MR Imaging Guided Radiofrequency Ablation of Lung Tissue: Necessity or Overkill?

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Synopsis:
The purpose of this study was to assess the feasibility of MRI to control radiofrequency ablation (RFA) of pulmonary tissue in a rabbit model. Puncture and lung RFA were performed in 5 New Zealand White rabbits under MR image control using a 0.2 T open MR scanner. The ablation effect was assessed using MRI, CT and pathology. MRI procedure guidance was feasible. Pneumothorax could be detected and treated during imaging. MR was superior to CT in defining the thermal lesion. Our results indicate MRI guidance is useful for thermal ablation of pulmonary tissue and suggest that patient trials may be warranted.

Introduction and Objectives:
According to the American Cancer Society, lung cancer remains the number one cause of cancer deaths in the U.S. The 161,400 estimated deaths expected in 2002 account for 28% of all cancer deaths. There has been limited progress in the management of this devastating disease [1]. Most patients with lung malignancies are poor surgical candidates. Systemic chemotherapy and radiation therapy has not greatly affected the outcome in these patients. The overall 10-year relative survival rate is as low as 7%. Therefore, there is a continuing search for better therapeutic regimens [1].

Since 1990, minimally invasive techniques have been introduced as potential alternatives for surgical resection. The image-guided interventional and video-assisted thoracoscopic approaches have become an alternative for open thoracic surgery. If endoscopic, bronchoscopic, or percutaneous treatments can provide similar disease-free survival with less perioperative mortality, morbidity, and cost, they could become first-choice therapies [2]. Image-guided thermal ablation techniques represent relatively recent additions to these new approaches. For lung tumors, LASER and predominantly radiofrequency ablation (RFA) have been used [3,4,5]. Although it is generally accepted that MR imaging provides the best monitoring capability for guiding thermal therapies, MR imaging guidance has not been well evaluated for lung ablation. The purpose of our study was to assess the feasibility of MR imaging to control RF ablation of pulmonary tissue in a rabbit model.

Methods:
5 New Zealand White rabbits were treated with RF ablation by using an 18-gauge internally cooled non-ferromagnetic electrode with a 1cm active tip. RF energy was applied for 3 to 5 minutes using an impedance based self-regulating feedback system. The electrode was simultaneously cooled to 10-15°C by circulating ice water through internal channels in the electrode using a pump. Probe-tip temperature, tissue impedance, and RF current were recorded from the generator display at baseline and at 1-minute intervals.

Puncture and thermal ablation were performed under MR image control using a 0.2 T open MR scanner (Magnetom Open, Siemens Medical Solutions, Germany). The ability of MRI to detect immediate complications such as bleeding and pneumothorax was evaluated. The lung tissue destruction was assessed using MRI utilizing different pulse sequences (FLASH, trueFISP, STIR and PSIF), and CT (MX 8000 IDT, Philips, The Netherlands). The rabbits were euthanized 2-6 hours (n=4) and 1 week (n=1) after thermal ablation. Gross and microscopic pathology were obtained and correlated with CT and MRI.

Results:
On gross pathological examination, the mean coagulation necrosis diameter was 11 mm. Oval areas of increased signal intensity in comparison to normal lung tissue were found with both T1w and T2w sequences. These areas consisted of a central zone, which was hyperintense in T1 and hypointense in T2, and a peripheral zone, which was hyperintense with both T1 and T2 weighted images. There was a good correlation in lesion size between pathology, FLASH imaging, and CT. The combination of FLASH and STIR was superior to CT in differentiating the actual thermal lesion from the surrounding edema. A pneumothorax occurred in 1 animal. It was rapidly detected on MR imaging and was successfully treated under MRI control by suction.

Conclusion:
An imaging modality for percutaneous tumor treatment should fulfill three conditions. First, insertion of the applicator should be possible in a safe and rapid fashion. CT has primary been used for percutaneous needle interventions in the lung in the past. This study shows that MR imaging is able to direct an RF electrode safely within the thorax. However, since there was no tumor involved in this study, further evaluation is necessary. Second, complications such as pneumothorax or bleeding must be detected in the course of treatment. In this study, a pneumothorax occurred during ablation in one animal and was rapidly detected and successfully treated under MRI control. Third, immediate control of the thermal damage is necessary to successfully guide the ablation therapy. MRI was able to monitor the tissue response immediately after therapy with higher precision as that achieved with CT. The combination of differently weighted images seems to offer better differentiation between induced necrosis and surrounding fluid. As it has been reported for other organs, such as the liver and kidney [6,7,8,9], this might allow superior monitoring of the thermal lung ablation and thus make it possible to detect residual untreated tumor during the ablation procedure, allowing re-application of RF as necessary during the same treatment session. On the basis of our current results, we concluded that MR imaging guidance is useful for thermal ablation of pulmonary tissue.

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