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Target Definition for Stereotactic Irradiation of Perirenal Lymph Node Metastases: The Impact of Multimodality Imaging

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Abstract

Objective: Accurate target delineation is critical for the success of stereotactic body radiotherapy (SBRT), especially in anatomically complex regions such as the retroperitoneum. This study evaluates the role of multimodal imaging-specifically magnetic resonance imaging (MRI) co-registered with computed tomography (CT)-in refining target volume definition for SBRT in patients with perirenal lymph node metastases.

Materials and Methods: Patients with isolated perirenal lymph node recurrence from malignancies were included. All patients were candidates for SBRT based on oligometastatic status and adequate performance (ECOG 0–2). CT-based simulation was performed with customized immobilization, followed by acquisition of Magnetic Resonance Imaging (MRI) sequences. Initial target definition was based on CT-simulation images alone and was later refined with MRI input.

Results: MRI refinement altered target definition in majority of cases. CT-based delineation commonly overestimated volume by including adjacent renal vessels, ureters, or fibrotic tissue, or underestimated disease extent masked by bowel or post-surgical changes. MRI-guided contours provided sharper nodal margins, enhancing dose conformity and steepening fall-off gradients.

Conclusion: MRI-augmented target delineation improves contouring accuracy and dosimetric quality in SBRT for perirenal lymph node metastases. Incorporating MRI into planning may be particularly valuable for lesions adjacent to radio-sensitive structures. Further studies are warranted to assess long-term outcomes and validate clinical benefit.

Keywords: Perirenal Lymph Nodes; SBRT; CT-MRI Fusion; Target Delineation

Abbreviations: SCLC: Small Cell Lung Cancer; IMRT: Intensity-Modulated Radiotherapy; stereotactic techniques, ART: Adaptive Radiotherapy; CT: Computed Tomography; MRI: Magnetic Resonance Imaging; AAPM: Association of Physicists in Medicine; ICRU: International Commission on Radiation Units and Measurements; HU: Hounsfield Units

Introduction

Perirenal lymph node metastases represent a relatively rare but clinically significant pattern of spread in malignancies. Their proximity to critical retroperitoneal structures, including the kidneys, ureters, adrenal glands, duodenum, and major vessels-poses a major challenge for local therapies such as stereotactic body radiotherapy (SBRT). In the era of precision oncology and management of oligometastatic disease, SBRT has emerged as a viable modality offering high-dose, conformal, image-guided treatment with potential for durable local control and minimal toxicity [1-7]. However, the success of SBRT relies heavily on accurate target definition, especially in anatomically complex and motion-sensitive regions such as the perirenal space.

Traditional CT-based planning frequently lacks the soft tissue contrast necessary to distinguish lymph nodes from adjacent vasculature or fibrotic tissue, increasing the risk of geographic miss or unnecessary irradiation of non-target tissue. Magnetic resonance imaging (MRI), with its superior soft tissue resolution, can significantly enhance target definition by improving the visualization of lymph node margins, surrounding bowel loops, renal vasculature, and postoperative changes. While MRI has shown utility in pelvic and abdominal SBRT planning, its specific role in the retroperitoneal/perirenal region remains underexplored. This study evaluates the impact of MRI on target volume delineation and treatment planning in patients undergoing SBRT for perirenal lymph node metastases.

Materials and Methods

This study was conducted in the Department of Radiation Oncology at the University of Health Sciences, Gulhane Medical Faculty. Patients with histologically or radiographically confirmed solitary perirenal lymph node metastases, with or without prior radiation, were studied. Selected patients had controlled primary tumor, oligometastatic disease (≤5 lesions), ECOG performance status 0–2, and suitability for SBRT based on detailed assessment. All patients underwent contrast-enhanced planning CT in the supine position with individualized immobilization. And MRI sequences were also acquired.

MRI and CT datasets were co-registered. Initially target definition was based on CT imaging alone, and the contours were then reviewed and refined based on MRI findings by board certified radiation oncologists, particularly in cases of perivascular involvement or ambiguous nodal margins. SBRT planning was performed on the institutional treatment planning system, and dose prescriptions were individualized based on prior radiation dose, target location, and adjacent OARs. Treatment delivery was performed on LINACs equipped with CBCT for daily IGRT.

Results

All patients in this study had radiographic or histologic confirmation of perirenal lymph node metastases. Eligibility for SBRT required the presence of oligometastatic disease, a controlled primary malignancy, and an Eastern Cooperative Oncology Group (ECOG) performance status of 0–2. Simulation was conducted using contrast-enhanced CT with patients immobilized in the supine position. MRI, including both standard and contrast-enhanced sequences, was acquired and co-registered with CT images to enable multimodal image alignment.

Initial target volumes were delineated using CT alone and subsequently refined with MRI input by experienced radiation oncologists. SBRT treatment plans were created using institutional planning systems and delivered via linear accelerator (LINAC) with daily cone-beam CT for image guidance. Prescriptions were designed to cover at least 95% of the target volume while conforming to organ-at-risk (OAR) constraints as defined by QUANTEC and AAPM guidelines.

MRI-guided contour refinement impacted target delineation in most patients. Over-contouring on CT alone was noted in some cases due to the inadvertent inclusion of renal vasculature, adrenal tissue, or fibrotic bands. Conversely, under-contouring occurred in cases where posterior nodal extension was missed due to bowel gas or suboptimal contrast resolution. Overall, MRI integration led to a reduction in target volumes and improved anatomical accuracy.

Discussion

Perirenal lymph node metastases represent an uncommon yet clinically important pattern of disease dissemination in various malignancies. Their anatomical proximity to critical retroperitoneal structures—including the kidneys, ureters, adrenal glands, duodenum, and major vessels—poses substantial challenges for local treatment approaches such as SBRT. In the era of precision oncology and the evolving management of oligometastatic disease, SBRT has emerged as a promising treatment modality, offering high-dose, conformal, and image-guided therapy with the potential for durable local control and low toxicity [1-7]. However, the effectiveness of SBRT is heavily contingent upon accurate target delineation, especially in anatomically complex and motion-sensitive regions like perirenal space.

Conventional CT-based planning often lacks sufficient soft tissue contrast to reliably differentiate lymph nodes from adjacent vasculature or fibrotic tissue, increasing the risk of either geographic miss or overtreatment of normal structures. MRI, owing to its superior soft tissue resolution, enhances the visualization of nodal margins, surrounding organs, and post-surgical or fibrotic changes. Although MRI has demonstrated value in SBRT planning for pelvic and abdominal tumors, its specific utility in the retroperitoneal and perirenal region remains under-investigated. Our study aimed at assessing the role of MRI in target delineation and treatment planning for patients receiving SBRT for perirenal lymph node metastases and was conducted in the Department of Radiation Oncology at the University of Health Sciences, Gulhane Medical Faculty.

Patients with histologically or radiographically confirmed solitary perirenal lymph node metastases were included. Eligibility criteria comprised controlled primary malignancy, oligometastatic status (≤5 lesions), ECOG performance status 0–2, and suitability for SBRT following comprehensive clinical and radiological evaluation. All patients underwent contrast-enhanced planning CT in the supine position with individualized immobilization. MRI scans, including both standard and contrast-enhanced sequences, were also acquired and co-registered with CT datasets. Initial target volumes were contoured based on CT alone and subsequently reviewed and refined by board-certified radiation oncologists using MRI, particularly in cases involving perivascular extension or unclear nodal margins. SBRT plans were generated using the institutional treatment planning system, with dose prescriptions tailored based on prior radiation history, target proximity to OARs, and anatomical considerations. Treatment was delivered using LINAC equipped with daily CBCT for image guidance.

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All patients included had confirmed perirenal lymph node metastases and met predefined eligibility criteria for SBRT. Simulation was conducted using contrast-enhanced CT with individualized immobilization, followed by acquisition of co-registered MRI sequences for enhanced anatomical assessment. Target volumes defined on CT were revised using MRI input. MRI-guided contour refinement affected delineation in most cases. Over-contouring on CT alone was observed due to the inadvertent inclusion of adjacent structures such as renal vessels, adrenal tissue, or fibrotic bands. In contrast, under-contouring occurred when posterior nodal extensions were obscured by bowel gas or limited contrast resolution. Integration of MRI led to reduced target volumes and more anatomically accurate contours.

SBRT plans achieved ≥95% target coverage while adhering to dose constraints for critical structures based on QUANTEC and AAPM guidelines. MRI-based refinement contributed to improved sparing of nearby OARs, including the kidneys and duodenum. Our study underscores the value of MRI in enhancing target delineation accuracy for SBRT in the retroperitoneal/perirenal region. CT alone often fails to adequately distinguish pathological lymph nodes from adjacent vascular or fibrotic structures, especially in patients with prior surgical or radiation history. MRI provides superior soft tissue contrast, allowing clearer visualization of lymph node architecture and adjacent critical anatomy.

Our findings align with existing literature demonstrating the benefits of multimodality imaging in improving dosimetric quality and minimizing toxicity in SBRT planning [8-112]. Importantly, MRI integration enabled a reduction in target volume without compromising coverage, facilitating safer and more precise treatment delivery. Clinically, this enhanced precision may translate into improved tolerance of irradiation and better local control outcomes, particularly in patients with previous abdominal radiotherapy. As SBRT continues to play a growing role in the management of oligometastatic disease, accurate target definition remains a cornerstone of effective treatment. Taken together, MRI integration into SBRT planning improves target delineation accuracy for perirenal lymph node metastases. Our findings support the routine consideration of MRI in planning SBRT for retroperitoneal targets. Prospective studies are warranted to further validate these results and assess their impact on long-term clinical outcomes, including local control and survival.

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