Minimally invasive MRI-guided cryotherapy of the brain with an artifact-free nitrogen supplied cryoprobe

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Introduction

Cryotherapy of the brain is a well-known therapeutic concept in tumors or dysfunctional cerebral foci (1). Presumably due to the development of modern micro-neurosurgery, it fell into oblivion as a therapeutic tool. By combining cryotherapy with the high temporal and spatial resolution properties of MRI (2, 3) and minimally invasiveness (4), a new approach was suggested in the management of size-limited brain lesions. The purpose of this experimental study was to evaluate the feasability of this technique in the brain of healthy pigs and to control the tissue lesions by MR imaging and histologic examination.

Methods

A liquid nitrogen supplied glass-built cryoprobe, described elsewhere (4), was modified to cylindrical shape with an outer diameter of 2.7 mm. The probe shaft was vacuum insulated except at the tip. The probe was supplied with liquid nitrogen of pressures up to 5 bar. It was inserted into the right frontal lobe of the brain of 7 pigs (mean b.w. 35 kg) through a 4 mm borehole under MRI control. Freezing procedures were monitored using a surface coil on an interventional 1.5 T imager (ACS-NT, Philips) by dynamic GRE (TR/TE/FA = 15/5.4/25°) and fast high resolution T2-weighted LoLo TSE (TR/TE=800/77, scan duration 440 ms) sequences. The iceball formation was controlled continuously by manually starting each scan at the magnet and controlling the procedure on LCD screens beside the scanner. Per animal, 3 freezing procedures of 3 minutes duration each were performed. Follow-up 3 and 7 days after cryotherapy was performed by MRI using pre/post contrast T1 SE, T2 TSE, FLAIR and GRE sequences. Finally, the animals were killed and the brains were sectioned and stained.

Results

Due to the MR-compatible, metal-free components of the probe, no artifacts of the probe were observed in any direction with respect to B0 (**Fig. A, B**). Neither probe breakage nor bleeding complications did occur during the experiments or follow-ups. The ice was completely spherically shaped and well delineated in all cases (**Fig. B**). The maximum diameter of the iceball was 12 mm. The complete lack of ice along the probe shaft proved the vacuum insulation to be sufficient.

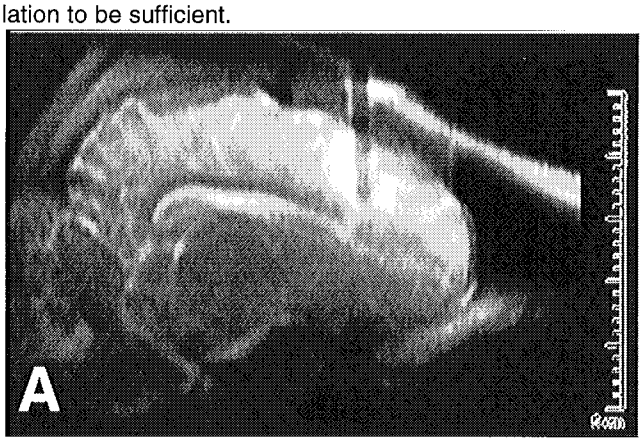

Fig. A: Sagittal LoLo with cryoprobe in right frontal lobe.

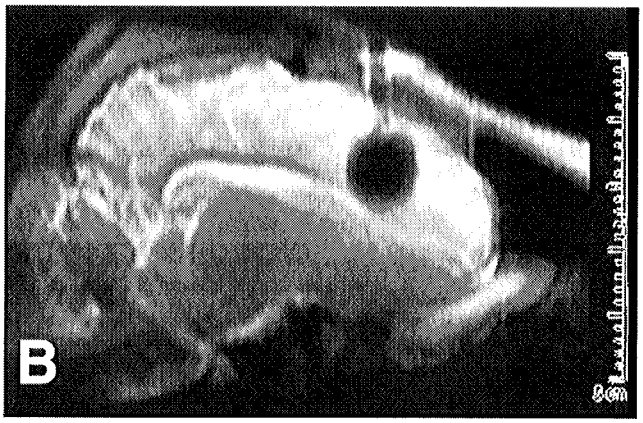

Fig. B: Sagittal LoLo. Signal-free ice formation after 2 min of freezing.

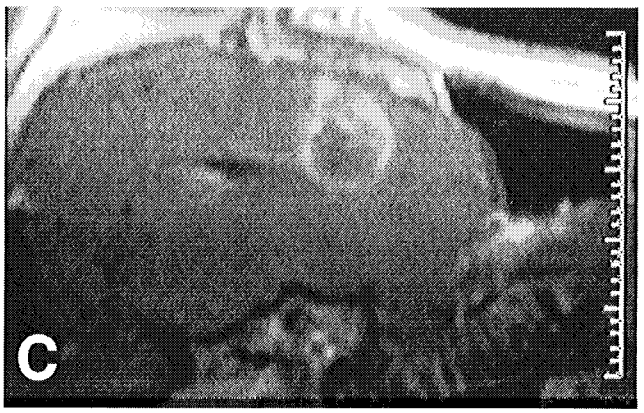

Fig. C: Sagittal T1SE post contrast (0.1 mmol Gd-DTPA/kg bw) 7 days after therapy. Hypointense necrosis with signal increased rim of granulation tissue around the necrosis.

The size of the lesions 7 days after therapy (**Fig. C**) were on average 1 mm larger in diameter as compared to the initial size of the iceball. Histologically, a thin layer of granulation tissue around a coagulation necrosis was found corresponding to the contrast enhancing rim around the lesion on MRI.

Conclusion

The combination of minimally invasive cryotherapy, high temporal resolution MRI and artifact-free cryoprobes holds great promise for MR-guided tissue ablation in the brain. Long-term follow-up, probe design and materials will be discussed.

References

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