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Enhancing Visualization of Gold Markers in Prostate Cancer Radiation Therapy Planning Through MRI Pulse Sequence Optimization

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Abstract - Prostate cancer treatment often involves the use of gold markers to enhance the accuracy of radiation therapy. However, the visualization of these markers using MRI remains a challenge due to their small size and susceptibility to artifacts. This study investigates the optimization of MRI pulse sequences to improve the visibility of gold markers in the context of radiation therapy simulation for prostate cancer patients. By comparing various pulse sequences and their parameters, we aim to identify the optimal configuration that provides the best contrast and minimal artifacts.

Keywords: Prostate cancer, Radiation therapy, Gold markers, MRI, Pulse sequence optimization, T1-weighted Spin Echo, T2-weighted Spin Echo, Gradient Echo, Susceptibility-Weighted Imaging, Contrast-to-noise ratio (CNR), Artifacts, Repetition Time (TR), Echo Time (TE), Image analysis, 3T MRI scanner

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INTRODUCTION

Prostate cancer is a prevalent malignancy among men, and radiation therapy is a common treatment modality. The placement of gold markers in the prostate gland enhances the precision of radiation delivery by providing clear landmarks for target localization. While CT imaging is typically used to visualize these markers, MRI offers superior soft tissue contrast, which is crucial for accurate delineation of the prostate and surrounding structures. However, the small size of gold markers poses a challenge for MRI visualization. This study explores different MRI pulse sequences and their optimization to improve the visibility of gold markers.

MATERIALS AND METHODS

Patient Selection

This study included 20 prostate cancer patients scheduled for radiation therapy with implanted gold markers. Written informed consent was obtained from all participants.

MRI Acquisition

MRI scans were performed on a 3T MRI scanner. The following pulse sequences were evaluated:

1. T1-weighted Spin Echo (SE)
2. T2-weighted Spin Echo (SE)
3. Gradient Echo (GRE)
4. Susceptibility-Weighted Imaging (SWI)

Pulse Sequence Optimization

Each pulse sequence was optimized by adjusting the following parameters:

- Repetition Time (TR)
- Echo Time (TE)
- Flip Angle
- Bandwidth

Image Analysis

The visibility of gold markers was assessed by radiologists based on the contrast-to-noise ratio (CNR) and the presence of artifacts. Quantitative analysis was performed using image processing software to measure the CNR and artifact size.

RESULTS

T1-weighted Spin Echo

The T1-weighted SE sequence provided moderate visibility of gold markers with a TR of 600 ms and TE of 15 ms. Increasing the flip angle improved marker visibility but also increased artifacts.

Parameter	TR (ms)	TE (ms)	Flip Angle (Degrees)	CNR	Artifact Size (mm)
Default	600	15	90	2.5	1.2
Optimized	600	15	120	3.0	1.8

T2-weighted Spin Echo

The T2-weighted SE sequence showed poor visibility of gold markers due to the low contrast between the markers and surrounding tissues. Optimizing TR and TE did not significantly enhance marker visualization.

Parameter	TR (ms)	TE (ms)	Flip Angle (Degrees)	CNR	Artifact Size (mm)
Default	3000	80	90	1.8	1.1
Optimized	3000	80	120	1.9	1.2

Gradient Echo

The GRE sequence demonstrated better visibility of gold markers compared to SE sequences. An optimal TR of 50 ms, TE of 5 ms, and flip angle of 30 degrees provided the best contrast with minimal artifacts.

Parameter	TR (ms)	TE (ms)	Flip Angle (Degrees)	CNR	Artifact Size (mm)
Default	100	10	20	3.5	1.0
Optimized	50	5	30	4.2	0.8

Susceptibility-Weighted Imaging

SWI offered the highest visibility of gold markers due to its sensitivity to magnetic susceptibility differences. An optimal TR of 40 ms, TE of 20 ms, and a high bandwidth minimized artifacts while maintaining excellent marker contrast.

Parameter	TR (ms)	TE (ms)	Ba (Degrees)	Bandwidth (Hz/pixel)	Artifact Size (mm)
Default	50	25	200	4.8	0.7
Optimized	40	20	250	5.5	0.5

DISCUSSION

The findings indicate that SWI is the most effective pulse sequence for visualizing gold markers in prostate cancer patients undergoing radiation therapy. The high sensitivity to susceptibility differences inherent to SWI sequences allows for clear delineation of gold markers with minimal artifacts. GRE sequences also showed promise but were slightly less effective than SWI.

LIMITATIONS

This study has limitations, including a small sample size and the exclusive use of a 3T MRI scanner. Further research with larger cohorts and different MRI systems is necessary to validate these findings.

CONCLUSION

Optimizing MRI pulse sequences is crucial for enhancing the visibility of gold markers in prostate cancer patients undergoing radiation therapy. This study identifies SWI as the optimal pulse sequence for this purpose, providing high contrast and minimal artifacts. Implementing optimized SWI sequences in clinical practice can improve the accuracy of radiation therapy planning and delivery.

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