Pencil beam scanning versus uniform scanning: Treatment planning for unilateral hip prosthesis prostate cancer

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Abstract

Purpose: The purpose of this study is to compare the dosimetric results between pencil beam scanning (PBS) and uniform scanning proton therapy (USPT) plans for a high-risk prostate cancer case involving a metallic right hip prosthesis. **Methods:** The USPT plans were generated using 3 fields (USPT-3 plan) and 2 fields (USPT-2 plan). In USPT-3 plan, two anterior-oblique beams (left-anterior-oblique (LAO) and right-anterior-oblique (RAO)) and one left lateral (LL) beam, weighted 25%, 25%, and 50%, respectively, were used, whereas in USPT-2 plan, equally weighted LL and LAO fields were used. The PBS plans were generated for a comparative purpose. Specifically, single field optimization (SFO) and multiple field optimization (MFO) intensity modulated proton therapy (IMPT) plans were generated using 2 and 3 fields. The MFO plan with 3 fields (MFO-3) and SFO plan with 3 fields (SFO-3) used the same beam parameters and delivery schema as in the USPT-3 plan. Similarly, MFO plan with 2 fields (MFO-2 plan) and SFO plan with 2 fields (SFO-2F) used the same beam parameters and delivery schema as in the USPT-2 plan. Each proton plan in this study was generated for a total dose of 79.2 Gy(RBE) with a daily dose of 1.8 Gy(RBE). The MFO and SFO plans were optimized for the planning target volume (PTV) using identical dose-volume constraints for the PTV, whereas no dose-volume constraints were applied to the organs at risk (OARs) during plan optimization. **Results:** The mean PTV dose among PBS plans (MFO-3, MFO-2, SFO-3, and SFO-2) was comparable, but the comparison against USPT plans showed that the mean PTV dose in PBS plans was higher by about 0.4 Gy (RBE). The PTV coverage ($V_{100\%}$) was the best in the MFO-3 plan (98.8%) followed by MFO-2 (98.7%), SFO-3 (98.4%), SFO-2 (98.2%), USPT-3 (94.0%), and USPT-2 (92.6%) plans. All four PBS plans produced similar dose homogeneity within the PTV (homogeneity index (HI) = 0.02), which was slightly better compared to the one in USPT plans (HI = 0.03). For both the rectum and bladder, PBS plans produced better dosimetric results when compared to USPT plans. Among four PBS plans, the SFO-3 plan was superior at sparing rectum and bladder in the low-, medium-, and high-dose regions (except for the bladder receiving 10 Gy(RBE)). The mean dose to the bladder was the lowest in the SFO-3 plan and highest in the USPT-3 plan. The rectal mean dose was the lowest in the SFO-3 plan and highest in the USPT-2 plan. The mean femoral head dose ranged from 29.2 to 35.79 Gy(RBE). **Conclusion:** The MFO and SFO plans provided better PTV coverage and reduced the rectal and bladder volume exposed to radiation when compared to USPT plans. Among four PBS plans, the MFO-3 plan provided the best PTV coverage, whereas the SFO-3 plan produced more favorable results for the rectum and bladder. The rectal and bladder dose in the MFO and SFO plans can be further reduced by applying dose-volume constraints to the OARs during plan optimization while maintaining good target coverage.

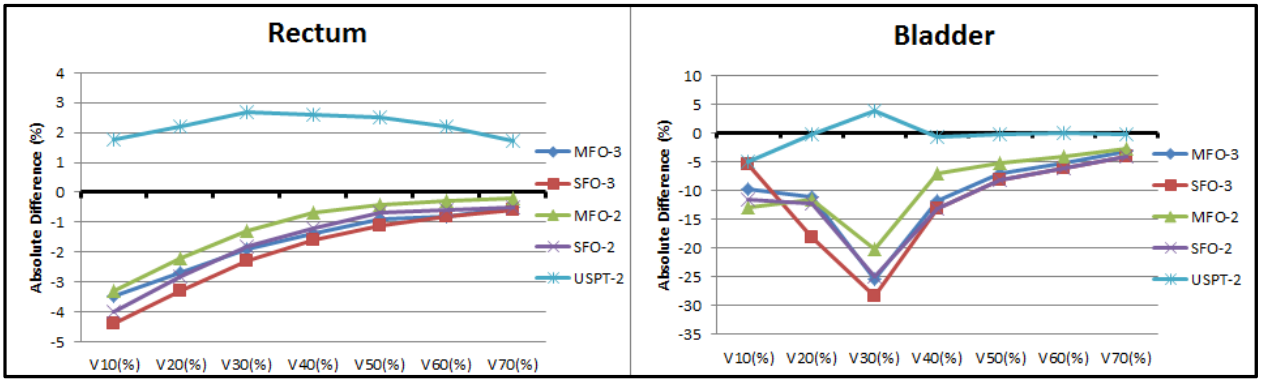

Figure 1: Absolute difference (D) in V_{10} to V_{70} between the reference plan (USPT-3) and other proton plans (MFO-3, MFO-2, SFO-3, SFO-2, and USPT-2). The absolute difference in above figure is calculated as:

D (v_n) = X (v_n) – USPT-3 (v_n); where X = proton plan, and X (v_n) = dosimetric result in a proton plan for a given V_n (e.g., V_{20}, V_{40}, etc.); and USPT-3 (v_n) = dosimetric result of V_n in USPT-3 plan