 min for SW versus 20 min in S&S technique.

This decrease has a direct impact on patients in terms of comfort and immobility and potentially in terms of intra-fraction movements. The published studies have shown a reduction in treatment time: between 1.2 min and 8.13 min in VMAT compared to a time between 6 min and 15 min in IMCR by stationary beams [19-24]. Bertelsen et al explain that these differences may be due to the stepwise dose rate variation mode on the Elekta Infinity accelerators used in these studies [24]. In addition, longer treatment times in our study can be explained by larger PTV volumes compared to those reported in the other studies.

Conclusion

Radiotherapy technology has undergone a fast development in recent years, allowing thus ease and more precision in treatment techniques. Indeed, the appearance of IMRT and the birth of VMAT allow a concave dose distribution, perfectly suited to the irradiation of nasopharyngeal cancers, which is the clinical justification for this work, and which requires special attention given its frequent incidence.

Radiotherapy of a tumor located in the ORL sphere is one of the most complex situations because it brings together all the greatest dosimetric difficulties. So, the perpetual challenge is to deliver an adequate tumor coverage with a sparing of organs at risk and to preserve their function well thanks to the reduction in the dose received.

This investigation aims to shed light on the contribution of IMRT (SS and SW) and VMAT techniques to the treatment of cavum cancer, as well as their role in the preservation of these organs at risk. The treatments were planned, using a Synergy Elekta linear electron accelerator associated with a TPS Monaco.

Results shown that the mean doses received by the parotid gland and the brainstem decrease by 2.19 in SS Gy and 5.89 Gy in VMAT respectively, however the dose received by the spinal cord was almost equal in the three modalities. The calculation revealed that the dosimetric indices were in line with objectives and close to ideal values, which illustrates that the treatment plans used were as satisfactory as possible.

For the statistical study which was based on the p-value, it was found that it retains the null hypothesis, and that the dose distribution and indices between the three treatment plans did not differ significantly.

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