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Dosimetric Evaluation of an MR Linac System Compared to Multiple Stereotactic Radiotherapy Delivery Systems for Large Brain Metastases

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Abstract
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Abstract

A new brain treatment package consisting of a dedicated head coil with an integrated stereotactic brain immobilization system was recently released for the ViewRay® MRIdianTM system. This, coupled with high-resolution volumetric MR imaging, enables treatment of intracranial lesions using a stereotactic technique. This work aims to compare the dosimetric performance of MR-guided Linac (MRL) treatment plans against established stereotactic delivery platforms, specifically Gamma Knife® (GK), CyberKnife® (CK) and Volumetric Modulated Arc Therapy (VMAT), for intracranial metastases.

Methods:

Ten (n=10) consecutive patients with large intact brain metastases who were previously treated on GK with no setup margin were re-planned using CK, VMAT, and MRL intensity-modulated radiation therapy (IMRT) to 27 Gy in 3 fractions. Plans were created for CK, VMAT, and MRL modalities with a setup margin of 1 mm added to the GTV. Plans across all modalities were optimized to not exceed OAR dose constraints and achieve a minimum target coverage (TC) of ⩾ 99.5% while maximizing Paddick Conformity Index (PCI) and minimizing beam-on time (BOT) and Gradient Index (GI) in this specified order of importance. Plan quality metrics and delivery parameters between GK, CK, & VMAT and MRL were compared for all patients. Wilcoxon signed rank test ($p< 0.05$) was used to establish statistical significance.

Results:

Average largest linear dimension and volumes of GTVs were 2.9+ 0.5 cm and 10.4 + 6.3 cc, respectively. MRL plans were developed with 39 to 41 beams arranged in a pseudo-arc geometry with a total of 120-180 segments. All MRL plans satisfied clinical goals with a median PCI of 0.94+0.03, median GI of 3.5+0.22 and average mean brain dose of 1.9 ± 0.9 Gy. Max dose within the target ranged from 34.3 to 44.3 Gy. PCIs of MRL plans were better as compared to GK (1.1%; 0.94±0.03 vs. 0.93±0.03; $p< 0.01$) and CK (2.8%; 0.91+0.06; $p< 0.05$) and worse than VMAT plans (-2.4%; 0.94±0.03 vs. 0.96+0.02; $p< 0.05$). GIs of MRL plans were worse than GK, CK and VMAT plans (3.5±0.22 vs. 2.5±0.07, 2.8±0.42, 2.6+0.35, $p< 0.05$). Normal brain receiving V20Gy with MRL was significantly higher compared to GK and VMAT plans (14.7±11.9cc vs. 10.4±9.6cc, 13.2+10.9cc, $p< 0.05$). Normal brain receiving V12Gy with MRL was also significantly higher as compared to GK, CK and VMAT plans (34.5±29.5 cc vs. 19.1±17.9cc, 28.9+19.1cc, 25.9+20.7cc, $p< 0.05$). Median MRL BOT was significantly lower than GK and CK (BOT: 5.8±1.4 min vs. 33.9±4.1 min@2.5Gy/min, 23.5+3.5cc $p< 0.05$) and was significantly higher than VMAT (BOT: 5.8±1.4 min vs. 3.5±0.8 min, $p< 0.05$). Maximum dose (D0.03cc) received by brainstem and chiasm in MRL plans was not statistically significantly different to GK, CK and VMAT plans.

Conclusion(s):

Cranial SRT plans using MRL IMRT is comparable to established stereotactic delivery modalities while providing daily, high contrast and real-time imaging. Due to the fixed coplanar beam arrangements of MRL plans as compared to non-coplanar beams of other modalities, the GI is statistically significantly inferior, but within acceptable clinical goals.