VMAT Optimization and Dose Calculation in the Presence of Metallic Hip Prostheses

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PURPOSE & OBJECTIVES:

This research quantifies and compares the effect of hip prostheses on dose distributions calculated using Collapsed Cone Convolution Superposition (CCCS) and Monte Carlo (MC) (with and without correcting for the density of the implant and surrounding tissues). The use of full VMAT arcs versus VMAT arcs avoiding the hip implants (i.e. skip arcs) was also studied. We consider this study to be impactful because it demonstrates the need to account for the densities of metallic hip prostheses and the surrounding tissues when planning for prostate cancer patients. Additionally, the findings of this study show that full VMAT arcs can be used to spare dose to surrounding organs at risk (OAR) such as the rectum and bladder with only a small decrease in PTV coverage, instead of the traditionally used skip arcs that avoid projecting the beam through the prostheses.

MATERIALS & METHODS:

Ion chamber measurements were taken to test the ability of the algorithms in each TPS to calculate dose near high-Z materials. The chamber was placed in solid water at isocenter beneath various metal sheets and the dose was compared to the doses calculated in the two TPS (using correct density information). Six prostate patients with hip prostheses were studied. The hip prostheses and the streaking artifacts on the CT images were contoured. Two plans were created in Pinnacle[3]: one using full VMAT arcs and one using VMAT skip arcs. Copies of these plans were made, and the doses were recalculated with the densities of the prostheses and surrounding tissues overridden (5 g/cc and 1 g/cc, respectively). The plans were then exported to Monaco and recalculated using a Monte Carlo dose calculation algorithm.

RESULTS:

For the ion chamber measurements, when correct density information was used, Monaco was within 3% whereas Pinnacle[3] varied up to 7%. Table I displays a summary of ion chamber measurements for regions near various metals. Figure 1 shows how dose distributions changed in Monaco (with correct density information when using skip arcs versus full arcs. This patient experienced only a small change in PTV dose while OAR (particularly the bladder) were significantly spared. Plans calculated with CCCS with correct density information showed reasonable agreement (within +/- 1.4%) with MC calculations. Table II displays an overview of percentage difference in mean dose for ROI with and without density overrides. Figure 3 displays dose volume histograms for full arcs and skip arcs in both TPS when density overrides were used. Doses to OAR (particularly the bladder) were significantly decreased when full arc VMAT plans were used instead of skip arc VMAT plans. For full arc plans, there was some difference in Pinnacle[3] when plans were recalculated using correct density information. Overall, when correct density information was used, Pinnacle showed reasonable agreement with Monaco.

CONCLUSIONS:

When planning for prostate patients with hip prostheses, correct density information for implants and surrounding tissues should be used to optimize the plan and ensure optimal accuracy. Full arcs could be used to spare dose to OAR (i.e. bladder, rectum), while maintaining adequate PTV coverage, when using a model-based or MC dose calculation.

	Measured Value	Pinnacle (No Overrides)	Pinnacle (W/ Overrides)	Monaco (No Overrides)	Monaco (W/ Overrides)
Aluminum	410.0 cGy	393.8 cGy	393.8 cGy	394.1 cGy	403.2 cGy
	% Error	4.0%	4.0%	3.9%	1.7%
	Measured Value	**Pinnacle (No Overrides)**	**Pinnacle (W/ Overrides)**	**Monaco (No Overrides)**	**Monaco (W/ Overrides)**
Zinc	430.6 cGy	393.5 cGy	400.2 cGy	388.6 cGy	420.9 cGy
	% Error	8.6%	7.1%	9.8%	2.3%
	Measured Value	**Pinnacle (No Overrides)**	**Pinnacle (W/ Overrides)**	**Monaco (No Overrides)**	**Monaco (W/ Overrides)**
Steel	431.5 cGy	393.5 cGy	406.7 cGy	390.5 cGy	418.6 cGy
	% Error	8.8%	5.8%	9.5%	3.0%

Table I. Summary of ion chamber measurements for regions near various metals.

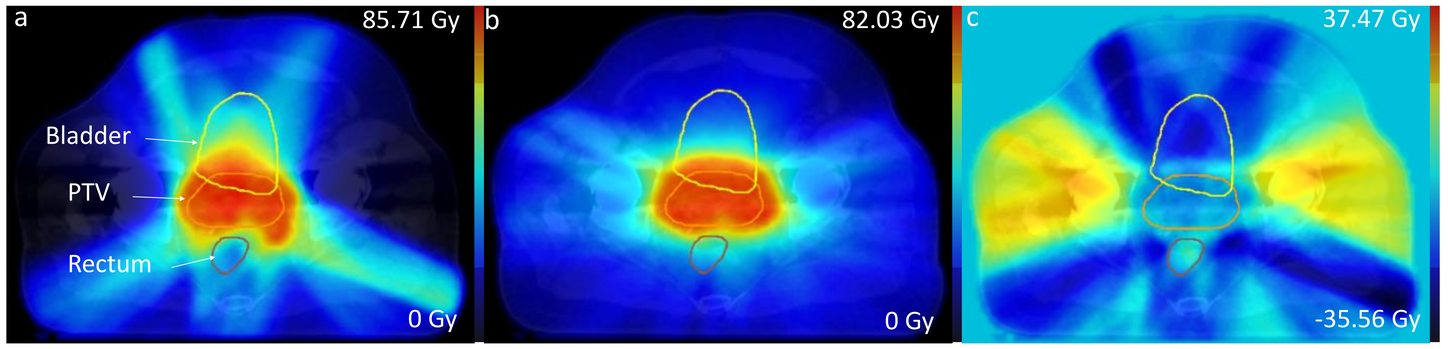

Figure 1. Dose distribution for PTV and OAR (bladder and rectum) for (a) Monaco skip arc plan (with density overrides), (b) Monaco full arc plan (with density overrides), and (c) Monaco skip arc plan dose (a) subtracted from the Monaco full arc plan dose (b).

	Pinnacle Full Arc (no Density Overrides) vs Pinnacle Full Arc (w/ Density Overrides)	Pinnacle Full Arc (w/ Density Overrides vs Monaco Full Arc (w/ Density Overrides)	Pinnacle Skip Arc (no Density Overrides) vs Pinnacle Skip Arc (w/ Density Overrides)	Pinnacle Skip Arc (w/ Density Overrides vs Monaco Skip Arc (w/ Density Overrides)
PTV	-1.88%	-0.21%	-0.18%	1.14%
Bladder	-1.77%	-4.73%	1.19%	-4.23%
Rectum	-1.23%	-2.69%	-0.30%	-2.25%

Table II. Overview of percentage difference in mean dose for ROI with and without density overrides. Negative values indicate a decrease in mean dose from one plan to the next (e.g. the mean dose to the PTV decreased by an average of 1.8% when the correct density information was used).

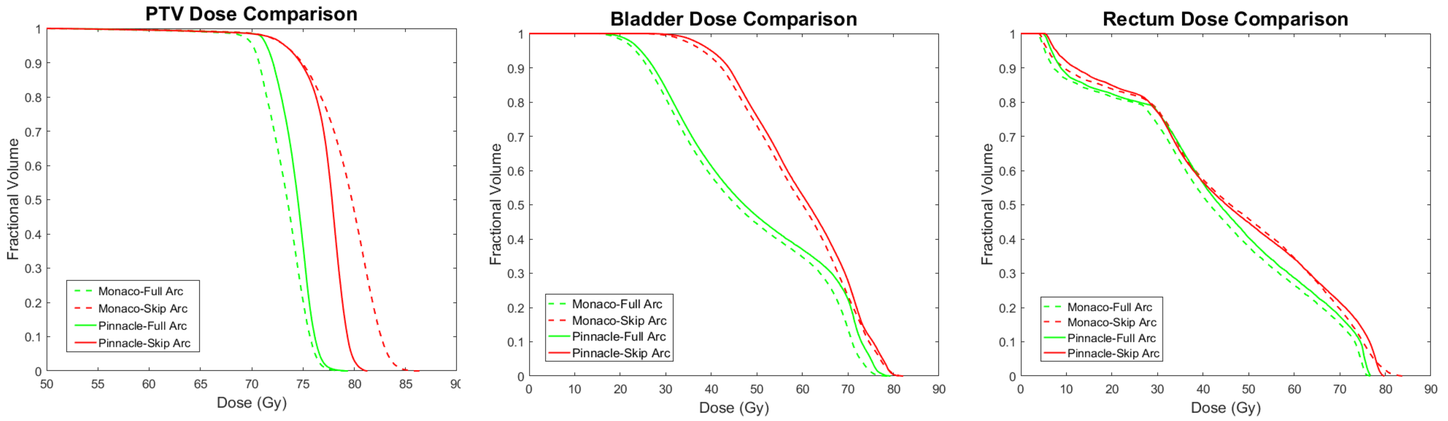

Figure 2. Dose volume histograms for PTV and OAR for full arcs and skip arcs with density overrides applied.

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