A Treatment Planning Comparison of Dual-Arc VMAT vs. Helical Tomotherapy for PMRT

Post-mastectomy radiotherapy (PMRT) has historically been treated with a conventional mixed-beam technique that used anterior electron beams to treat the internal mammary nodes (IMN) and medial chest wall (CW), and an oblique electron beam to treat the lateral CW. The supraclavicular (SC) and axillary (AX) nodes were treated with parallel-opposed x-rays. Field abutment issues often resulted in poor dose homogeneity in the planning target volume (PTV). A study by our group demonstrated the ability of helical tomotherapy (HT) to improve dose homogeneity for PMRT\(^1\), and as a result, HT became the standard treatment for PMRT at our clinic. However, there are several shortcomings with this technique, including (1) long treatment delivery times, (2) limited availability of HT technology, (3) sub-optimal contrast of MVCT images, and (4) lack of integration with commercial oncology information systems. As a result, there has been interest in our clinic in examining the potential of volumetric modulated arc therapy (VMAT) for PMRT.

While previous studies\(^2-4\) have shown mixed results when comparing VMAT to HT for other treatment sites, no studies have been published to date comparing the modalities for PMRT. The purpose of this study was to investigate the feasibility of VMAT for PMRT delivery, and to compare it with HT on the basis of dosimetric quality, radiobiological calculations and delivery efficiency.

Dual-arc VMAT and HT treatment plans were generated for a mixture of right and left side CW treatment sites. Eleven of the fifteen patients selected for this study received a unilateral mastectomy, while four received bilateral mastectomies, though all treatment plans were for unilateral treatment sites. The standard practice at our clinic is to deliver PMRT with a 1 cm bolus in order to extend the dose build-up region beyond the surface of the skin. The radiation oncologist’s original PTV was contracted 0.4 cm from the bolus surface in order to avoid any over-correction of intensity modulation in this build-up region. Contouring of organs at risk (OARs) was performed in Pinnacle, and CT image and structure sets were subsequently transferred to Hi-Art. 50.4 Gy was prescribed to the PTV to be delivered in 28 fractions for both modalities. VMAT plans were created using two 220-degree arcs with a final gantry spacing of 4 degrees. The default dose grid of 0.4 cm\(^3\) was used. HT plans were created with a field width of 4.98 cm, a pitch of 0.287 and the “normal” dose grid of 3.91 x 3.91 x 2.5 mm\(^3\). Beamlet optimization mode was used with a modulation factor of 3.0.

Figure 1 shows isodose distributions in the axial slice containing the VMAT beam isocenter for one patient representative of the study. The thick blue isodose line represents the prescription dose, 50.4 Gy, while the green and teal lines represent doses of 5% above and below the prescription respectively. The
VMAT plan contained a fairly large region in the PTV, shown in red, receiving greater than 105% of the prescription, or 52.9 Gy. This was not the case in the HT plan, as the dose distribution within the PTV appears to be more homogeneous. There were very small hot spots (doses greater than 55 Gy) in the lateral portion of the PTV in the VMAT plan and the medial portion of the PTV in the HT plan. However, these volumes did not exceed the planning goal of less than 55 Gy to 1% of the volume, thus were considered clinically insignificant. The distributions showed comparable PTV dose coverage between the two modalities, however, the prescription isodose line in the HT plan extended slightly farther toward the surface of the PTV. Figure 2 contains a dose volume histogram (DVH) of the VMAT (solid lines) and HT (dashed lines) treatment plans for this patient.

In general, VMAT showed significantly better conformity index (CI) than HT (0.778 ± 0.008 vs. 0.719 ± 0.008). Most HT plans contained a region posterior to the lateral portion of the PTV (Figure 1.b) that received the prescription dose or greater. However, HT plans achieved significantly better dose homogeneity index (DHI) than VMAT (0.096 ± 0.005 vs. 0.147 ± 0.009). Dosimetric results outside the PTV were also mixed. VMAT achieved better OAR sparing at lower doses, and lower mean doses to the lungs, heart, contralateral breast and normal tissue. V_{20Gy} in the lungs, the maximum dose to the lungs, and the maximum dose to the heart in left CW patients were all significantly lower in the HT plans. Both modalities achieved nearly 100% tumor control and approximately 1% NTCP in the lungs and heart, but VMAT plans showed significantly lower SCCP in the lungs, contralateral breast and normal tissue. VMAT plans required less time to deliver, with treatment times of 382.4 ± 10.9 s for HT and 128.6 ± 0.6 s for VMAT.

In summary, VMAT is capable of generating clinically acceptable treatment plans for PMRT and achieves better CI and sparing of OARs from lower doses when compared with HT. HT achieves better DHI and coverage of the PTV, but both modalities are capable of nearly 100% tumor control.