Cureus

Identification of Cases Eligible for Dynamic Conformal Arc Therapy (DCAT) in Lung Stereotactic Body Radiotherapy Based on Dosimetric Analysis in Comparison with Volumetric Arc Therapy (VMAT)

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Abstract
Published 03/04/2026

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Categories: Radiation Oncology
Keywords: dynamic conformal arc therapy, lung stereotactic body radiotherapy

How to cite this abstract
Alqurashi T, Wang I (March 04, 2026) Identification of Cases Eligible for Dynamic Conformal Arc Therapy (DCAT) in Lung Stereotactic Body Radiotherapy Based on Dosimetric Analysis in Comparison with Volumetric Arc Therapy (VMAT). Cureus 18(3): a1634

Abstract

Objectives: Stereotactic body radiotherapy (SBRT) techniques provide high conformity to the tumor target and sharp dose falloffs to spare healthy tissue. Arc-based techniques such as Volumetric Arc Therapy (VMAT) and Dynamic Conformal Arc Therapy (DCAT) are commonly used but have their own pros and cons. VMAT utilizes inverse-planning optimization algorithms to generate a treatment plan that meets the preset dose constraints. However, the interplay between MLC motion and target movement can result in localized overdosage or underdosage of both the target and surrounding healthy tissue. DCAT utilizes forward-planning techniques to fit the beam aperture to conform to the target shape. Compared with VMAT, DCAT can potentially reduce the total number of MUs and thus improve the treatment efficiency with minimal interplay errors. This study evaluates the dosimetric equivalence of DCAT versus VMAT for early-stage NSCLC to help identify appropriate patient selection criteria for DCAT-based versus VMAT-based lung SBRT.

Methods: The hypothesis is small peripheral tumors are likely suitable for DCAT; thus, patient selection in this study is limited to patients with the largest tumor size of 11 cc ITV. Fifty single-fraction (34 Gy) SBRT treatment plans using the VMAT technique for early-stage NSCLC were retrospectively replanned in the Eclipse Treatment Planning System using DCAT. Comparison of dosimetric metrics between the two techniques were analyzed, which included conformity index (CI), geometric measure (GM), %V5Gy, %V10Gy, and %V20Gy to the lungs, and D0.035cc to the spinal cord, heart and ribs, respectively. Total number of MUs per plan were also compared between VMAT and DCAT plans. In addition, subgroup analyses were performed according to the tumor sizes (0 to 2 cc, >2 to < 5 cc, >5 cc) and laterality (left or right). Statistical significance was defined as $p < 0.05$ using paired T-test, with non-significant results ($p \geqslant 0.05$) indicating clinical equivalence between the two techniques.

Results: CI and GM differences were non-significant across all subgroups. Lung %V5Gy and %V10Gy also showed equivalence between VMAT and DCAT among all subgroups. However, Lung %V20Gy were not comparable between VMAT and DCAT for subgroup >5cc including both literalities and for the left lung subgroup >2 to < 5cc. The D0.035cc to the spinal cord, heart, and ribs were comparable between DCAT and VMAT in all groups as well. Overall, DCAT achieved conformity and organ-at-risk sparing comparable to VMAT for small peripheral early-stage NSCLC tumors (up to 11 cc). A substantial reduction in MU of on average 41.4% (mean diff= 4692 MU; p value= 0.00) was observed for all DCAT plans compared to VMAT.

Conclusion(s): Collectively, these results support our hypothesis that small peripheral tumors are optimal candidates for DCAT, justifying further validation and creation of practical selection criteria. For the group of patients studied, VMAT and DCAT exhibited statistically equivalent dosimetry and most OAR parameters, supporting the feasibility of DCAT as a simplified SBRT delivery method in appropriate cases. These findings provide a foundation for developing a nomogram that integrates dosimetric and anatomical predictors to identify patients most likely to benefit from DCAT, offering a practical framework to deliver high-quality and resource-efficient SBRT.