ISSN: 2577-2996

PROGRESS IN MEDICAL SCIENCES, 2024
VOL 8, NO. 4, PAGE 1 – 3
DOI: doi.org/10.47363/PMS/2024(8)230

REVIEW ARTICLE

Open Access

RapidArc Planning for Stereotactic Body Radiation Therapy (SBRT) of Liver: An Institutional Experience

Priya Jacob* and Alex Antony

USA

ABSTRACT

The study aims institutional experience with liver SBRT planning and evaluate the plan quality through dosimetric parameters. Thirty patients who had undergone liver SBRT treatment in our Clinic were chosen retrospectively for the study. RapidArc plans with, non-coplanar beam arrangement generated in Eclipse (16.1v) planning system for Varian TrueBeam Linac using 6MV and 6MV FFF photon. The NC- RapidArc plans were created by two to four arcs which includes non-coplanar partial arcs with couch rotation of ±20° to± 15° had an arc span of 130° to 160° and coplanar 360° full arc. Plans were analysed with various dosimetric and technical parameters. The dosimetric parameters for PTV coverage were PTV100% 94.1±2.5 and PTV95% 97.4±1.2. The Conformality Index (CI) of all plans was 0.898±0.104 on average, and the Gradient Index (GI) for non-coplanar plans was 4.315±1.214 on average. The dose-volumetric parameters for OARs are also within the acceptable consraints. The average dose to 1 cm³ (D1cc) of the spine was 465±114cGy, and that of the left kidney, 352±217cGy. The average volume of normal tissue that received a low-dose spillage of 15Gy was 820±174cc. Technically, the average monitor units (MU) for non-coplanar RapidArc plans were 2525. 2±452.The plan quality of NC- RapidArc plans was acceptable based on RTOG 1112 and QUANTEC guidelines.

ARTICLE HISTORY

Received August 03, 2024
Accepted August 14, 2024
Published August 19, 2024

KEYWORDS

SBRT- Liver Cancer, Hepatocellular Carcinoma (HCC) and Cholangiocarcinoma, Non-Coplanar RapidArc

Introduction

Liver cancer remains a formidable global health problem, ranking among the leading cancer-related causes of mortality [1]. The two prevalent types of liver cancer, hepatocellular carcinoma (HCC) and cholangiocarcinoma, are serious treatment challenges, particularly for patients who are not candidates for surgery [2-4]. While liver transplantation and surgical resection offer high survival rates, they are not available to all patients due to high recurrence and other medical comorbidities.

For those who cannot undergo surgery, Stereotactic Body Radiotherapy (SBRT) is a powerful alternative that with great accuracy delivers ultra-high doses of radiation to tumors directly and avoids nearby normal tissue [5-7]. Even more precision is made possible by the evolution of image-guidance technology and breath-holding methods, which minimize the effects of organ motion on treatment.

More recent advances in SBRT, particularly with the use of Volumetric-Modulated Arc Therapy (VMAT) and RapidArc with Flattening Filter Free (FFF) photon beams, have shown great promise. They offer highly conformal dose distributions and have minimized treatment times compared to the older modalities like Intensity-Modulated Radiation Therapy (IMRT) and 3D Conformal Radiation Therapy (3D-CRT).

Our study examines the institutional experience with liver SBRT planning, with a specific focus on the non-coplanar (NC) RapidArc plans [8,9]. By analyzing dosimetric parameters in addition to technical parameters, we aim to highlight the advantages of NC-RapidArc plans in reducing spine dose, decreasing low-dose spillage into normal tissues, and optimizing monitor unit (MU) efficiency. This research points to the potential of NC-RapidArc in enhancing the treatment outcomes of liver cancer patients, offering these patients a glimmer of hope in their battle with this aggressive disease.

Materials and Methods

Patient Selection and Imaging: A total of 30 patients with liver cancer who received RapidArc SBRT treatment at our clinic from 2022 to 2024 were included in this retrospective study. All patients were immobilized with a vac-lock system, supported by an Abdominal Compression Plate and Pressure Belt for reproducible positioning. Planning CT images, 1.5mm slice thickness, were acquired on the GE Discovery RT Big Bore CT scanner during free breathing and slow CT scanning. The images were exported to the Eclipse Treatment Planning System (TPS) (Version 16.1) for target volume delineation and organ-at-risk (OAR). Contrast-enhanced CT, MRI, and PET scans were registered to accurately outline the ITV and PTV with 2-4mm margins from the ITV. Significant OARs,

Contact: Priya Jacob*, Alex Antony

including the spinal cord, Esophagus, duodenum, stomach, normal liver, and kidneys, were outlined with care.

Treatment Planning: Plans for RapidArc SBRT5,6 were produced with combinations of non-coplanar and coplanar beam arrangements, either 6MV flattening-filter-free (FFF) or 6MV flattened photon energy from Varian TrueBeam Linear Accelerator with HD 120 Multi-Leaf Collimator (MLC). The plans comprised 2-4 arcs, including full 360° arcs or partial arcs spanning 120° to 160°, with couch angles ranging from ±15° to ±20°. These angles were chosen carefully to avoid gantry-couch collisions, verified through dry runs before preparing the plans. The isocenter was positioned at the PTV center, and the collimator angle was at zero degrees. The primary planning objective was to achieve 100% prescription dose coverage for 95% of the PTV (PTV100% RX=100%) and to achieve 95% of the PTV covered with 95% of the prescribed dose (PTV95% RX=95%). Safe hot spots of 120%-130% of the planned dose were allowed in the Gross Tumor Volume (GTV) to allow for dose heterogeneity. Dose constraints were put on the liver-GTV (mean dose 15Gy, V10Gy <70%), spinal cord (D1cc 11Gy), bilateral kidneys (mean dose 10Gy), and chest wall (D0.5cc 40Gy), based on RTOG 1112 and QUANTEC guidelines. Plan optimization was performed using the AAA algorithm with a calculation grid of 2mm in Eclipse TPS, iterating to various priorities to achieve an optimal plan.

Plan Evaluation: The monitor units were acquired for each plan. All plans were evaluated by comparing the Dose Volume Histogram (DVH) metrics of PTV coverage and OARs. The dosimetric parameters of PTV coverage selected for comparison were PTV100% and PTV95%. V95% (Volume receiving 95% of P.D), V50% (Volume receiving 50% of P.D), and PTV volume were used for calculating the conformality index (CI) and Gradient Index (GI) as follows.

CI =VPI/PTV Volume, Where VPI is Volume receiving prescription isodose.

GI = 50% Prescription Isodose Volume/ Prescription isodose volume.

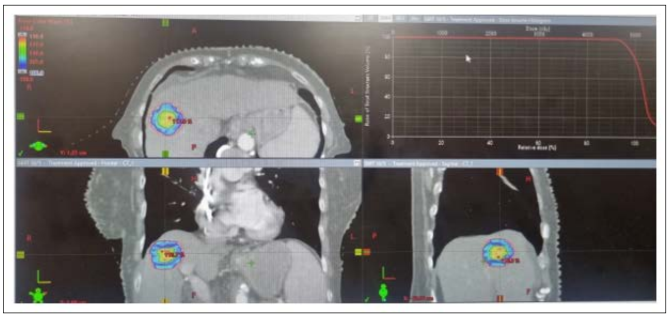

Figure 1: The Isodose Distribution and Target DVH Assessment for a Sample Patient Plan

Patient-Specific Quality Assurance: Point dosimetry with a pinpoint chamber (PTW, Germany) in a slab phantom was carried out as patient-specific quality assurance (PSQA) for RapidArc SBRT plans. The variation from TPS-generated QA plans was less than 3%. Portal dosimetry for gamma analysis (2%, 2mm criteria with a 10% threshold) was also carried out to demonstrate treatment delivery accuracy.

Statistical Analysis: Descriptive statistics including mean and standard deviation (SD) were calculated for all the dosimetric parameters in all RapidArc plans.

Results and Discussion

The isodose distribution and target Dose Volume Histogram (DVH) analysis of all RapidArc SBRT plans, prescription dose 50Gy in 5 fractions were evaluated. Figure.1shows the isodose distribution and target DVH assessment for a sample patient plan .The dosimetric parameters for PTV coverage were PTV100% 94.1±2.5 and PTV95% 97.4±1.2. The Conformality Index (CI) of all plans was 0.898±0.104 on average, and the Gradient Index (GI) for non-coplanar plans was 4.315±1.214 on average. The dose-volumetric parameters for OARs are given in Table 1. The average dose to 1 cm^3 (D1cc) of the spine was 465±114cGy, and that of the left kidney, 352±217cGy. The average volume of normal tissue that received a low-dose spillage of 15Gy was 820±174cc. Technically, the average monitor units (MU) for non-coplanar RapidArc plans were 2525.2±452.

Hypo-fractionated SBRT delivers ultra-high fractional doses in a small number of sessions, with a high biologically effective dose (BED), primarily for liver and lung treatments. With the organ movement at these sites, high-precision treatment is extremely crucial, which can be achieved with newer linear accelerators equipped with image-guided radiotherapy capabilities. In liver SBRT, conformal treatment delivery reduces the volume of normal liver tissue irradiated and hence radiation-induced liver diseases.

Due to the off-centered location of liver lesions, literature has often recommended non-coplanar IMRT fields for high dose conformality and improved organ sparing. Over the past decades, RapidArc/VMAT has achieved a huge advancement in radiotherapy, and studies have advocated RapidArc using FFF photons for time efficiency. Most of the LINAC-based dosimetric comparison studies on non-coplanar RapidArc plans for liver SBRT utilize computer-optimized beam directions with multiple beams and photon energies of 6MV or higher, which complicate planning and delivery [10-12].

In this study, we analysed manually selected non-coplanar partial arc RapidArc in hypo-fractionated liver SBRT using 6MV FFF and 6MV photons [13]. The novelty is the application of simpler ipsilateral NC-RapidArc partial arcs based on BEV to avoid gantry and couch collisions. We evaluated several dosimetric and technical parameters to ascertain plan quality. The PTV coverage and OAR sparing were similar to previous studies. We also recorded the technical parameter of monitor units delivered and verified the PSQA results.

Table 1: Dosimetric Parameters

Dosimetric Parameter	Mean ± SD
MU	2525.2±452
Liver-GTV Mean Dse(cGy)	727±325
Esophagus D0.5cc(cGy)	685.9±122
Stomach D1cc(cGy)	1293.84±425
DuodenumD0.5cc(cGy)	1278.84±543
RT Kidney Mean Dose(cGy)	250±180
LT Kidney Mean Dose(cGy)	185±112
RT Kidney D1CC(cGy)	758±531
LT Kidney D1CC(cGy)	352±217
Heart D30cc(cGy)	565±316
Liver 15Gy Spare Volume(cm3)	820±174
SPINAL CORD D1cc(cGy)	465±114
PTV100%	94.1±2.5
PTV95%	97.4±1.2
Conformity Index(CI)	0.898±0.104
Gradient Index(GI)	4.315±1.214

Although non-coplanar arc treatment planning increases complexity, potential setup errors, collision risks, and treatment time, the application of a limited number of non-coplanar arcs can be favourable over coplanar arcs when clinically indicated.

The NC-RapidArc plan, using two to three manually selected ipsilateral partial arcs for liver SBRT, streamlined planning without sacrificing target coverage and OAR sparing. The approach is an acceptable alternative to traditional coplanar arcs, balancing efficacy and practicality in liver SBRT planning.

Conclusion

This study underscores the transformative potential of non-coplanar RapidArc (NC-RapidArc) planning in the realm of liver SBRT. By leveraging manually selected ipsilateral partial arcs, we demonstrated that NC-RapidArc plans not only simplify the planning process but also deliver comparable, if not superior, dosimetric outcomes compared to traditional coplanar VMAT plans. Our findings highlight significant reductions in spine dose, low-dose spillage to healthy tissues, and monitor unit (MU) requirements, all while maintaining robust target coverage and organ-at-risk (OAR) sparing.

The integration of advanced imaging techniques and precise beam arrangements has enabled us to push the boundaries of what is achievable in liver SBRT, offering a beacon of hope for patients who are ineligible for surgical interventions. This approach mitigates the complexities and risks associated with non-coplanar beam arrangements, making high-precision radiotherapy more accessible and efficient.

In conclusion, the NC-RapidArc technique represents a significant advancement in liver SBRT, providing a balanced solution that enhances treatment efficacy while reducing planning and delivery challenges. This study paves the way for broader adoption of NC-RapidArc in clinical practice, promising improved outcomes and quality of life for liver cancer patients worldwide.

References

[1] SH Sung, J Ferlay, RL Siegel, M Laversanne, I Soerjomataram, et al. Global cancer statistics 2020: Globocan estimates of incidence and mortality worldwide for 36 cancers in 185 countries. CA Cancer J Clin. 2021; 71: 209-249.

[2] PR Galle, A Forner, JM Llovet, V Mazzaferro, F Piscaglia, et al. EASL clinical practice guidelines: Management of hepatocellular carcinoma. J Hepatol. 2018; 69: 182-236.

[3] SG Delis, C Dervenis. Selection criteria for liver resection in patients with hepatocellular carcinoma and chronic liver disease. World J Gastroenterol. 2008; 14: 3452-3460.

[4] RA Burkhart, TM Pawlik. Staging and prognostic models for hepatocellular carcinoma and intrahepatic cholangiocarcinoma. Cancer Control. 2017; 24: 1073274817729235.

[5] H Blomgren, I Lax, I Näslund, R Svanström. Stereotactic high dose fraction radiation therapy of extracranial tumors using an accelerator, clinical experience of the first thirty-one patients, Acta Oncol. 1995; 34: 861-870.

[6] J Lee, IS Shin, WS Yoon, WS Koom, CH Rim. Comparisons between radiofrequency ablation and stereotactic body radiotherapy for liver malignancies: Meta-analyses and a systematic review. Radiother Oncol. 2020; 145: 63-70.

[7] WI Jang, SH Bae, MS Kim, CJ Han, SC Park, et al. A phase 2 multicenter study of stereotactic body radiotherapy for hepatocellular carcinoma: Safety and efficacy. Cancer. 2020; 126: 363-372.

[8] EYW Cheung, KHY Lee, WTL Lau, APY Lau, PY Wat. Non-coplanar VMAT plans for postoperative primary brain tumour to reduce dose to hippocampus, temporal lobe and cochlea: A planning study. BJR Open. 2021; 3: 20210009.

[9] M Teoh, CH Clark, K Wood, S Whitaker, A Nisbet. Volumetric modulated arc therapy: A review of current literature and clinical use in practice. Br J Radiol. 2011; 84: 967-996.

[10] PM Wang, WC Hsu, NN Chung, FL Chang, CJ Jang, et al. Feasibility of stereotactic body radiation therapy with volumetric modulated arc therapy and high intensity photon beams for hepatocellular carcinoma patients. Radiat Oncol. 2014; 9: 18.

[11] P Dong, P Lee, D Ruan, T Long, E Romeijn, et al. 4π non-coplanar liver SBRT: A novel delivery technique. Int J Radiat Oncol Biol Phys. 2013; 85: 1360-1366.

[12] EYW Cheung, KHY Lee, WTL Lau, APY Lau, PY Wat. Non-coplanar VMAT plans for postoperative primary brain tumour to reduce dose to hippocampus, temporal lobe and cochlea: A planning study. BJR Open. 2021; 3: 20210009.

[13] Nisha A, Shambhavi C, Nagesh J, Nair SS. Comparison between Volumetric Modulated arc Therapy based Coplanar and Noncoplanar Planning for Stereotactic Body Radiation Therapy of Liver. Asian Pac J Cancer Prev. 2024; 25: 1383-1390.