Comparison between Conformal 3D Radiotherapy (3D-CRT) and Volumetric Modulated Arc Radiotherapy (VMAT) in the sparing of organs at risk for prostate cancer

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Introduction:

Prostate cancer is the first noncutaneous cancer in men and the second cause of cancer mortality after lung cancer. External Beam Radiation (RT) is recommended for prostate cancer treatment in all risk patients. In RT, irradiation of the prostate gland and seminal vesicles (SV) is done with doses from 71-80Gy. For patients with high and intermediate risk, an irradiation of the pelvic lymph nodes is also performed with 45-46.8Gy[1,2]. In this case, the irradiation is done in two phases. Generally, the first phase is performed with an irradiation of the pelvic lymph nodes, seminal vesicles and prostate gland and the second phase (Boost) only with the irradiation of the prostate and seminal vesicles.
Volumetric modulated arc radiotherapy (VMAT) with RapidArc® (Varian Medical Systems) is a recent technique that provides intensity-modulated radiation therapy. Unlike conformal 3D Radiotherapy (3DCRT), RapidArc is delivered with dynamic gantry, multi-leaf collimator and dose rate.

The purpose of this study was to evaluate the differences in the dose received by the major organs at risk for both 3DCRT and VMAT techniques for prostate cancer patients.

Materials and Methods:

The analysis was performed on 26 patients. Both VMAT and 3D-CRT planning techniques with the same prescribed dose and planning target volumes were applied to each patient. The treatment planning system used was Eclipse (version 8.6) with Anisotropic Analytical Algorithm.

VMAT planning technique **(RapidArc)** (Figure 3) was performed with two arcs using simultaneous integrated boost (SIB) technique[3] for the pelvic lymph nodes, SV and prostate gland. Two arcs were also applied in the Boost plan.

In the 3D-CRT planning of the first phase, two distinct techniques were performed — the traditional Four-Field box[2] **(3D-CRT: BOX)** (Figure 1)and a more conformal approach of six to eight-field plan **(3D-CRT: CONF)** (Figure 2). The Boost in 3D-CRT was planned using both the five and six-field techniques[2].

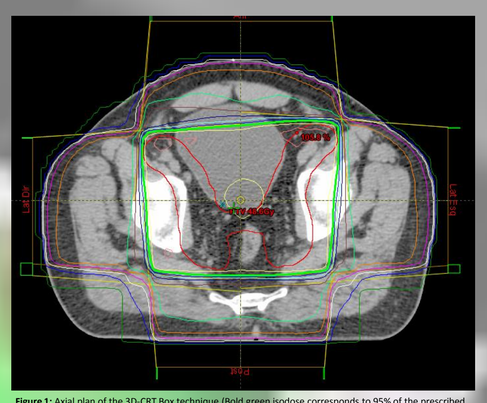


Figure 1: Axial plan of the 3D-CRT Box technique (Bold green isodose corresponds to 95% of the prescribed dose for phase 1).

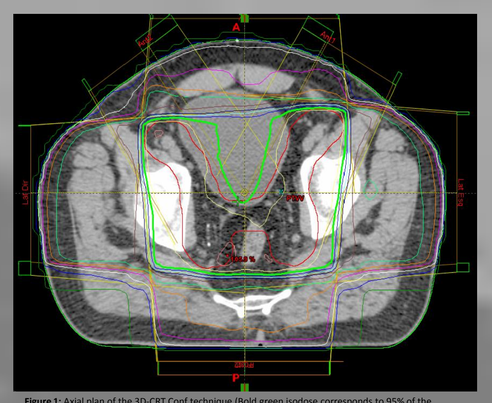


Figure 1: Axial plan of the 3D-CRT Conf technique (Bold green isodose corresponds to 95% of the prescribed dose for phase 1).

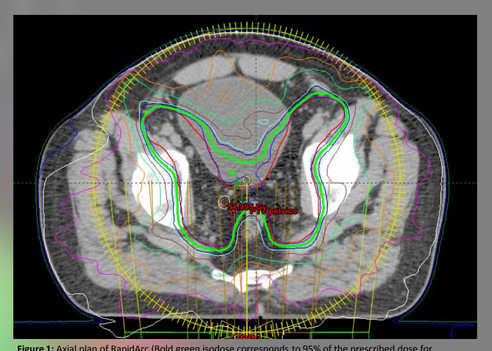


Figure 1: Axial plan of RapidArc (Bold green isodose corresponds to 95% of the prescribed dose for phase 1).

The dose volume histograms (DVHs) of the rectum, bladder, femoral heads, small bowel and penis were analyzed and compared. Because RapidArc is an arc technique, the dose received by the body was also analyzed.
Considering the Box technique is still a standard planning approach in many clinics, both the Box and the conformal techniques were included in the analysis. As for the prostate gland boost in 3D-CRT, only the technique that presented less dose to the rectum and bladder was included.
The DVHs were analyzed at the 2% (near-maximum), 10%, 25% and 50% volume of the major organs at risk (OARs) and at 33% and 66% for the body. All the doses received by the OARs were normalized to the total prescribed dose.

Results:

Results show that the plans performed with RapidArc received on average less dose for all the major organs at risk. The most significant differences were found for femoral heads, rectum and bladder.

With RapidArc, 50% and 2% of the total volume of the femoral heads received on average 24% and 19% less of the total dose, respectively (Table IV; Graph IV). Regarding the dose received by the rectum (Table I; Graph I), RapidArc plans showed greater differences at 25% volume with an average of approximately 15% less dose than 3D-CRT conformal. Smaller differences of an average of 13% and 10% less dose were found for 50% and 10% of the total volume, respectively.

For near-maximum doses (2%) in the rectum and bladder no major differences were found (<2% total dose). Results showed greater sparing at 25% and 50% of the bladder with an average of 10% and 13% less dose (Table II; Graph II).

An average of 10% sparing with RapidArc was also observed at 10% volume of the penis (Table VI).

RapidArc had better results in the small intestine, but significant differences (5%-6%) were only found when compared with 3D-CRT Box technique (Table III; Graph III).

Results showed a slight increase in the dose (6-7%) received at 33% volume of the body for RapidArc plans (Table V).

RECTUM		
VOLUME	3D-CRT: BOX DIF.	3D-CRT: CONF DIF.
2%	-1,3%	-1,2%
10%	-9,4%	-9,8%
25%	-16,9%	-15,3%
50%	-13,2%	-13,6%

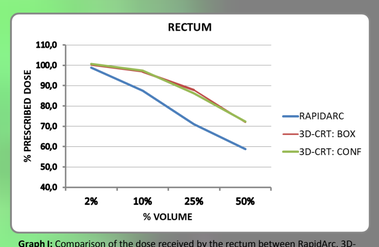
Table I: Dose difference between RapidArc and 3D-CRT tecniques received by the rectum.

BLADDER		
VOLUME	3D-CRT: BOX DIF.	3D-CRT: CONF DIF.
2%	-0,8%	-0,9%
10%	-5,8%	-4,5%
25%	-12,0%	-10,3%
50%	-16,8%	-13,2%

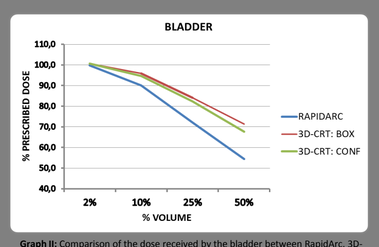
Table II: Dose difference between RapidArc and 3D-CRT tecniques received by the bladder.

SMALL INTESTINE		
VOLUME	3D-CRT: BOX DIF.	3D-CRT: CONF DIF.
2%	-5,1%	-2,2%
10%	-5,8%	-3,0%
25%	-3,7%	-3,4%
50%	-2,8%	-1,7%

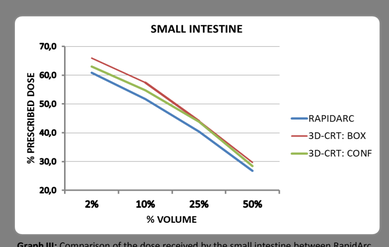
Table III: Dose difference between RapidArc and 3D-CRT tecniques received by the small intestine.



Graph I: Comparison of the dose received by the rectum between RapidArc, 3D-CRT Box and 3D-CRT Conformal techniques



Graph II: Comparison of the dose received by the bladder between RapidArc, 3D-CRT Box and 3D-CRT Conformal techniques.



Graph III: Comparison of the dose received by the small intestine between RapidArc, 3D-CRT Box and 3D-CRT Conformal techniques.

PENIS		
VOLUME	3D-CRT: BOX DIF.	3D-CRT: CONF DIF.
10%	-10,6%	-9,5%

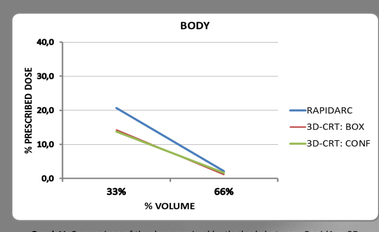
Table VI: Dose difference between RapidArc and 3D-CRT tecniques received by the penis.

BODY		
VOLUME	3D-CRT: BOX DIF.	3D-CRT: CONF DIF.
33%	+6,3%	+6,8%
66%	+1,1%	+0,5%

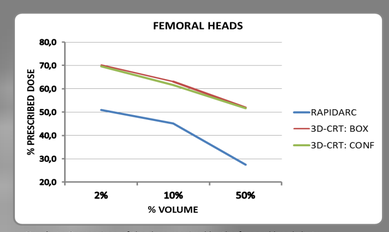
Table V: Dose difference between RapidArc and 3D-CRT tecniques received by the body.

FEMORAL HEADS		
VOLUME	3D-CRT: BOX DIF.	3D-CRT: CONF DIF.
2%	-19,3%	-18,8%
10%	-18,0%	-16,6%
50%	-24,4%	-24,2%

Table IV: Dose difference between RapidArc and 3D-CRT tecniques received by the femoral heads.



Graph V: Comparison of the dose received by the body between RapidArc, 3D-CRT Box and 3D-CRT Conformal techniques.



Graph IV: Comparison of the dose received by the femoral heads between RapidArc, 3D-CRT Box and 3D-CRT Conformal techniques.

Discussion:

The total dose administered in Radiotherapy is often limited by the organs at risk. Better sparing of the OARs could allow dose escalation with greater tumor control probability and reduced acute and late reactions of normal tissues. Although a slight increase on the dose received at 33% of the body volume was reported, the “dose bath” doesn’t appear to be significant. In this sense, VMAT seems to be a powerful tool in Radiotherapy as our results showed a much greater sparing in the critical OARs for prostate cancer irradiation (rectum, bladder and femoral heads). However the planning and validation time for RapidArc should be taken into consideration when considering VMAT treatment techniques. RapidArc plans are far more time consuming than for 3D-CRT and patient quality assurance is also necessary prior to the first treatment.
Due to the variability of the patient’s anatomy and prescribed doses, we are hoping to collect more data to be able to hold statistically stronger results in the future.

Conclusion:

Regarding the evaluation of the organs at risk, results showed that RapidArc plans had a significant better sparing of the femoral heads, rectum and bladder when irradiating the same planning target volumes.

References: 1 - NCCN Guidelines™ Version 4.2011—Prostate Cancer. ; **2 -** PEREZ, C.A. *et al.,* Principles and Practicec of Radiation Therapy, 3rd edition, Lippincott – Raven Publisher, Philadelphia, 1995. ; **3 -** POPPLE, Richard A. *et al*., Rapidarc radiation therapy: first year experience at the university, Radiother Oncol, 2010

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