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Multimodality Imaging-Based Target Definition for Stereotactic Reirradiation of Periportal Lymph Nodes

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Abstract

Objective: Magnetic Resonance Imaging (MRI), with its superior soft tissue contrast, provides critical supplemental information that enhances target delineation. Particularly in the periportal region, MRI improves the differentiation of lymph nodes from the bile ducts, hepatic vessels, and duodenum-structures that are notoriously difficult to separate on Computed Tomography (CT). This study explores the value of integrating MRI into the radiotherapy planning workflow for stereotactic reirradiation of periportal lymph nodes.

Materials and Methods: Patients with solitary periportal lymph node recurrence, previously treated with radiotherapy were assessed. CT-based simulation was performed with patients immobilized in the supine position using individualized positioning devices. High-resolution axial images were acquired. MRI sequences were also obtained and co-registered to the planning CT dataset. Target definition was initially based on CT images, followed by refinement with MRI input. Treatment planning was conducted using a dedicated radiotherapy planning system, with Stereotactic Body Radiotherapy (SBRT) delivered via LINAC equipped with cone-beam CT for image-guided radiotherapy (IGRT).

Results: MRI integration led to substantial refinements in target definition, particularly in cases involving nodes adjacent to the porta hepatis, bile ducts, or major vasculature. In multiple instances, CT-based contours overestimated the target by including vessels or underrepresented nodal boundaries due to poor soft tissue contrast. MRI-guided contours exhibited more accurate exclusion of non-target structures, resulting in reduced target volume and improved dose gradients.

Conclusion: MRI-enhanced target delineation improves the safety and efficacy of stereotactic reirradiation for periportal lymph node metastases. Further studies are warranted to validate these findings and assess their impact on long-term outcomes.

Keywords: Periportal lymph nodes, SBRT, reirradiation, CT-MRI fusion, target delineation, multimodal imaging

Abbreviations: ACTH: Adrenocorticotropic Hormone; ART: Adaptive Radiotherapy; IGRT: Image-Guided Radiotherapy; IMRT: Intensity-Modulated Radiotherapy

Introduction

Periportal lymph node metastases represent a uniquely challenging target for local therapies due to the dense clustering of critical gastrointestinal and vascular structures in the upper abdomen. As systemic therapies extend survival in patients with advanced malignancies, reirradiation using stereotactic techniques is increasingly being pursued [1-7]. Stereotactic body radiotherapy (SBRT) offers high-dose, image-guided, conformal treatment with potential for long-term local control and minimal toxicity. However, the success of SBRT in periportal locations is highly dependent on the accuracy of target definition.

Traditional Computed Tomography (CT)-based planning often fails to clearly distinguish nodal tissue from adjacent vessels or fibrotic tissues, leading to risks of geographic miss or overtreatment. Magnetic Resonance Imaging (MRI), with its

superior soft tissue contrast, provides critical supplemental information that enhances target delineation. Particularly in the periportal region, MRI improves the differentiation of lymph nodes from the bile ducts, hepatic vessels, and duodenum—structures that are notoriously difficult to separate on CT. This study explores the value of integrating MRI into the radiotherapy planning workflow for stereotactic reirradiation in this high-risk anatomical zone.

Materials and Methods

Our study was conducted in the Department of Radiation Oncology at the University of Health Sciences, Gulhane Medical Faculty. Patients with periportal lymph node recurrence, confirmed radiographically or histologically, and previously treated with radiation were studied. All patients were selected for SBRT based on oligometastatic disease status, controlled primary malignancy, and satisfactory performance status (ECOG 0–2). Simulation consisted of contrast-enhanced CT imaging with patients immobilized in the supine position.

MRI was obtained using standard and contrast-enhanced sequences. Image registration was performed to align CT and MRI datasets. Contouring was initially performed using CT images alone and subsequently refined using MRI input by experienced radiation oncologists. SBRT plans were generated using departmental treatment planning systems and delivered via LINAC with cone-beam CT for daily image guidance. Prescription doses aimed for ≥95% coverage while respecting organ-at-risk (OAR) constraints per QUANTEC and AAPM recommendations.

Results

Patients included in this study had periportal lymph node recurrence, confirmed either radiographically or histologically, and had previously undergone radiotherapy. Eligibility for SBRT was based on the presence of oligometastatic disease, a controlled primary tumor, and an ECOG performance status of 0–2. Simulation involved contrast-enhanced CT imaging with patients immobilized in the supine position. MRI, including standard and contrast-enhanced sequences, was acquired and co-registered with CT scans for multimodal image alignment. Initial target delineation was performed using CT alone, followed by refinement with MRI guidance by experienced radiation oncologists. SBRT treatment plans were developed using institutional planning software and delivered via a LINAC system with daily image guidance using cone-beam CT.

Dose prescriptions were designed to achieve at least 95% target coverage while adhering to organ-at-risk (OAR) constraints in accordance with QUANTEC and AAPM guidelines. MRI-based refinement significantly impacted target definition in most cases. CT-alone contours commonly overestimated target volume due to inclusion of adjacent hepatic arteries or portal vein segments or underestimated nodal spread obscured by bowel gas or postoperative changes. MRI fusion allowed for precise retraction of contours from non-target tissues and better delineation of true nodal margins. Incorporating MRI data reduced the average target volume and improved dose conformity. MRI-guided plans demonstrated tighter dose falloffs and enhanced treatment plan quality.

Discussion

Periportal lymph node metastases pose a distinct challenge for local therapies due to the proximity of critical gastrointestinal and vascular structures densely clustered in the upper abdomen. With systemic therapies extending survival in patients with advanced cancers, stereotactic reirradiation is increasingly being explored as a viable option for achieving durable local control [1-7]. SBRT enables precise, high-dose, image-guided treatment delivery with the potential for long-term control and acceptable toxicity. However, the success of SBRT in the periportal region relies heavily on accurate target delineation. Conventional CT-based planning often struggles to differentiate lymphatic tissue from adjacent vascular or fibrotic structures, increasing the risk of geographic misses or unnecessary exposure to surrounding organs.

MRI, with its superior soft tissue contrast, provides critical complementary data that enhances target identification. In the periportal region specifically, MRI facilitates improved distinction between lymph nodes and nearby structures such as the bile ducts, hepatic vasculature, and duodenum—anatomical features that are often poorly visualized on CT. Our study evaluated the integration of MRI into the SBRT planning workflow for reirradiation in this anatomically complex and high-risk site. Eligible patients had periportal lymph node recurrence confirmed via imaging or biopsy and had previously received radiotherapy. Selection for SBRT was based on oligometastatic disease status, control of the primary malignancy, and an ECOG performance status of 0–2.

Treatment simulation included contrast-enhanced CT with patients immobilized in the supine position. MRI, acquired with standard and contrast-enhanced sequences, was co-registered with CT to enable multimodal image alignment. Initial target delineation was performed on CT alone and subsequently refined using MRI input by experienced radiation oncologists. SBRT plans were generated using institutional treatment planning systems and delivered on a LINAC platform with daily cone-beam CT guidance. Dose prescriptions aimed to cover at least 95% of the planning target volume while adhering to organ-at-risk (OAR) constraints based on QUANTEC and AAPM guidelines.

MRI-based refinement had a substantial impact on target definition in most cases. CT-alone contours frequently overestimated target volume by inadvertently including portions of the hepatic artery or portal vein or underestimated the extent of nodal disease masked by bowel gas or surgical changes. MRI fusion enabled more accurate exclusion of non-target tissues and clearer delineation of true nodal boundaries. The incorporation

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of MRI data resulted in reduced target volumes, improved dose conformity, and more favorable dose gradients. MRI-guided planning led to enhanced plan quality, supporting its utility in reirradiation of periportal lymph node metastases. Reirradiation in the periportal region poses a formidable challenge due to the cumulative dose burden and the complexity of surrounding anatomy. Accurate target definition is essential to minimize toxicity and maximize local control.

Our findings underscore the importance of incorporating MRI into SBRT planning, especially in previously irradiated patients, where small deviations in contouring can translate into significant toxicity or treatment failure. These results align with existing literature advocating multimodal imaging in radiotherapy planning for abdominal and pelvic malignancies, including rectal, hepatobiliary, pancreatic cancers and several other disease sites [8-112]. While implementation requires access to high-quality MRI and robust registration workflows, the dosimetric and clinical advantages justify the additional resource investment in high-risk cases. In summary, MRI-enhanced target delineation improves the safety and efficacy of stereotactic reirradiation for periportal lymph node metastases. Further studies are warranted to validate these findings and assess their impact on long-term outcomes.

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