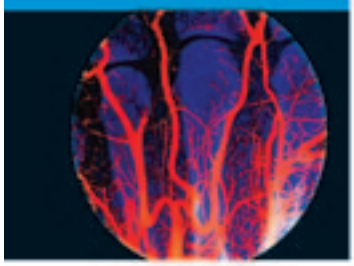
Radiofrequency ablation: the new 'wave' therapy

Key words: radiofrequency ablation; hepatocellular carcinoma; hepatic metastases; non-small-cell lung cancer; pulmonary metastases; renal cell carcinoma



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Abstract

Radiofrequency ablation (RFA) is a minimally invasive technique used to treat solid tumours. Following recent technological advances, RFA has gained an increasingly important role in the treatment of unresectable hepatic malignancies, and is challenging partial hepatectomy as the treatment of choice for patients with limited hepatic tumours. Although RFA of non-hepatic malignant tumours is at an early stage of clinical application, recent studies have shown that this technique could offer a valuable treatment option for lung, bone and renal malignancies. This article reviews the current status of RFA, with a focus on the treatment of liver and lung tumours.

Introduction

The goal of radiofrequency ablation (RFA) is to destroy a target tumour through electromagnetic energy deposition. In RFA, a needle electrode is guided into the tumour using an imaging technique such as ultrasound, computed-tomography (CT) scanning or magnetic-resonance imaging. A current from a radiofrequency generator is passed between the needle electrode and a large dispersive electrode placed on the patient's skin, and the patient becomes part of a closed-loop circuit. The alternating electric field that is created between the electrodes induces marked agitation of the ions present in the tissue surrounding the electrode, since the tissue ions attempt to follow the changes in the direction of the alternating electric current.
This agitation results in frictional heat around the electrode, which can reach 100–110 °C.

Early experiences with RFA exposed a major limitation with the technique: the conventional monopolar electrodes could create only a small volume of thermal necrosis. Major progress was achieved with the introduction of modified electrodes, including cooled-tip electrode needles and expandable electrode needles with multiple retractable lateral-exit prongs on the tip (Figures 1a and 1b). These technological advances have enabled substantial and reproducible enlargement of the volume of thermal necrosis produced with a single needle insertion, and have initiated the clinical application of RFA.

Figure 1.(a) Professor Lencioni performs computed tomography-guided radiofrequency ablation of a lung tumour;

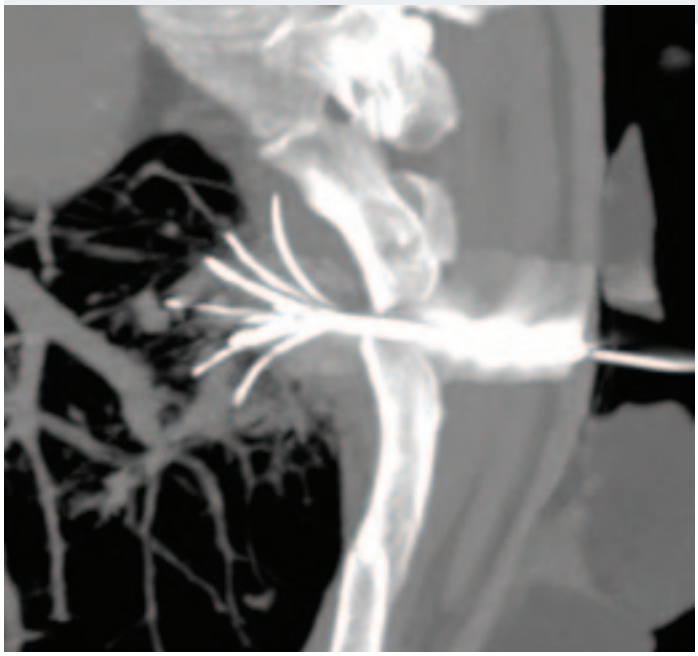
Figure 1. (b) lung tumou

Liver tumours

Despite advances in the surgical techniques and improvements in the results of resective liver surgery, the large majority of patients with either primary or secondary liver malignancies are not suitable candidates for partial hepatectomy.[1] Patients with hepatocellular carcinoma (HCC) usually have a limited hepatic reserve because of coexisting cirrhosis, and their morbidity and mortality are significant, even in the hands of experienced surgeons. Moreover, multiple lesions may be present with HCC, owing to the propensity of HCC to generate intrahepatic metastatic nodules – especially via the invasion of peripheral portal vein branches. Additionally, because of the carcinogenic

potential of the underlying cirrhosis, patients with HCC are at a high risk of developing new lesions in the remnant liver after resection of the initial tumour. Similarly, hepatic resection may not be feasible in patients with liver metastases because of the extent of liver invasion, the presence of extrahepatic malignancy or concurrent medical conditions.

In view of the limitations of surgical resection and the severe shortage of donor livers for transplantation, there is an ever-increasing demand for minimally invasive treatments able to provide local destruction of hepatic tumours. Radiofrequency ablation is emerging as the most attractive method for percutaneous treatment because it is effective, produces reproducible results, is associated with a lower rate of morbidity and is less expensive compared with other interventions.[2]
With regard to other percutaneous techniques, RFA produces larger thermal lesions than those obtained with a microwave electrode, and is easier to perform than interstitial laser photocoagulation, which involves multiple fibre insertions.
At present, RFA is considered in many centres as the first-line treatment for patients with small HCC (one tumour <5 cm in diameter, or up to three tumours, each <3 cm in diameter) who are not suitable candidates for resection or transplantation.[2,3]
In particular, RFA has been shown to be superior to percutaneous ethanol injection (PEI) in comparative trials.[2,3] In one randomised trial, a complete tumour response was achieved with RFA in 91% of HCC nodules (average of 1.1 ± 0.5 treatment sessions) and with ethanol injection in 82% of HCC nodules (average of 5.4 ± 1.6 treatment sessions).[4] Moreover, local recurrence-free survival rates were significantly higher in the RFA group (98% at 1 year and 96% at 2 years) than in the ethanol injection group (83% at 1 year and 62% at 2 years; p=0.002) (Figure 2).



1. (b) Computed tomography shows a multi-prong radiofrequency needle deployed within the target ım our (*Starburst XL, RITA Medical Systems, Mountain View, CA, USA)*

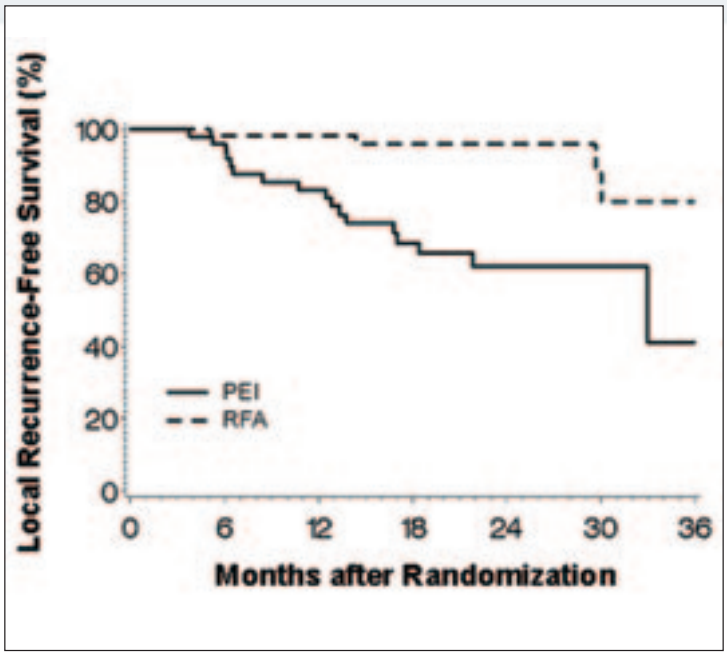
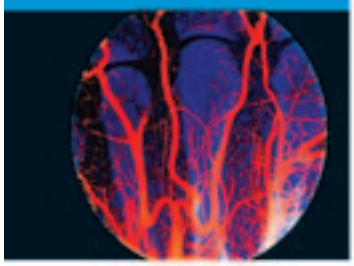


Figure 2. Probability of local recurrence-free survival of patients with early-stage hepatocellular carcinoma treated by percutaneous ethanol injection (PEI) or radiofrequency ablation (RFA). The difference between the groups was statistically significant[4]

Radiofrequency ablation: the new 'wave' therapy *continued*

Riccardo Lencioni



Further investigation is warranted to clarify whether current RFA technology could offer improved long-term results in patients with more advanced tumours.[5]

In addition to treating HCC, RFA has been successful in the treatment of hepatic colorectal metastases.[6–9] Studies examining long-term outcome showed that survival rates at 1-, 2- and 3-years were 90–93%, 60–69% and 34–46%, respectively.[8,9] The survival rates with RFA are substantially higher than those achieved with chemotherapy protocols.[10] In addition, one recent study has demonstrated similar success rates for RFA as for surgery in the treatment of solitary colorectal liver metastases: median survival 37 months with a 3-year survival rate of 52.6%, compared with median survival 41 months with a 3-year survival rate of 55.4%, respectively.[11] In the absence of further trials, it is suggested that RFA could substantially increase survival rates in patients with inoperable but limited hepatic metastatic disease.

Lung tumours

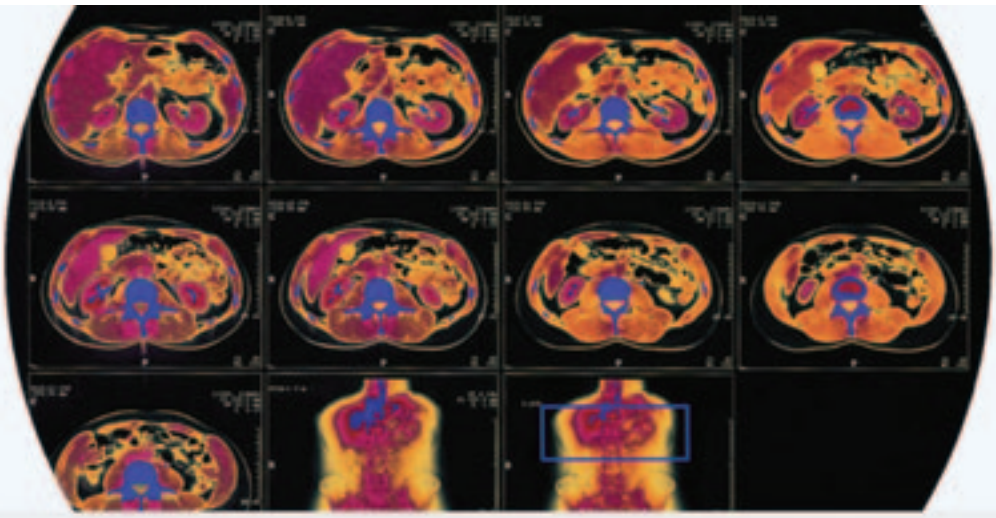
Lung cancer is among the most commonly occurring malignancies and is the leading cause of cancer mortality. Approximately 80% of primary malignant tumours of the lung are non-small cell lung cancer (NSCLC), while the remainder are mainly small-cell carcinomas. Surgical resection is the treatment of choice for early-stage NSCLC, yet patients with NSCLC are frequently poor surgical candidates because of co-existent chronic obstructive pulmonary disease or other comorbid conditions. In addition, NSCLC tends to recur even after successful resection. However, conventional treatment of non-operable or non-resectable patients, using systemic chemotherapy or external-beam radiation therapy, has not been satisfactory in terms of survival outcomes.

The lungs are the second most frequent site of metastatic disease. In patients with pulmonary metastases of favourable histology, greater survival benefits have been shown in those who were completely resected, compared with unresectable individuals. Surgery in these patients is frequently precluded by the number and location of metastatic nodules, the high risk of recurrence of metastatic tumours and the amount of functioning lung tissue that must be removed along with the lesions.

In light of the limitations of surgery, chemotherapy and radiotherapy, attention has turned to RFA for the treatment of lung malignancies. In fact, lung tumours are well suited to RFA because the surrounding air in adjacent normal pulmonary parenchyma provides an insulating effect, which facilitates energy concentration within the tumour tissue. The safety and efficacy of pulmonary RFA, performed via a percutaneous, transthoracic approach, was preliminarily demonstrated in the rabbit model, and has prompted clinical investigations.[12–15] The results of lung RFA have been recently examined in a series of 71 patients with 117 malignant lung tumours ≤3.5 cm in diameter who were treated in an ongoing, prospective, multicentre, clinical trial.[16] Diagnoses included NSCLC (n=27), metastasis from colorectal adenocarcinoma (n=34) and metastasis from other primary malignancies (n=10). All patients were considered unfit for surgery and had exhausted radiation and chemotherapy alternatives. One month after RFA, CT images were obtained and, in all cases, these showed a characteristic round, ground-glass density area encompassing the treated lesion. Sixty of 66 lesions (91%) in 41 patients who were followed up for ≥6 months after RFA showed no tumour progression with CT. Complete ablation of treated lesions was confirmed in 20 patients, by the absence of tumour re-growth over a follow-up period of ≥1 year. Life-threatening complications did not occur in any patient.

Other clinical applications

Tumours in other organ sites, such as osteoid osteomas can be treated with RFA (Figures 3a and 3b). Rosenthal *et al* treated over 100 osteoid osteomas and found that pain, which is the primary clinical manifestation of this lesion, was eradicated in more than 95% of cases.[17]



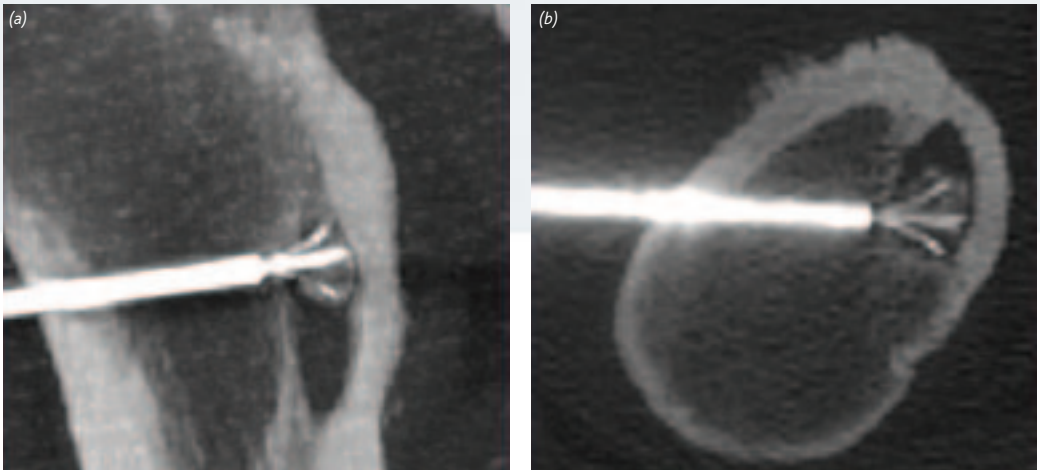


Figure 3. Radiofrequency ablation of osteoid osteoma. Computed tomography images (a) and (b) show multi-prong radiofrequency needles deployed within target lesions (*Starburst SDE, RITA Medical Systems, Mountain View, CA, USA)*

In addition, RFA has been shown to provide effective pain management for terminally ill patients with metastatic neoplasms involving bone. This has translated into decreased interference from pain in activities of daily living and an increased quality of life.[17] Gervais *et al* treated 42 renal cell carcinomas with RFA and achieved complete ablation of all exophytic tumours ≤5.0 cm in diameter with acceptable morbidity, no procedure-related mortality and the absence of tumour recurrences for 3.5 years.[19]

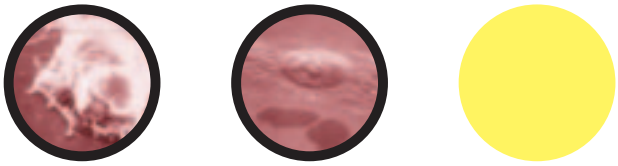
What we knew before and what this tells us

Radiofrequency ablation:

- Is a minimally invasive technique used to treat solid tumours
- Is the treatment of choice for patients with small hepatocellular carcinoma who are not suitable candidates for resection or transplantation
- Is used to treat patients with inoperable but limited hepatic metastatic disease of favourable histologies, such as colorectal carcinoma
- Has the potential to play an increasingly important role in the clinical management of other malignancies, such as those involving the lung, bone and kidney

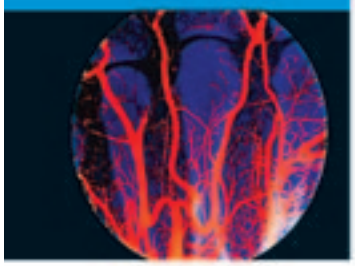
Conclusions

Radiofrequency ablation is a minimally invasive procedure that can achieve effective and reproducible tumour destruction with acceptable morbidity. It is recognised as a viable alternative or complementary treatment for patients with HCC or hepatic colorectal metastases, who are not candidates for surgery. With continued improvement in technology and large-scale clinical experience, this technique has the potential to play an increasingly important role in the clinical management of other malignancies, such as those involving the lung, bone and kidney. However, appropriate use of RFA can only be achieved when the therapeutic strategy is decided by a multidisciplinary team, and is tailored to the individual patient and to the features of the disease.



Radiofrequency ablation: the new 'wave' therapy *continued*

Riccardo Lencioni



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