MR-Guided Radiofrequency (RF) Thermal Ablation Of The Lumbar Vertebrae In A Porcine Model

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Introduction

Radiofrequency thermal ablation had been effectively and safely applied to treat a diverse of benign and malignant coditions (1). Target organs included, among others, the liver (2), brain (3), and prostate (4). The ability of MRI to detect the immediate effect of therapy, thus defining the treatment endpoint, gives it an edge over other imaging modalities to monitor such kind of therapy (5). Successful CT-guided RF-ablation of osteoid osteomas have been reported (6,7). Goyal et al have recently reported initial success in alcohol ablation of symptomatic vertebral hemangiomas (8). As MR-guided RF-ablations have been applied to almost every body organ, our study was conducted to evaluate its use in the vertebrae as a potential future application of minimally invasive therapy of spine pathology. Purpose: To test the: (1) Feasibility of MR-guided radiofrequency (RF) thermal ablation of the vertebrae in a porcine model. (2) Safety of the procedure in relation to the ablated part of the vertebra. (3) Predictability of the size and shape of induced thermal lesions.

Materials and Methods

MR-guided RF ablation of 10 vertebrae was performed in 7 pigs under general anesthesia, using a protocol approved by the animal use and care committee of our institution. All procedures were performed on a 0.2 T open MR system (Magnetom open, Siemens Medical Systems, Germany). Ablation sites were randomized to include all lumbar vertebral levels (L1=1, L2=4, L3=1, L4=3, L5=1), as well as variable locations within the vertebra (center of vertebral body=4, body close to anterior cortex=1, body close to posterior cortex=1, body close to inferior cortex= 1, body close to posterior and inferior cortices=1, right pedicle= 2). Under MR-fluoroscopy, an 11G (3.0 X 100 mm) MR-compatible bone biopsy needle (Somatex, Berlin, Germany) was introduced into the planned part of the vertebra via a transpedicular approach in 9 procedures and through direct puncture of the lateral cortex in one procedure. The stylet of the biopsy needle was then replaced by a 2-cm exposed tip 17G MR-compatible RF electrode (Radionics Inc., Burlington, MA). Vertebral ablation was then started for 10 minutes, keeping the electrode tip temperature at 90°C ± 2°C. Immediate post-ablation MR scanning was performed using TSE T2, turbo STIR, and and post-gadolinium SE T1-weighted pulse sequences. Pigs harboring the first 6 lesions were observed for 1 week, whereas the pig harboring the 7th and 8th lesions was observed for 2 days due to expected complication, and that harboring the 9th and 10th lesions was observed for 14 days. The animals were then rescanned using the same pulse sequences utilized for the immediate scans, sacrificed and the vertebrae were harvested. The vertebrae were then sliced for gross pathology and decalcified for histological examination using HE stain. The maximum diameter of thermal lesions was measured on the immediate and follow up scans and compared to those at gross pathology. The lesion-to-vertebra contrast-to-noise ratio was calculated on the different pulse sequences.

Results

Successful introduction of the bone biopsy needle followed by RF electrode placement into the targeted part of the vertebra was achieved under direct MR guidance in all cases. In one case, a large retroperitoneal hematoma complicated the trials to place the needle as close to the anterior vertebral cortex as possible. Apart from slight post-procedure pain that was relieved by pain medications, ablations away from the neural elements were well tolerated by all the animals. In one of the two ablations performed within the vertebral pedicles, the pig limped on the ipsilateral leg for several days before it gradually improved. In both ablations performed flush with the posterior vertebral cortex, the pig developed immediate paraplegia which necessitated earlier sacrifice after 2 days. In the latter case, an area of focal myelopathy at the ablated level was evident on both the immediate and follow-up MRI scans. The intervening cortex appeared intact on both MRI and CT. The mean absolute difference between the however, was not significantly less than the differences measured on the post-contrast T1 and STIR images. The lesion-to-vertebra contrast-to-noise ratio was significantly higher for post-contrast T1-weighted images than for T2-weighted images($p<0.0001$) or STIR images($p<0.0001$).

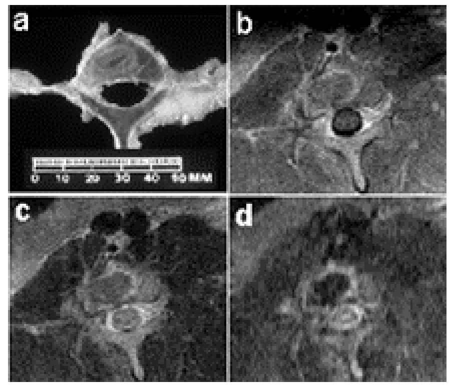

Figure 1: RF-ablation at the center of L2 vertebral body as seen on gross pathological section (a), post-contrast T1 (B), TSE T2 (C), and turbo STIR (D) images.

Conclusion

Radiofrequency (RF) thermal ablation of the vertebrae under MR guidance is technically feasible, and can be used to produce thermal lesions of controlled size and shape. The safety of the procedure depends largely on the targeted part of the vertebra. Ablations away from neural elements are generally safe to perform. Pedicular ablations are likely to result in radiculopathy, whereas ablations close to the posterior vertebral cortex should be avoided.

References

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