Reduction of Metal Artifacts in 7T MRI for Pre-Clinical Diffusing Alpha-Emitting Radiation Therapy Rectal Studies

M. Cyr[1], N. Chabaytah[1], J. Babik[1], B. Behmand[1], I. R. Levesque[1] & S. A. Enger[1]

[1] Medical Physics Unit, Department of Oncology, Faculty of Medicine, McGill University, Montreal, QC, Canada.

Introduction

In magnetic resonance imaging (MRI) the presence of metal can result in severe variations in the static magnetic field, significantly impeding the quality of the images acquired. Metal artifacts in MRI present roadblocks for some treatment modalities, such as brachytherapy (BT) [5]. Recently, a novel interstitial treatment modality, diffusing alpha-emitter radiation therapy (Alpha-DaRT), has emerged. This method utilizes a ^{224}Ra-loaded stainless steel source that emits both short-lived α-emitting atoms and α particles. By leveraging the diffusion of ^{220}Rn and ^{212}Pb, Alpha-DaRT sources can effectively treat tumors within a range of several millimeters [1][2][3][4]. However, steel causes larger artifacts than standard gold BT seeds. Hence, the impact of MRI parameters on the presence of metal artifacts in phantoms and *in vivo* was investigated.

Aim

To reduce metal artifacts when imaging mice with intra-rectal colorectal adenocarcinoma solid tumors injected with inert Alpha-DaRT sources during a feasibility study.

Methods

Orthotopic Intra-Rectal Mice Model Procedure:

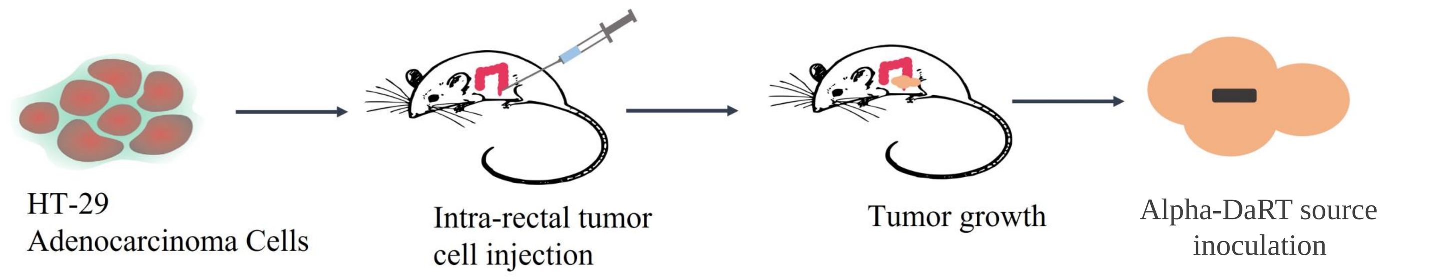

Figure 1. Orthotopic intra-rectal injection procedure for inert Alpha-DaRT sources for NSG mice models.

MR Imaging :

The small animal imaging facility at the Research Institute of McGill University Health Center (RI-MUHC) is equipped with a 7T MRI machine. Parameters such as receive/transmit frequency coil type, relaxation time (TR), echo time (TE), slice thickness, and resonance frequency bandwidth were altered to reduce metal artifacts.

Imaging experiments were performed using a 50 ml gelatin phantoms with inert seeds, mouse carcasses with seeds in the intestinal cavity, and finally with live mice containing 5-7 mm diameter rectal tumors with an inert seed in their center.

Initial parameters chosen by the imaging facility were altered one by one for the phantom until there was significant qualitative improvements in the metal artifacts such as reduction of signal loss (darkness), geometric distortions, and signal pile-up (sharp white), such that the artifacts did not impede tumor and seed visualization.

Results

Phantoms:

- Experimental set-up is shown in figure 2.
- Original sequence chosen by the imaging facility for the pilot study was a T2-weighted RARE-acquisition sequence and resulted in many metal artifacts from the metal sources.
- Optimized sequence reduced metal artifacts by using phantoms, mouse carcasses and live animals (equipment in Figure 3).
- Phantom imaging tests resulted in improved image quality that demonstrated metal artifact reduction (Figure 4).

Figure 2. 7T MRI scanner at the RI-MUHC – Glen Hospital for small animal imaging. NSG mouse in supine position strapped to a surface coil.

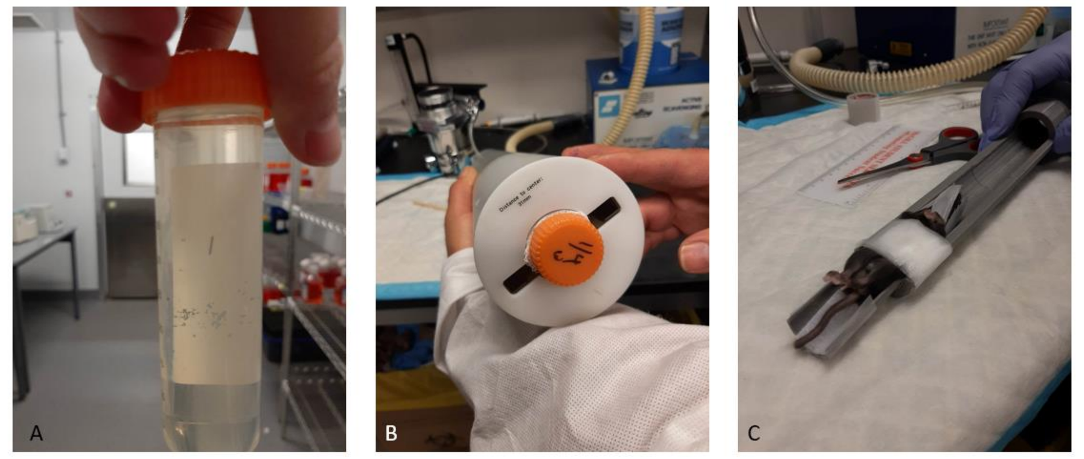

Figure 3. 7T MRI optimization equipment and methods where A) 50 ml gelatin phantom with an inert Alpha-DaRT source inserted in its center. B) Gelatin phantom placed into the volume transmit/receive frequency coil. C) Carcass inserted with an inert Alpha-DaRT source into its rectum.

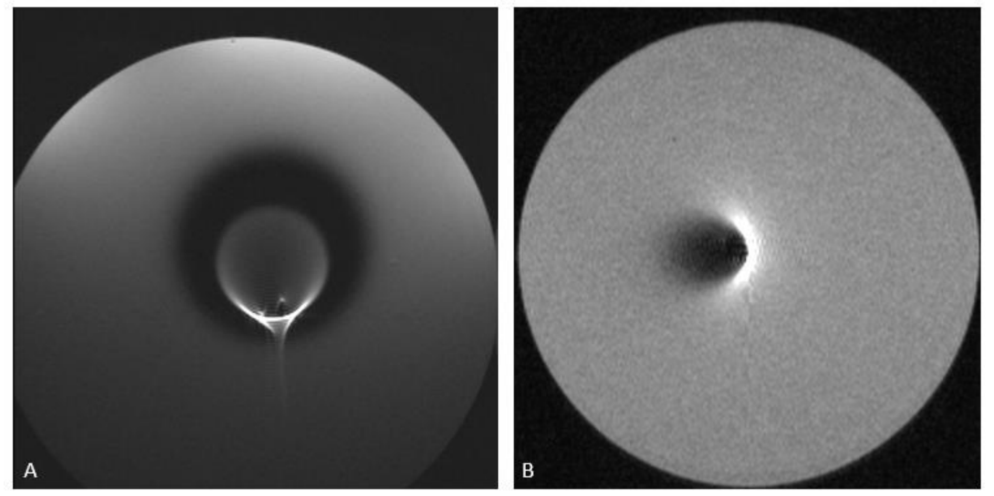

Figure 4. Example of responses seen with phantom. A) Original sequence with surface coil and a T2 weighted image. B) Altered TE, TR, slice thickness, volume coil, and proton density weighted image.

Live Mice:

- Original sequence chosen by the animal facility efficiently visualized rectal anatomy (Figure 5A) and solid tumor (Figure 5B). However, resulted in large metal artifacts such as geometric distortions, signal voids, and "pile-up" (Figure 6A).

	Weight	TR (ms)	TE (ms)	Frequency Bandwidth (kHz)	Slice Thickness (mm)	Figures
Original	T2	3794	25.6	34	0.4	6A
Improved	Proton density	5937	30	100	0.27	6B

- Parameters that significantly reduced the metal artifacts were TE, frequency bandwidth, and slice thickness.

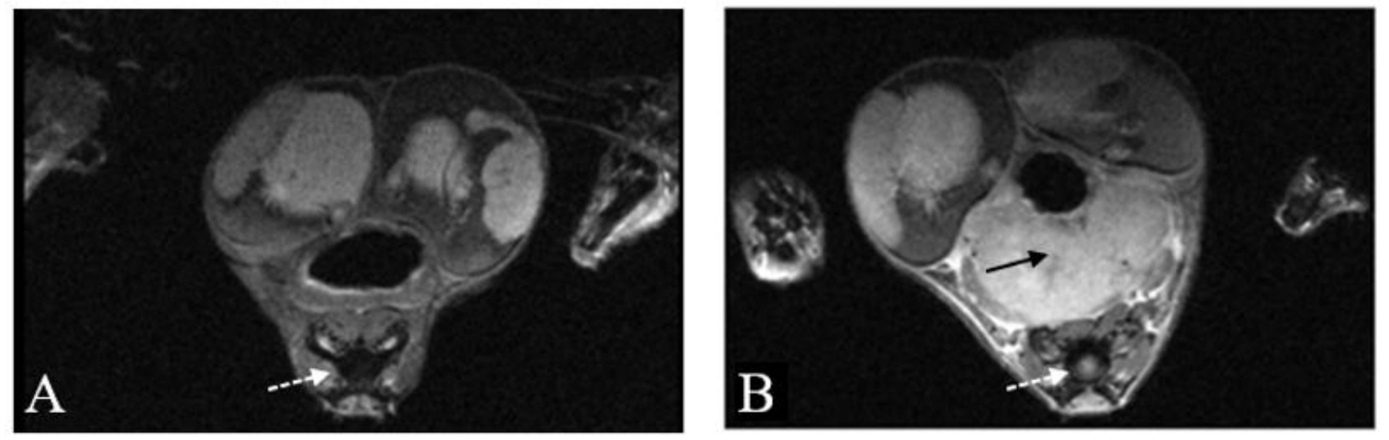

Figure 5. 7T MRI of a mouse A) before the HT-29 cell intra-rectal injection, where the mouse is supine position. The tail is shown with a dashed white arrow. B) After intra-rectal injection with a tumor of size 6 mm x 3.3 mm x 3.2 mm (solid black arrow).

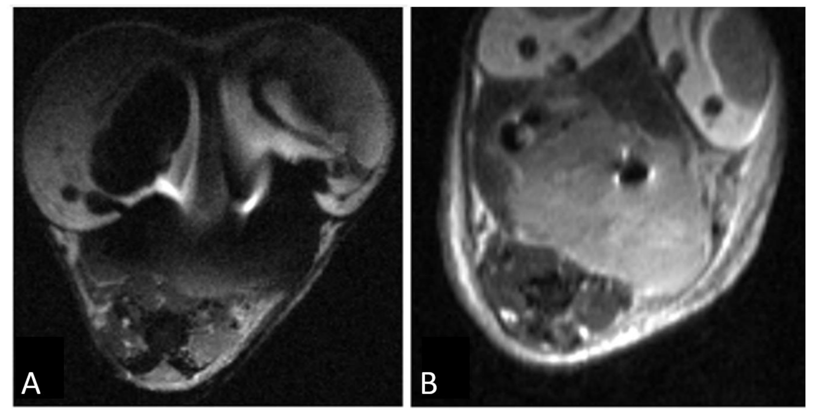

Figure 6. 7T MRI of a mouse A) rectal tumor in mouse with significant metal artifacts impeding tumor visualization and seed location. B) Tumor in mouse imaged with optimized sequence, showing reduced metal artifacts.

Conclusions

First successful *in vivo* pilot study for an orthotopic intra-rectal model using inert Alpha-DaRT sources for the treatment of colorectal cancer was conducted.

The metal artifacts were reduced significantly to visualize tumor dimensions and seed placements.

Future Work:

- This may guide future human clinical trials for treatment of rectal cancer with Alpha-DaRT.

References

[1] **L. Arazi, *et al.*** (2007). DOI: 10.1088/0031-9155/52/16/021
[2] **L. Arazi, *et al.*** (2019). DOI: 10.1016/j.jmir.2019.03.083
[3] **T. Cooks, *et al.*** (2009). DOI: 10.1016/j.ijrobp.2009.02.063
[4] **T. Cooks, *et al.*** (2009). DOI: 10.1016/j.ijrobp.2009.02.063
[5] **B. Hargreaves, *et al.*** (2010). DOI: 10.1002/jmri.22112

Acknowledgements

The authors extend their gratitude to Mathieu Simard from Small Animal Imaging Laboratory at the RI-MUHC, for providing valuable support regarding metal artifact reduction. They would also like to acknowledge the entire Radiation Biology Research Group of the Enger Lab for their contributions and collaboration.

Contact Information

melodie.cyr@mail.mcgill.ca