Radiofrequency Ablation of Lung Tumours

a report by

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Radiofrequency (RF) is a sinusoidal current with a frequency of 400 to 500KHz. When delivered through electrodes inserted in tissues, it can heat the tissues through ionic agitation and produce coagulation necrosis when temperature rises to 60°C. RF ablation has achieved impressive results in the treatment of unresectable liver primary cancer and metastases. This has encouraged interventional radiologists to use the same technique to treat cancers at other sites. The characteristics of tissue that surrounds the tumour such as vascularity and electric conductivity affects heat diffusion and ablation outcome.[1] Because RF was initially applied to treat liver tumours, RF algorithm for current delivery had to be tailored to the lung in order to obtain a predictable and reproducible volume of destruction. However, several experimental works have demonstrated that RF ablation can completely destroy a healthy lung or animal tumour models in the lung.[2,3]

Technique

The RF current is delivered through an electrode inserted in the target tumour under computed tomography (CT) guidance, in the same manner as a biopsy needle. However, where a biopsy involves heating the tumour tissue anywhere (this being enough for sampling), with RF ablation the electrode has to be placed accurately in the centre of the tumour (see *Figures 1b and 1c*). Most electrodes used for lung RF ablation use a needle containing expandable electrodes to be deployed after needle insertion (see *Figure 1a*). Size of the expended electrode is chosen according to the volume of tissue targeted for ablation. The goal is to ablate the tumour and safety margins of 1cm all around the tumour. The procedure can be performed under conscious sedation but general anaesthesia provides a higher feasibility. Indeed, under conscious sedation, 3% to 10% of treatment must be interrupted due to pain or intractable coughing.[4,5]

Usually, lungs are treated one at a time in order to avoid the possibility of life-threatening complications from bilateral adverse events, such as massive haemorrhage or pneumothorax. Several tumours can be treated on one side during the same session. When patients have had previous lung surgery, the risk of pneumothorax is low and bilateral treatment can be attempted.

Tolerance – Complications

Pneumothoraces are found on CT scans immediately after ablation in about 54% of treatment sessions. This is probably due to the needle caliber of RF electrode being around 14 Gauge, and thus larger than that used for a biopsy. However, in 31% of the procedures they are small enough not to require any treatment. The remaining 23% are expelled manually after inserting a small bore needle catheter with side holes while the patient is still lying on the CT table immediately after or during RF ablation. Finally, chest tube drainage was necessary in 9% of RF sessions, and retrieved one or two days later in every case. Post-procedural minor haemoptysis, which lasts from two to seven days, is encountered in roughly 10% of patients without the need for any treatment. The only report of severe haemorrhage concerns tumours in contact with the hilum.[6] The author treated patients with FEV_1 down to 0.8L/second and noticed that post-ablation was

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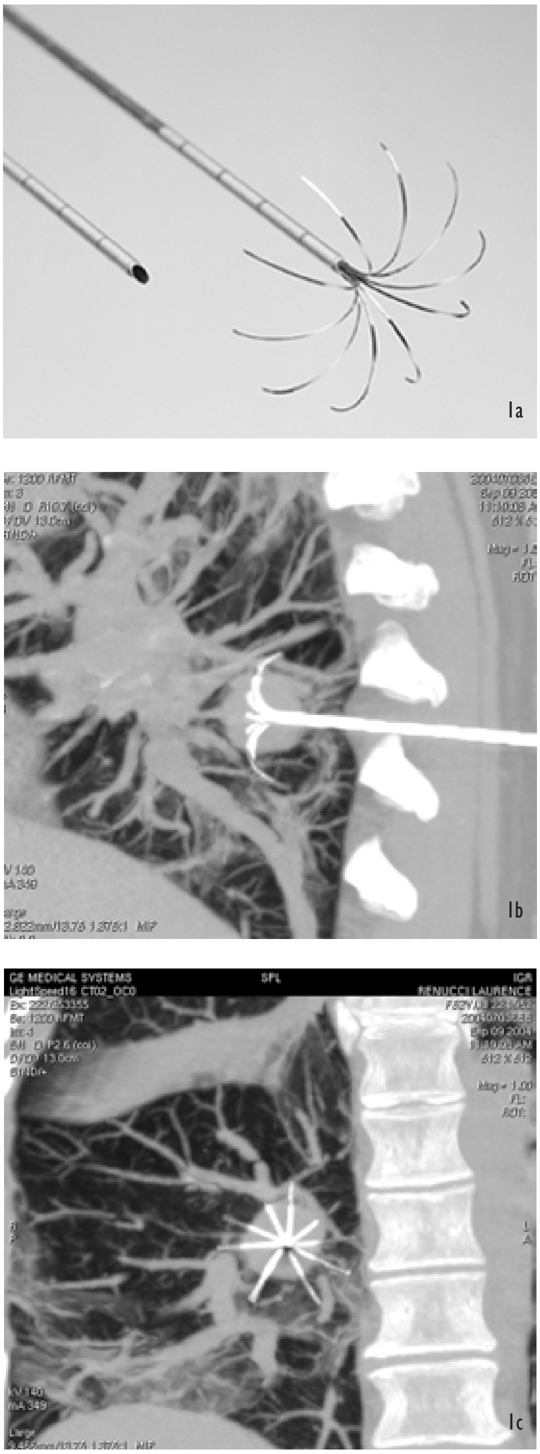
1. *Ahmed M, Liu Z, Afzal K S et al., "Radiofrequency ablation: effect of surrounding tissue composition on coagulation necrosis in a canine tumor model",* Radiology *(2004);230: pp. 761–767.*
2. *Goldberg S N, Gazelle G S, Compton C C et al., "Radiofrequency tissue ablation in the rabbit lung: efficacy and complications",* Acad Radiol *(1995);2: pp. 776–784.*
3. *Miao Y, Ni Y, Bosmans H et al., "Radiofrequency ablation for eradication of pulmonary tumor in rabbits",* J Surg Res *(2001);99: pp. 265–271.*
4. *Yasui K, Kanazawa S, Sano Y et al., "Thoracic tumors treated with CT-guided radiofrequency ablation: initial experience",* Radiology *(2004);231: pp. 850–857.*
5. *Lee J M, Jin G Y, Goldberg S N et al., "Percutaneous radiofrequency ablation for inoperable non-small cell lung cancer and metastases: preliminary report",* Radiology *(2004);230: pp. 125–134.*

Figure 1



A view of the tip of the Leveen electrode (Boston Scientific, Nattick, MA) demonstrated needle shaft without tines deployment on the left and after tines deployment on the right (1a). Sagital (1b) and frontal (1c) view of lung CT after electrode deployment shows the shaft in the central axis of the tumour and electrodes that reach normal lung tissue outside of the tumour in order to obtain safety margins

uneventful for patients with a FEV_1 superior to 1.2L. Patient with lower FEV_1 required some oxygenotherapy during the initial post-ablation weeks. Mean hospital stay was two nights in patients who did not have complications from treatment.

Imaging

CT images obtained within a few minutes following the end of RF energy delivery show the lung tumour surrounded by ground glass opacity. This opacity enlarges the diameter of the hyper-attenuating area, and this enlargement is even greater on images acquired after 24 and 48 hours, although opacity then decreases in size during follow-up (see *Figure 2*). In the authors' experience of 100 tumours, the largest diameter of the ablated zone was still measuring 19mm at one year, while the initial tumour diameter was 17mm. This enhanced the fact that World Health Organization (WHO) or response evaluation criteria in solid tumours (RECIST) criterion cannot be used because the goal of RF ablation is to produce a volume of ablation larger than the initial tumour volume. It is generally considered that an ablation volume that does not increase in size on subsequent imaging is a complete ablation. This method of evaluation has some drawbacks, namely late discovery of incomplete treatment. Indeed, in the author's experience, after a minimum of one year follow-up (mean=18 months), six incomplete treatments were depicted at four, six, nine and 12 months in one, two, two and one patients, respectively. Positron emission tomography (PET)-CT, which is under investigation in clinical practice in the author's centre, appears a promising method of providing early evaluation of treatment response.[7]

Results

Recent reports on lung RF ablation presented short-term retrospective results with minimal follow-up ranging from one to six months and mean or median follow-up ranging from 7.1 to 12 months[4,5,8,9] with a success rate of more than 90% in tumours smaller than 30mm. Lee et al.[5] observed success rates declining to 38% for tumours between 30 and 50mm and to 8% for tumours larger than 50mm.

The author's experience is made up of 60 non-surgical patients bearing 100 tumours (15% primary lung tumour and 85% metastases) less than 40mm (m±sd =

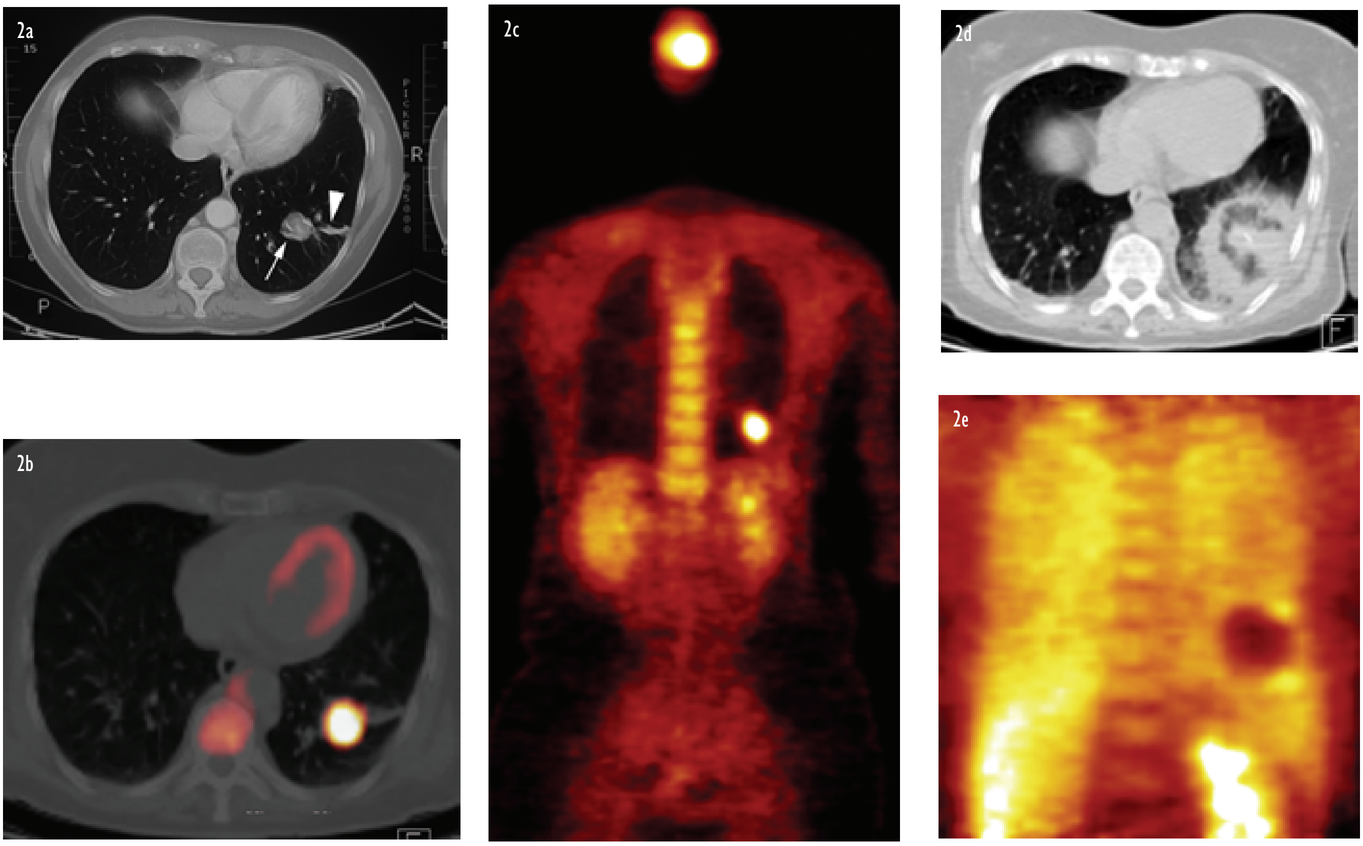
6. *Vaughn C, Mychaskiw G, 2nd, Sewell P et al., "Massive hemorrhage during radiofrequency ablation of a pulmonary neoplasm",* Anesth Analg *(2002);94: pp. 1,149–1,151.*
7. *Antoch G, Vogt F M, Veit P et al., "Assessment of liver tissue after radiofrequency ablation: findings with different imaging procedures",* J Nucl Med *(2005);46: pp. 520–525.*
8. *Steinke K, Glenn D, King J et al., "Percutaneous imaging-guided radiofrequency ablation in patients with colorectal pulmonary metastases: 1-year follow-up",* Ann Surg Oncol *(2004);11: pp. 207–212.*

17±10mm). Metastatic disease was from colorectal cancer (n=23), renal cell carcinoma (n=12), soft tissue sarcoma (n=8) and miscellaneous tumours (n=8). The estimated rate of complete local treatment at 18 months was 93% [IC95% = 86 -97] per tumour. The relative risk [0.49 (IC95%=0.06-4.2)] of incomplete local treatment was no different (p=0.51) between the 22 patients who received chemotherapy for a new distant tumour and the patients who did not. The estimated rate of incomplete local treatment per tumour at 18 months was 5% for tumours measuring 2cm or less in their largest diameter and 13% for tumours larger than 2cm. This difference was not statistically significant, but a trend was noted (p=0.066). In the 73 tumours with a ratio between the area of ground glass opacity imaged at 24 to 48 hours and the tumour area before treatment of at least four, the rate of incomplete local treatment was 4%, which is significantly lower (p=0.02) than when this ratio was below four with a 19% incomplete local treatment rate. The rate of incomplete local treatment compares favourably with the rate of incomplete surgical resection reported to be 12% in the largest world report.[10] However, a major limitation of the comparison of these results with the surgical literature is the difference in tumour sizes between this study and most of the studies reported in the literature. Indeed, the rate of incomplete resection is linked to

RF ablations of metachronous lung metastases allowed patients to be maintained as tumour-free without any other systemic or local therapy.

9. *Gadaleta C, et al., "Radiofrequency thermal ablation of 69 lung neoplasms",* J Chemother *(2004);16 Suppl 5: pp. 86–89.*

Figure 2



Axial CT (2a) shows a 27mm left lower lobe metastasis from adrenal carcinoma (arrow) developed on a surgical scar (arrowhead). Pet CT axial view (2b) and frontal View (2c) confirm glucose uptake of the metastasis two months after a wedge resection, after RF ablation of the metastasis. CT scan obtain one day after RF ablation shows (2d) shows enlargement of the CT hyperattenuating area while pet CT shows no more glucose uptake (2e).

the tumour size in many reports – tumours exceeding 1cm recurred more often for Higashiyama et al.,[11] while 2cm was the threshold for Yano et al.[12]

Although follow-up is short, overall survival and lung disease-free survival at 18 months were, respectively, 71% and 34% for metastatic patients. Additionally, good tolerance of the treatment demonstrated no significant changes in lung function and spirometry one month after ablation when compared with pre-ablation spirometry (FEV_1 = 2.2±0.74L before treatment and 2.2±0.8L after treatment). This makes it possible to treat patients with several previous pulmonary resections and to propose repeated treatments on demand for patients with new metastases. In the author's experience, five patients underwent a second RF ablation to treat a metachronous lung tumour three, six, nine, 18 and 21 months after the first RF ablation. One patient underwent two additional RF ablations 20 and 26 months after the first one for metachronous lung metastases. Follow-up of these six patients after the second or third RF ablation is too short (3.5 to nine months) to present any conclusive results regarding repeated RF ablation of lung tumours. However, these RF ablations of metachronous lung metastases allowed patients to be maintained as tumour-free without any other systemic or local therapy. Moreover, low invasiveness of RF ablation allowed the combination in a single session of RF ablation of lung and liver metastases in six patients with a limited number of tumour deposits.

Conclusion

RF appears to demonstrate a high success rate for ablation of tumours smaller than 4cm. Follow-up imaging has to be improved in order to depict incomplete treatment earlier. RF should be considered as an alternative in non-surgical candidates, even with poor pulmonary function. Further evaluation of this promising technique is needed. ■

10. *Pastorino U, et al., "Long-term results of lung metastasectomy: Prognostic analyses based on 5206 cases. The International Registry of Lung Metastases",* J Thorac Cardiovasc Surg *(1997);113(1): pp. 37–49.*
11. *Higashiyama M, et al., "Intraoperative lavage cytologic analysis of surgical margins as a predictor of local recurrence in pulmonary metastasectomy",* Arch Surg *(2002);137(4): pp. 469–474.*
12. *Yano T, et al., "Results of a limited resection for compromised or poor-risk patients with clinical stage I non-small cell carcinoma of the lung",* J Am Coll Surg *(1995);181(1): pp. 33–37.*