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DOSIMETRIC COMPARATIVE EVALUATION PARAMETERS FOR DIFFERENT RADIOTHERAPY TECHNIQUES (3D-CRT, IMRT, VMAT) IN PARANASAL SINUSES CANCERS TREATMENT

BY

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Abstract. Rinosinusal cancers accounts for about 3% of all malignancies, most developing to the maxillary sinuses (70%), followed by ethmoid (20%), frontal (3%) and sphenoidal (1%) sinuses. Anatomical position and late symptomatology in advanced stages make these malignancies difficult to diagnose, surgical approach and adjuvant treatment with radiation having a role in getting local control. Radiosensitive organs in proximity made difficult to deliver tumoricidal dose irradiation by conventional radiotherapy. Implementation of 3D-CRT technologies (3D conformal) based on the use of MLC (multi-leaf collimator) and then inverse planning techniques IMRT (intensity modulated radiation therapy) and VMAT (volumetric modulated arc

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therapy) resulted in dose reductions in OAR (organs at risk) and better dose homogeneity in PTV (planning target volume).

Keywords: radiotherapy; paranasal sinuses; IMRT; VMAT.

1. Introduction

Nasal cavity and paranasal sinuses cancers include tumors originate from the paranasal cavities (ethmoid, maxillary, frontal and sphenoidal) or from the nose (excluding nasal vestibule) and is a rare type of cancer, about 0.2-0.8% of all cancers and 5% of head and neck cancers. It is often late diagnosed with nonspecific clinical symptoms having high tumor aggressivity and a poor prognosis. Most commonly occurs in the maxillary sinus (70%), followed by ethmoid (20%), frontal (3%) and sphenoidal (1%) sinus (Jégoux *et al*., 2013). Surgical resection with negative margins followed by adjuvant radiotherapy is the optimal treatment. In some advanced cases surgical anatomical limits make impossible a complete resection, definitive radiotherapy with or without concurrent chemotherapy being the only therapeutic option. The challenge to deliver a tumoricidal dose on a relatively large volume in the immediate vicinity of radiosensitive critical organs (optic nerves, lenses, optic chiasma, brain) made necessary the development of new high precision methods in radiotherapy. Inverse planning techniques provides superior dose conformity compared to 2D and 3D radiotherapy often associated with high toxicity: radical cataract, dry eye syndrome caused by lacrimal gland function loss, retinopathy or even blindness caused by irradiation of optical aperture (optic nerve and chiasm). Non-coplanar IMRT technique can provide superiority in terms of organs at risk protection, especially for tumors of the nasal cavity and for target volume situated between the eyes. Implementation of rotational intensity modulated technique VMAT brings advantages over IMRT technique in particular by decreasing treatment time and number of monitor units (Bortfeld *et al*., 2006). The paper aims to benchmark target volume coverage and mean doses and Dmax (maximum doses) receive by organs at risk in case of neoplasm of maxillary sinus locally advanced, comparing alternative treatment plans IMRT and VMAT (two half arcs, single arc, double arc) (Jeong *et al.*, 2014).

2. Materials and Methods

We present a case of a locally advanced right maxillary sinus cancer who received definitive radiotherapy in total dose DT = 66Gy/33fr/PTV-T (3D-CRT technique). For a patient with an advanced right maxillary sinus cancer previously treated with 3D-CRT radiotherapy, IMRT and VMAT alternative plans were proposed (two half arcs, single arc and double arc) comparing the dose to OARs, MU (number of monitor units) and target volume coverage. All plans offered doses in accepted limits for organs at risk with similar target volume coverage. VMAT technique offers the advantage of a short treatment time and is a feasible option for busy radiotherapy centers (Biagioli *et al*., 2007).

Patient immobilization was made using a thermoplastic mask and for target delineation volumes (GTV, CTV, PTV) was performed CT simulation, a rigid registration being made between the diagnosis and the simulation CT. Delineation of interest volumes, organs at risk and dosimetry calculation were performed by Eclipse Treatment Planning System™(TPS) software. Dosimetric evaluation of treatment plans took into account target coverage by the 95% isodose and doses received by organs at risk according to recommendations of Quantec and Emami papers (Miura *et al*., 2012). In order to verify the accuracy of the positioning, X-rays kV was performed weekly (every 5 fractions) from the treatment machine, a linear accelerator Varian Clinac iX with 120 multi-leaf collimator.

Subsequently alternative plans were proposed by coplanar IMRT and three different plans using VMAT different from each other by the angle described by the gantry (two half arcs, single or double arc) for a comparative dosimetric evaluation, reproducibility with plans being validated by ArcCHECK® platform (Figs. 1-3).

Conformity index-CI (ratio of volume surrounded by 95% isodose and the volume of PTV), homogeneity index-HI (the ratio of difference between volume which receives 2% and 98% of the prescribed dose and the volume surrounded by 50% isodose) for target volume (PTV), were evaluated together with mean dose (Dmean), maximum dose (Dmax) and the number of monitor units for each technique received by the OARs.

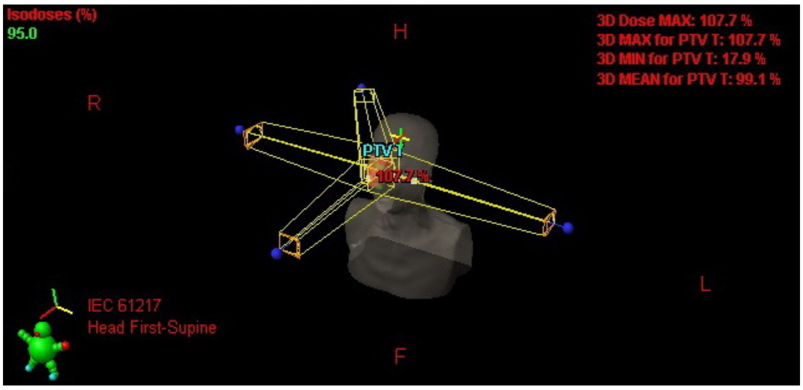

Fig. 1 – Beam orientation for 3D-CRT plan.

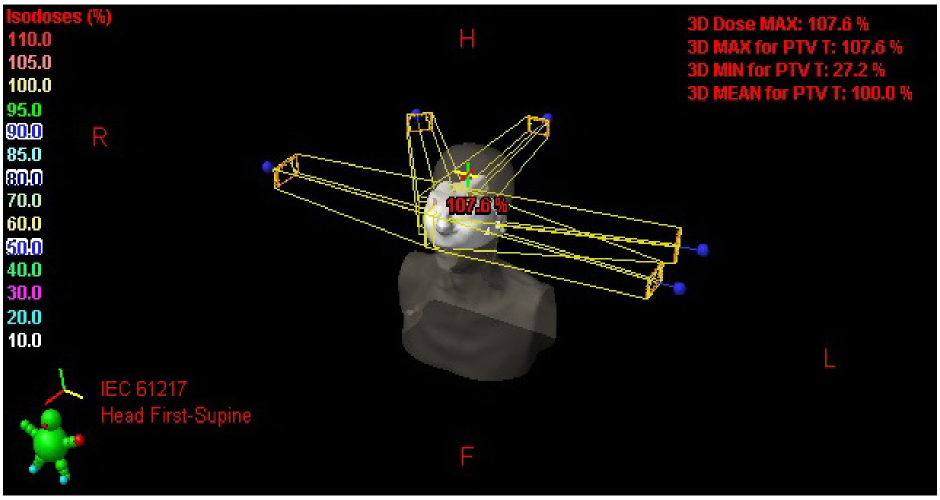

Fig. 2 – Beam orientation for IMRT plan.

Fig. 3 – Half arc radiotherapy plan – beam angle rotation and isodose curves.

3. Results

All doses received by organs at risk using IMRT and VMAT techniques (two half arcs, single arc, double arc) were compared to the dose received by the same organs in 3D-CRT technique (Fig. 4).

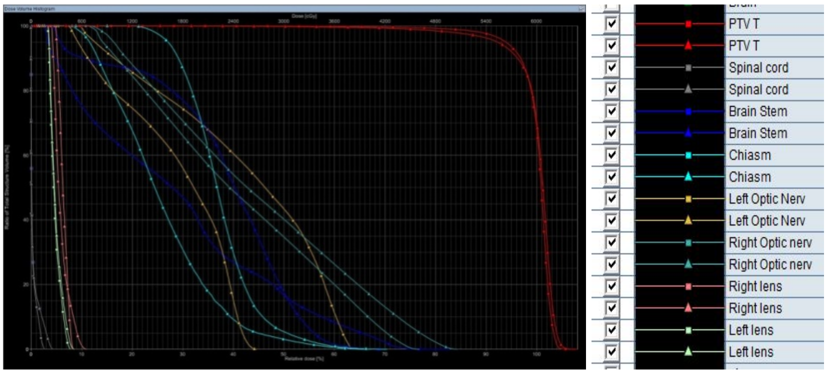

Fig. 4 – DVH comparison for OAR and PTV between
IMRT and VMAT- 2 arcs plans.

IMRT method significantly reduces the mean dose received by spinal cord (46.77%) but significantly increase the dose to the right optic nerve (70.03%). The VMAT methods (two half arcs, single arc, double arc) shows the disadvantage of significantly increasing the dose received by the brainstem with 48.28%, 55.61%, 60.59%, optic nerve as with 65.16%, 79.93%, 84.93% and optic chiasm 62.36%, 57.50% and 31.64% (Table 1).

Table 1
Absolute (cGy) and Relative Dmean for OAR Reported to 3D-CRT

	Absolute number of MU					Relative number of MU			
Radiotherapy Technique	3D - CRT	IMRT	VMAT- 1/2 arc	VMAT- 1 arc	VMAT- 2 arcs	IMRT (%)	VMAT- 1/2 arc (%)	VMAT- 1 arc (%)	VMAT- 2 arcs (%)
Spinal cord	38.70	20.60	32.30	35.30	31.90	-46.77	-16.54	-8.79	-17.57
Brainstem	1403.20	1715.10	2080.70	2183.50	2253.40	22.23	48.28	55.61	60.59
Brain	502.90	547.40	357.70	738.00	739.40	8.85	-28.87	46.75	47.03
Left eye	769.40	789.70	517.00	553.80	605.30	2.64	-32.80	-28.02	-21.33
Left lens	322.40	284.20	289.60	290.90	294.90	-11.85	-10.17	-9.77	-8.53
Right eye	1488.30	1321.80	1047.30	1022.70	972.90	-11.19	-29.63	-31.28	-34.63
Right lens	329.90	354.20	325.30	368.50	382.00	7.37	-1.39	11.70	15.79
Right optic nerve	1443.60	2454.60	2384.30	2597.50	2669.70	70.03	65.16	79.93	84.93
Left optic nerve	1920.40	2541.30	1496.60	1656.40	1740.60	32.33	-22.07	-13.75	-9.36
Optic chiasma	1702.30	1546.00	2763.90	2681.10	2240.90	-9.18	62.36	57.50	31.64

All VMAT methods decrease the mean dose to the spinal cord, contralateral eye and contralateral lens. The maximum dose is reduced or almost equal for all OARs except spinal cord in which significant increases were observed (57.87%, 62.53%, 37.57%).

IMRT technique significantly increases the number of M.U. compared to the number of M.U. delivered by 3D-CRT (128%). VMAT techniques (two half arcs, single arc, double arc) decrease the number of MU with 31.67%, 27.67%, 30.67% (Table 2).

Table 2

Absolute and Relative Number of MU Reported to 3D-CRT

	Absolute number of MU					Relative number of MU			
Radiotherapy technique	3D	IMRT	VMAT-1/2 arc	VMAT-1 arc	VMAT-2 arcs	IMRT (%)	VMAT-1/2 arc (%)	VMAT-1 arc (%)	VMAT-2 arcs (%)
MU	300.00	684.00	395.00	383.00	392.00	128.00	31.67	31.67	30.67

CI closest to the optimum value "1" is obtained with IMRT techniques and VMAT and HI is closest to the optimum value "0" technique IMRT (Table 3).

Table 3

Absolute (cGy) and Relative Dmax for OAR Reported to 3D-CRT

	Absolute number of MU					Relative number of MU			
Radiotherapy Technique	3D - CRT	IMRT	VMAT-1/2 arc	VMAT-1 arc	VMAT-2 arcs	IMRT (%)	VMAT-1/2 arc (%)	VMAT-1 arc (%)	VMAT-2 arcs (%)
Spinal cord	195.10	169.00	308.00	317.10	268.40	-13.38	57.87	62.53	37.57
Brainstem	4791.5	4965.8	4091.4	4089.7	4191.3	3.64	-14.61	-14.65	-12.53
Brain	6462.2	6132.1	6581.0	6115.9	6075.4	-5.11	1.84	-5.36	-5.99
Left eye	3365.6	3645.4	1564.1	1882.7	2143.7	8.31	-53.53	-44.06	-36.31
Left lens	574.10	469.90	495.70	504.60	515.90	-18.15	-13.66	-12.11	-10.14
Right eye	6105.5	6026.7	5870.7	5648.1	5605.0	-1.29	-3.85	-7.49	-8.20
Right lens	608.10	657.40	463.40	505.00	505.60	8.11	-23.80	-16.95	-16.86
Right optic nerve	3392.7	4609.6	4862.6	5130.8	5065.0	35.87	43.33	51.23	49.29
Left optic nerve	3303.8	3803.1	2393.5	2508.3	2681.1	15.11	-27.55	-24.08	-18.85
Optic chiasma	4761.3	4026.3	4569.6	4482.5	4226.4	-15.44	-4.03	-5.86	-11.23

4. Discussion

In head and neck cancer radiotherapy dosimetry, a 43-45Gy constriction spinal cord in order to reduce the risk of radio-induced myelopathy, limits delivered dose in the target volume during conventional radiation therapy. Inverse planning techniques made possible the simultaneous irradiation with different fractionations and different doses for different volumes allowing dose escalation in the areas of tumor radio-resistance. The inclusion of functional imaging PET-CT and diffusion MRI combined with a high-resolution structural imaging could bring benefit in dose escalation.

Basic treatment leads to local failure in 70%. Salvage therapy has a success rate of 30-40% off in head and neck cancers but few patients will be long-time survivors. Re-irradiation and chemo-radiotherapy using IMRT technique are feasible options decreasing the risk of medullary toxicity.

Miura and collaborators have obtained a dose reduction for brainstem and brain by using half-arc VMAT radiotherapy. Similar results were obtained in the case presented for half-arc VMAT method. 3D and IMRT technique still offers best dose solutions for the brainstem but 2 half-arcs VMAT method offers the lowest mean dose for the brain.

For advanced cases involving large irregularly shaped, requiring elective lymph node irradiation, non-coplanar IMRT and VMAT techniques offers dosimetric advantages but clinical benefits will be validated in the future (Orlandi *et al*., 2014).

5. Conclusions

VMAT technique offers a rapid option with comparable dosimetric results and coverage of the target volume in maxillary sinus cancer. By significantly reducing the dose to the spinal cord compared to 3D-CRT, IMRT can be used in selected cases for dose escalation in order to improve local control. Saving machine-time can be an advantage for choosing VMAT in crowded radiotherapy centers.

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EVALUARE DOZIMETRICĂ COMPARATIVĂ A DIFERITELOR TEHNICI DE RADIOTERAPIE (3D-CRT, IMRT, VMAT) ÎN TRATAMENTUL CANCERELOR RINOSINUSALE

(Rezumat)

Cancerele rinosinusale reprezintă aproximativ 3% din totalul afecțiunilor maligne, majoritatea dezvoltându-se la nivelul sinusurilor maxilare (70%), urmate de etmoid (20%), sinusurile frontale (3%) și sfenoidale (1%). Poziția anatomică și simptomatologia tardivă fac ca aceste tumori maligne să fie dificil de diagnosticat, adesea fiind descoperite în stadii avansate. Abordul chirurgical și tratamentul adjuvant cu radiații are un rol esențial în obținerea controlului local. Organele radiosensibile aflate în proximitate fac dificilă livrarea unor doze de iradiere tumoricidale prin radioterapia convențională. Implementarea tehnologiilor 3D-CRT (3D conformațional), bazate pe utilizarea MLC (colimator multi - lamă) și apoi a tehnicilor de planificare inversă IMRT (terapie cu radiații modulate în intensitate) și VMAT (terapie în arc modulată volumetric) a condus la reducerea dozelor la OAR (organe la risc) și o mai bună omogenitate a dozei în PTV (volumul țintă planificat).