Comparison of inverse planning systems based on biological or physical factors: Pinnacle®, Corvus® and Monaco®

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Introduction:

Radiotherapy (RT) is one of the most important approaches in the treatment of cancer[1] and its performance can be improved in three different ways: through the optimization of the dose distribution, by the use of different irradiation techniques or through the study of radiobiological initiatives[1-2]. The first is purely physical because is related to the physical dose distributiuon[2]. The others are purely radiobiological because they increase the differential effect between the tumour and the health tissues[2].

The Treatment Planning Systems (TPS) are used in RT to create dose distributions with the purpose to maximize the tumoral control and minimize the complications in the healthy tissues[3]. The inverse planning uses dose optimization techniques that satisfy the criteria specified by the user, regarding de target and the organs at risk (OAR's)[3-5]. The dose optimization is possible through the analysis of dose-volume histograms (DVH) and with the use of computed tomography, magnetic resonance and other digital image techniques[3].

It is usual to use the calculation of the Equivalent Uniform Dose (EUD) to compare different TPS's. This is defined as the uniform dose that presents the same biological effect than a non-uniform dose distribution and it's calculated based on the law of the dose response dependency in the PTV and OAR's[6].

This review discusses three TPS's, namely Pinnacle®, Monaco® and Corvus®. The first is an inverse treatment planning system (ITPS) that integrates different modalities of RT treatment and uses the Collapsed Cone Convulotion Superposition (CCCS) algorithm that deals with the effects of the heterogeneities in the patient regarding the primary radiation and also the secondary scattering radiation[7]. The optimization of the dose distribution can be verified through the isodose curves, the 3D dose shades and the DVH's that are updated in real time whenever the field contribution, dose prescription or normalization point are modified[8].

Corvus® tests and rejects millions of pencil beam (PB) intensities will building a dose planning that achieves the defined goals[9]. This is the only TPS that supports tomotherapy[9] and that has the ActiveRx tool which allows the manipulation of the isodose curves after the calculation, improving the planning with an immediate graphical feedback[10]. Because this TPS uses a finite size PB algorithm it becomes adequate for homogeneous phantoms but may result in estimations above or below the prescribed dose in areas that involve heterogeneities[11].

Monaco® is an ITPS that uses radiobiological factors, biological functions and the Monte Carlo (MC) algorithm, which allows it a correct and sophisticated planning for intensity modulated RT[12]. The use of the biological model improves the dose optimization and provides a wide range of cost functions[12] that are used to directly relate the dose in the target and in the OAR's[13]. For each cost function assigned to a structure the ITPS calculates an index that reflects the biological response of the structure to a specific dose and after the optimization that index is compared with the constraints specified by the user[13-14].

The purpose of this review is to make a comparison of ITPS's based on biological factors and ITPS's based on physical factors (dose and volume).

Methodology:

It was made a literature research through B-on between April and June 2011 with the following key-words: treatment planning system, Corvus, Pinnacle, Monaco, biologic factors and physical factors. There were considered articles that included at least one ITPS in study; the existence of comparisons between various ITPS's that provided evidence of conclusions; evidence on the use of biological and physical factors; development of the results or discussion on PTV coverage and OAR's protection. Based on these criteria there were selected five articles.

Results:

Table 1 shows the main results of the six articles analyzed and allow us to understand that the ITPS's that use biological models showed a similar or slightly higher coverage of the PTV than the ones that used physical factors, in prostate and head and neck cancers. There were achieved higher values of EUD in ITPS's using biological factors and a greater preservation of OAR's, when compare to the values of ITPS's using physical factors, in prostate and head and neck cancers.

Table 1. Results of the different analyzed studies

Study	ITPS's	Location	N	EUD (Gy)	Dose prescription at 95% (Gy)	PTV coverage at 95% (Gy)	Dose in the OAR's (Gy)
Gordon et al[15]	Pinnacle®	Prostate	28		75.24	81	D_{50} Rectum – 45 D_{50} Bladder – 45
Qi et al[5]	Pinnacle®	Head & neck	1	PTV – 66 Mandible – 52 Spine – 38		66	 D_{50} Mandible – 47 D_{50} Spine – 21
		Prostate	1	PTV – 77 Bladder – 29 Rectum – 53 R. Femur – 34 L. Femur - 28		76	 D_{50} Bladder – 10 D_{50} Rectum – 29 D_{50} R. Femur – 34 D_{50} L. Femur – 28
		Amygdale	5	L. Parotid – 20.7 R. Parotid – 17.01 Spine – 38.50	47.50	50.5	D_{50} L. Parotid –]16;22] D_{50} R. Parotid –]14;19] D_{50} Spine – 50% →]35;38]
	Monaco®	Head & neck	1	PTV – 69 Mandible – 50 Spine – 31		61.5	 D_{50} Mandible – 36 D_{50} Spine – 15
		Prostate	1	PTV – 78 Bladder – 24 Rectum – 49 R. Femur – 26 L. Femur - 28		77	 D_{50} Bladder – 7 D_{50} Rectum – 24 D_{50} R. Femur – 26 D_{50} L. Femur – 28
Semenenko et al[13]	Monaco®	Head & neck	1	PTV – 74 Mandible – 41.5 Spine – 27.5		71	 D_{50} Mandible – 25 D_{50} Spine – 50
		Prostate	1	PTV – 73 Bladder – 12 Rectum – 46 R. Femur – 13 L. Femur - 10		72	 D_{50} Bladder – 2 D_{50} Rectum – 3.5 D_{50} R. Femur – 4 D_{50} L. Femur – 6
Fogliata et al[16]	Pinnacle®	Ewing Sarcoma	1		51.68	48	D_{50} Vertebra – 5 D_{50} R. Lung – 12 D_{50} Heart – 27
Boudreau et al[14]	Corvus®	Head & neck	1		47.50*	53*	D_{50} Spine – 33 D_{50} Mandible – 42

*CTV

Discussion/Conclusion:

The optimization algorithms of the ITPS's result in acceptable plans in terms of PTV total coverage and maximum protection of the OAR's. The use of biological IMRT plans leads to a consistent spare of the OAR's when compared with the plans based on conventional cost function of dose-volume, with the same field arrangement[6]. The explanation for a slight increase of the dose heterogeneity in plans made with Monaco® is that the biological model of optimization intends to achieve a better tumour control minimizing the toxicity in the healthy tissue. In theory a biological cost function it's not sensitive to the hot spots inside the target if they increase the death of the cancer cells[6].

Boudreau et al[14] concluded that same changes in the dose-volume plans can be caused by the bony structures, secondary electron fluency, differences in the tissues composition, existence of air cavities near the PTV and also the tissue-air and bone-tissue ratios[14]. One of the hypothesis would be to exclude the air cavities from the target, although this exclusion can lead to very complex structures that may compromise the dosimetric plan by blocking the optimization process and leading to a worse distribution[14]. Therefore the use of PTV margins to include geometric uncertainties and variations requires the inclusion of the air cavities[14].

Gordon et al[15] concluded that with would be better to expand the voxels that can contribute to the CTV coverage. By expanding the CTV (≈1.4cm) in this system it's possible to reach the goal of the target coverage[15].

There were achieved better dose distribution in the ITPS's who used biological models, with additional protection of OAR's and a good coverage of PTV, however these ITPS's showed higher heterogeneity than the ITPS's using physical factors. The use of biological factors in ITPS's is recent, and their use requires a learning period for its effective use in the daily practice.

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