Introduction

Previously, both imaging and treatment machines were separate and unique to one another. Today, healthcare providers can perform both tasks on a single machine as Swedish company, Elekta, has pioneered the technology of integrating MRI imaging – instead of KV-imaging – with a linear accelerator, called the MR-Linac (MRL). Elekta commissioned a 1.5T split-coil MRI to ensure quality imaging with a modern 7MV linac; however, the magnet strength in the MRL is lessened where the linac sits. Furthermore, the TPS is established on Elekta’s Monaco program, which utilizes the Monte Carlo Algorithm to calculate dose more precisely.

Usage of MRI in radiation therapy planning (RTP) has been established for various oncology sites, while proven to have a superior advantage over its traditional counterparts. However, clinical use of MRI for RTP is constrained primarily based on geometric distortion and the absence of electron density information. In order to diminish distortion, engineers and physicists used modified sequence parameters and distortion correction algorithms. Moreover, the absence of electron density information is resolved by co-registering MR images to CT images. Nonetheless, there are inherent collimator size limitations and only small shifts that can be accomplished on an MRL.

With focus on GYN cases, the purpose of this research is: to determine which GYN patients/cases can be treated with the MRL, to discuss how the MRL treats tumors; to describe possible solutions to MRL treatment planning and treatment challenges; and to compare MRL to current irradiation techniques and machinery.

Methods & Materials

A set of 46 randomly selected GYN patients, who were previously treated with external beam radiation at MD Anderson Cancer Center (MDACC), was generated to evaluate treatability on the MRL. Three-dimensional (3D) data was collected from the original treatments planned on Pinnacle (Philips, Andover, MA) TPS. The data included Gross Tumor Volumes (GTVs), max GTV dimensions (X, Y, and Z), Planning Target Volumes (PTVs), max PTV dimensions (X, Y, and Z), and max patient circumspheres within or around the treatment region. In determining treatability of GYN cases, the inherent physical limitations of the MRL were applied during assessment, with Y-dimension constraints the most significant limiting factors. Ultimately, patients were deemed treatable if PTV dimensions fit within the inherent constraints of the MRL.

Statistical Analysis

To visualize the difference in treatment planning and systems, five of the treatable cases were re-planned using the Monaco TPS for MRL and was compared to VMAT Pinnacle TPS re-plans for Varian Linacs. Dose Volume Histogram (DVH), isodose line distribution, calculation speed, optimization outcomes, and the overall treatment was contrasted for the comparison.

Results

| TABLE 1. NON-ALIGNMENT OF TREATMENT (CT) SYSTEMS FOR MRL AND Pinnacle *Treatability: GTV volume ≤ 165 cc; GTV Z-dimension ≤ 11 cm; GTV Y-dimension ≤ 11 cm; GTV X-dimension ≤ 8 cm; PTV Z-dimension ≤ 12 cm; PTV Y-dimension ≤ 11 cm; PTV X-dimension ≤ 8 cm; PTV volume ≤ 775 cc; PTV X-dimension ≤ 8 cm; GTV Z-dimension ≤ 8 cm; GTV X-dimension ≤ 7 cm; PTV volume ≤ 775 cc; PTV X-dimension ≤ 15 cm; PTV Y-dimension ≤ 14 cm and (Y_PTV < 10 cm); PTV Z-dimension ≤ 12 cm; axial-circumference ≤ 135 cm, and no periaortic lymph node involvement. |  |

| TABLE 2. Comparison of Treated Patient Dimensions of GTV’s & PTV’s for Varian Linacs vs. MRL |  |

| TABLE 3. Comparison of Dose Treatment Planning of MRL vs. Non-Treatable GYN Patient Using an Independent Treatment Planning System |  |

Conclusions

Due to MRL’s Y-dimension Field Size (FS) limitations (Y_PTV ≤11cm; Y_PTV ≤8cm; Y_Total ≤22cm), 74% of the GYN cases did not meet the standard treatment constraints of the MRL. Statistical analysis determined PTV volume and PTV 3D measurements determined treatability, with Y-dimension size the major source. The 34 non-treatable patient PTV Y-dimensions delineated a standard mean of 25.4 ± 1.29 cm at 95% confidence compared to the 12 treatable patient PTV Y-dimensions delineating at 12 ± 2.09 cm. Analytics also confirmed maximum patient circumference is a determining factor of treatability; as circumference increases, treatability, on average, decreases. Moreover, the comparison revealed qualitative equivalence of treatment plans generated in Monaco for MRL treatment and in Pinnacle for conventional linac treatment. MRL planning is equally conformal to VMAT.

The ideal GYN candidate to be treated on the MRL should fall within the following estimated constraints, with approximately 95% confidence of treatability: GTV volume ≤ 165 cc; GTV X-dimension ≤ 7 cm; GTV Y-dimension ≤ 8 cm; GTV Z-dimension ≤ 8 cm; PTV volume ≤ 775 cc; PTV X-dimension ≤ 15 cm; PTV Y-dimension ≤ 14 cm and (Y_PTV ≤ 10 cm); PTV Z-dimension ≤ 12 cm; axial-circumference ≤ 135 cm, and no periaortic lymph node involvement.

In conclusion, the MRL showcases assurance in not only maintaining quality of treatment but also revolutionizing radiation therapy.

References